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Village-Scale Feed Carrying Capacity and Dependence on Maize Stover for Beef Cattle in Taluditi, Indonesia

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Abstract: Livestock carrying capacity is commonly expressed as an aggregate feed supply-to-demand ratio, but a high ratio can mask reliance on a single feed source. This study quantified village-scale feed carrying capacity for beef cattle in Taluditi Subdistrict, Indonesia, examined the structural dependence of the surplus, and interpreted it through field verification. Official 2023–2025 records were converted to livestock units and available dry matter from natural pasture, maize stover, rice straw, and cocoa pod husk, complemented by observation and interviews with 14 farmers across all villages. In 2025, available feed was 10,338.67 tonnes of dry matter per year against a requirement of 2,193.42 tonnes per year, giving an index of 4.71. Maize stover contributed 82.81% of available dry matter; only 2.4% of its potential was needed for balance, yet four of seven villages fell below balance without it. More diversified villages retained stronger non-maize balances. Most interviewed farmers used maize residue routinely after harvest and all reported greater feed difficulty during the dry season, while unused stover was observed being burned or left to decompose. The novelty lies in separating surplus magnitude from structural dependence, which supports residue storage, reduced burning, and village-targeted livestock policy.

Keywords: Beef Cattle, Carrying Capacity, Crop Residues, Dry Matter, Feed-Source Diversity

INTRODUCTION

The capacity of livestock production systems to sustain existing animal populations depends partly on whether locally available feed resources can meet livestock requirements. Feed assessment therefore requires an explicit comparison of feed supply and demand rather than reliance on livestock numbers or biomass production alone. Coughenour and Makkar (2012) frame feed assessment as a data- and computation-based evaluation of livestock feed supplies and demands, and recent feed-balance research shows that subnational resolution can

reveal localized feed-scarcity hotspots that disappear under larger-scale aggregation (Fraval et al., 2024). In this study, feed resource-based carrying capacity is defined as the annual quantitative balance between locally available feed dry matter and the requirements of the existing beef-cattle population.

Agricultural landscapes provide ruminants with feed from natural pasture, crop residues, and other by-products. Ruminants can utilize substantial quantities of biomass that are not directly edible by humans (Mottet et al., 2017), while crop residues can broaden the feed base when their nutritional quality, processing, storage, and practical availability are adequately managed (Shah et al., 2025). Potential biomass, however, does not automatically become livestock feed because residues may have competing uses, be lost during handling, or remain inaccessible (Jaleta et al., 2015). Where residues are burned in the field, they also generate air pollution and health costs while foregoing opportunities for alternative use or nutrient recycling (Krishna & Mkondiwa, 2023).

Indonesian studies show that regional feed potential and carrying capacity can be estimated from locally available forage, agricultural by-products, and livestock populations (Ilham, 2015; Edi, 2020), and Paat et al. (2021) demonstrated the regional relevance of maize biomass as cattle feed in North Sulawesi. Elsewhere, Lessmann et al. (2024) and Qi et al. (2025) reported strong spatial disparities in feed-related resource balances and livestock carrying capacity. In West Java, Fathurohman et al. (2026) found large aggregate crop-residue resources but uneven spatial distribution, with feed insecurity linked more strongly to distribution constraints than to total biological availability. Together, these studies show that the spatial scale of assessment matters.

A second issue is the composition of the surplus. Because the carrying capacity index aggregates all feed sources, the same index value can arise from a diversified feed portfolio or from strong dependence on a single residue concentrated around harvest periods. Diversification can reduce exposure to price and production shocks, although it may involve cost trade-offs (Komarek et al., 2022), while seasonal shortages often increase reliance on alternative feeds (Alimi et al., 2024). Resilience theory offers a lens for this distinction: the capacity of a system to persist through disturbance depends not only on the size of its reserves but also on whether its functions rest on more than one component (Holling, 1973). Consistent with this view, greater effective crop diversity has been associated with more stable national food production (Renard & Tilman, 2019). Read through this lens, the carrying capacity index measures the size of a feed buffer, whereas dependence on the dominant feed source indicates how much redundancy that buffer contains. Indonesian feed-balance studies have largely emphasized total supply and carrying capacity, leaving dependence on the dominant feed source less explicitly examined.

Taluditi Subdistrict, Pohuwato Regency, is an agricultural landscape in which beef-cattle production coexists with maize, rice, cocoa, and natural pasture. An earlier assessment reported substantial aggregate feed potential at subdistrict level (Diko & Dunggio, 2025). The present study extends that work by resolving the balance at village scale, applying a common analytical framework to official 2023–2025 records, and examining how strongly the surplus depends on its dominant feed source. The state of the art of this study therefore lies in adding a structural perspective to conventional feed-balance assessment and linking residue management with an observed local environmental issue: open burning of unused maize stover.

Accordingly, this study addresses three research questions: 1. How large are feed dry-matter availability, requirement, and carrying capacity in each village of Taluditi in 2025? 2. How does the carrying capacity index vary among villages and between 2023 and 2025, and what drives that variation? 3. How dependent is the surplus on maize stover, and how does feed-source diversity relate to the persistence of the balance when maize stover is excluded?

The findings are further interpreted in terms of residue-use practices observed in the field, their environmental implications, and policy implications for village-scale livestock development.

METHOD

Study Area and Data

The study was conducted in the seven villages of Taluditi Subdistrict, Pohuwato Regency, Gorontalo Province: Kalimas, Makarti Jaya, Malango, Pancakarsa I, Pancakarsa II, Puncak Jaya, and Tirto Asri (Figure 1). UPT Sandalan is not a separate definitive village and was included administratively within Pancakarsa I (Badan Pusat Statistik Kabupaten Pohuwato, 2025). A quantitative descriptive design based on annual dry-matter balance was applied, with 2025 as the primary analytical year and 2023–2025 providing short-term temporal context. Cattle numbers by village and age class were obtained from the Livestock Division of the Pohuwato Regency Agriculture Office; natural-pasture area and annual harvested areas of maize and paddy from the Taluditi Agricultural Extension Center; and dry cocoa-bean production from Taluditi plantation statistics.

Livestock Demand

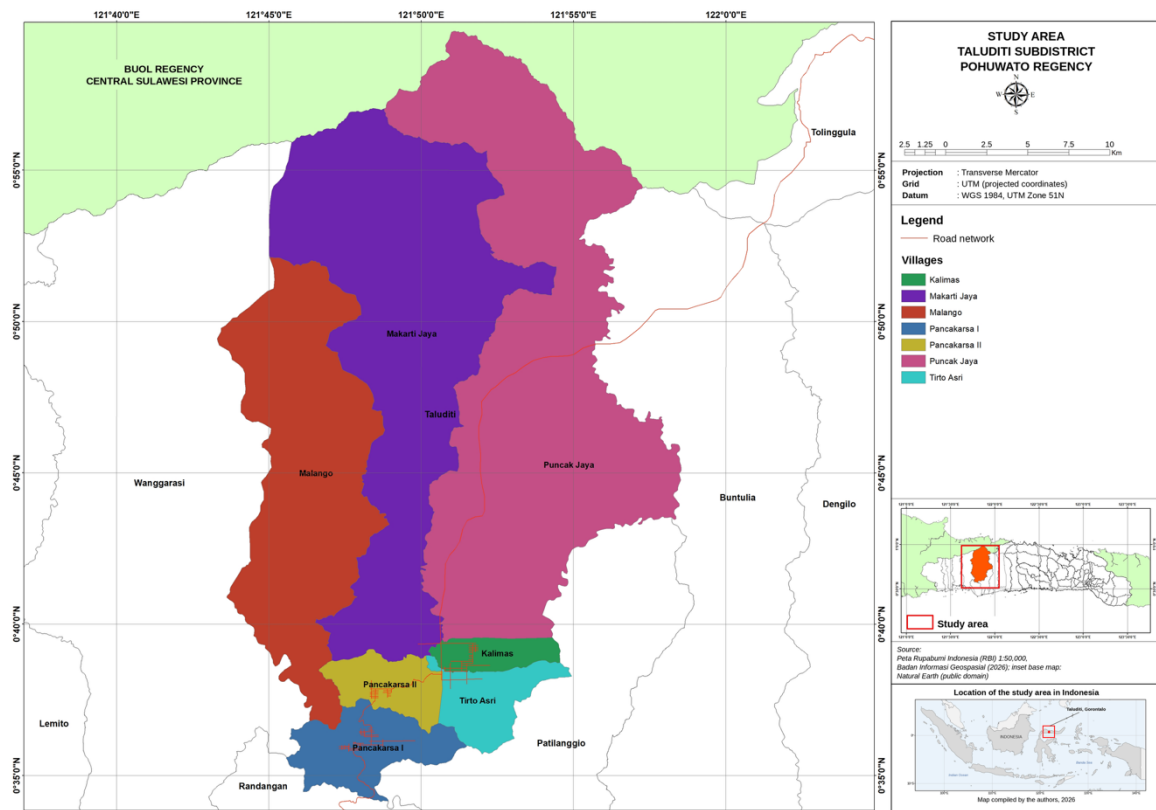
Cattle were converted to livestock units (LU) using technical coefficients of 0.25 for calves, 0.50 for young cattle, and 1.00 for adults, as reported by Ilham (2015). These coefficients were mapped to the age classes available in the Taluditi administrative records: calves (<1 year), young cattle (1–2 years), and adults (>2 years). One LU was assigned a reference live weight of 250 kg and dry-matter intake of 2.5% of live weight per day, consistent with the reference tropical livestock-unit framework of Kassam et al. (1991), giving an annual requirement (RDM) of 2.28125 t DM LU⁻¹ yr⁻¹.

$$LU = 0.25 N_{\text{calf}} + 0.50 N_{\text{young}} + 1.00 N_{\text{adult}}; \quad DM_{\text{req}} = LU \times RDM$$

Feed Supply

Available dry matter from area-based resources was estimated as area × dry-matter yield × utilization factor, and from cocoa pod husk as dry cocoa-bean production × conversion coefficient × utilization factor (Table 1); utilization factors express the share of potential biomass included in the feed balance. For cocoa pod husk, about 10 t of wet husk is generated per tonne of dry beans (Vriesmann et al., 2011) and fresh husk contains 16.59% dry matter (Holguín Posso et al., 2024); this value, the upper end of reported fresh-husk dry-matter contents, was rounded down to 0.16, giving $k_{\text{CPH}} = 10 \times 0.16 = 1.60 \text{ t DM t}^{-1}$ dry beans. A study-specific availability factor of $U_{\text{CPH}} = 0.12$ was adopted for the feed-balance calculation; field interviews, which showed limited and variable local use of cocoa pod husk, were used only to contextualize this partial use, not to derive the factor.

$$DM_{\text{av}} = \sum_i A_i \times DMY_i \times U_i + Q_{\text{CB}} \times k_{\text{CPH}} \times U_{\text{CPH}}$$



Source: processed by the authors (2026) from Peta Rupabumi Indonesia (RBI) 1:50,000.

Figure 1. Location of the seven study villages in Taluditi Subdistrict, Pohuwato Regency

Table 1. Analytical parameters and their sources

Parameter	Value	Source/status
Livestock-unit coefficients (calf; young; adult)	0.25; 0.50; 1.00 LU head ⁻¹	Ilham (2015); age classes from official records
Reference body weight; dry-matter intake	250 kg LU ⁻¹ ; 2.5% BW day ⁻¹	Kassam et al. (1991)
Natural pasture DMY; U	7.50 t DM ha ⁻¹ yr ⁻¹ ; 0.30	Study value; benchmarked against Khaerani et al. (2024) and Sema et al. (2025)
Maize stover DMY; U	1.66 t DM ha ⁻¹ harvest ⁻¹ ; 0.50	DMY: Paath et al. (2012); U: baseline, with 0.40–0.56 scenario set (Jaleta et al., 2015)
Rice straw DMY; U	3.86 t DM ha ⁻¹ harvest ⁻¹ ; 0.31	Martawidjaja (2003); U: Komar (1984), as cited by Martawidjaja (2003)
Cocoa pod husk kCPH; U	1.60 t DM t ⁻¹ dry beans; 0.12	k: Vriesmann et al. (2011) and Holguín Posso et al. (2024); U: study-specific factor

DM = dry matter; DMY = dry-matter yield; LU = livestock unit. Study-specific parameters were applied consistently across villages and years.

Carrying Capacity and Structural Dependence

Feed balance (FB), carrying capacity (CC), and the carrying capacity index (CCI) followed the supply–demand logic of feed assessment (Coughenour & Makkar, 2012). The CCI was interpreted as >1 for quantitative dry-matter surplus, =1 for balance, and <1 for deficit.

$$FB = DM_{av} - DM_{req}; \quad CC = DM_{av} / RDM; \quad CCI = DM_{av} / DM_{req}$$

Structural dependence was defined as the extent to which the annual dry-matter balance persisted when maize stover was reduced or omitted, using three diagnostics: the maize-excluded index (CCI_{MS}), which recalculates CCI without maize stover; the break-even

utilization factor (U^*_{MS}), the fraction of potential maize stover required for CCI to equal 1 (values ≤ 0 indicate that non-maize resources alone meet demand); and the Shannon index, H' (Shannon, 1948), where p_i is the dry-matter share of source i (maximum $\ln 4 = 1.386$). The primary maize-stover sensitivity set was $U_{MS} = 0.40, 0.50$, and 0.56 : 0.56 is the feed-use share reported by Jaleta et al. (2015), 0.50 a conservative baseline below it, and 0.40 a 20% relative reduction reflecting lower recoverability under competing uses, field retention, and handling losses. A deterministic stress test from $U_{MS} = 0$ to 0.50 in 0.10 steps traced the response toward break-even. Because CCI is proportional to DM_{av}/LU , interannual change was decomposed as $\Delta \ln(CCI) = \Delta \ln(DM_{av}) - \Delta \ln(LU)$, with the supply contribution calculated as $|\Delta \ln(DM_{av})| / [|\Delta \ln(DM_{av})| + |\Delta \ln(LU)|]$.

$$CCI_{-MS} = (DM_{av} - DM_{MS}) / DM_{req}$$

$$U^*_{MS} = (DM_{req} - DM_{av} + DM_{MS}) / (A_{MS} \times DM_{MS})$$

$$H' = -\sum p_i \ln p_i$$

Field Verification

Field verification in all seven villages in September 2026 combined direct observation of residue handling with directed interviews of 14 cattle-keeping farmers, two per village, conducted on 6–11 September 2026 with a 26-question structured guide on rearing systems, feed sources, residue and cocoa pod husk use, and seasonal feed strategies. Informed consent was obtained from all informants before the interviews. Responses were summarized as frequencies and used descriptively to interpret feeding practices; they were neither treated as a representative sample nor used in the dry-matter calculations.

RESULTS AND DISCUSSION

Feed Availability and Demand in 2025

In 2025, the recorded population of 1,309 head was equivalent to 961.50 LU, requiring 2,193.42 t DM yr⁻¹. Estimated available dry matter was 10,338.67 t DM yr⁻¹, giving a feed balance of +8,145.25 t, a theoretical carrying capacity of 4,532.02 LU, and a CCI of 4.71. Maize stover dominated the supply (82.81%), followed by rice straw (12.45%), natural pasture (3.76%), and cocoa pod husk (0.98%) (Table 2).

Table 2. Composition of available feed dry matter in Taluditi Subdistrict, 2025

Feed resource	Available DM (t yr ⁻¹)	Contribution (%)
Maize stover	8,561.45	82.81
Rice straw	1,287.54	12.45
Natural pasture	388.44	3.76
Cocoa pod husk	101.24	0.98
Total	10,338.67	100.00

Source: authors' calculations from official 2025 records.

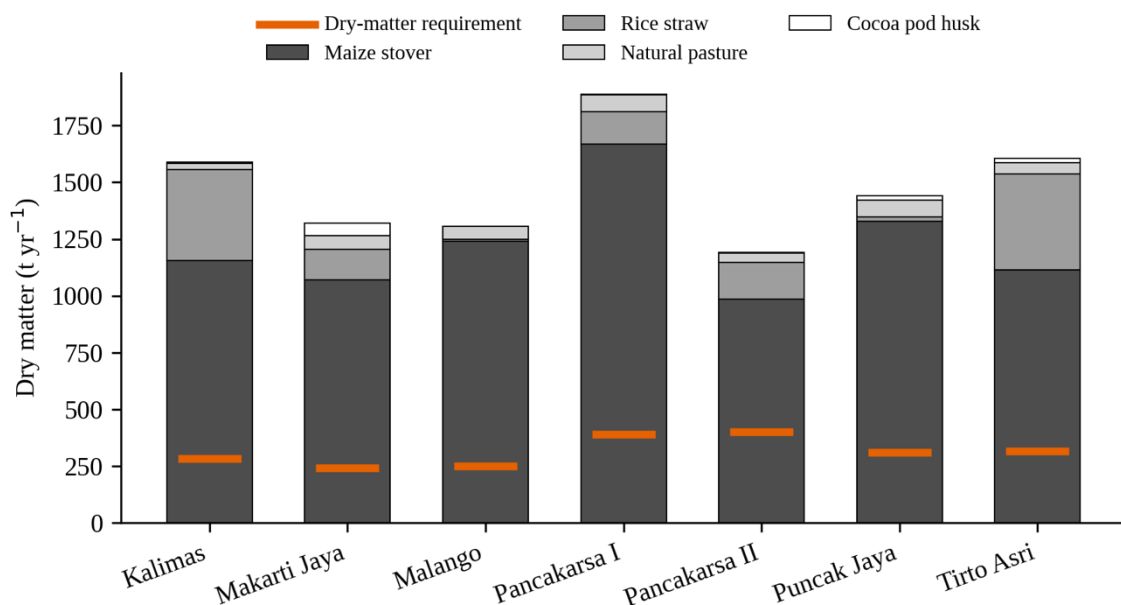
Table 3. Feed balance and carrying capacity by village, 2025

Village	LU	Available DM	DM requirement	Feed balance	CC (LU)	CCI
Kalimas	124.00	1,588.04	282.88	1,305.16	696.13	5.61
Makarti Jaya	106.25	1,319.43	242.38	1,077.05	578.38	5.44
Malango	109.75	1,307.45	250.37	1,057.08	573.13	5.22
Pancakarsa I	171.25	1,887.39	390.66	1,496.72	827.35	4.83
Pancakarsa II	176.25	1,190.47	402.07	788.40	521.85	2.96
Puncak Jaya	135.75	1,441.98	309.68	1,132.30	632.10	4.66
Tirto Asri	138.25	1,603.91	315.38	1,288.53	703.09	5.09
Taluditi	961.50	10,338.67	2,193.42	8,145.25	4,532.02	4.71

DM values in t DM yr⁻¹; minor differences are due to rounding. Source: authors' calculations.

All seven villages had CCI > 1, ranging from 2.96 in Pancakarsa II to 5.61 in Kalimas (Table 3, Figure 2). Pancakarsa II combined the largest livestock demand (176.25 LU) with the smallest supply (1,190.47 t), whereas Pancakarsa I had the largest supply but, because of similarly high demand, only an intermediate CCI of 4.83. Carrying capacity therefore reflects the relationship between supply and demand rather than the size of either component alone.

The dominance of maize stover shows that feed availability in Taluditi is closely coupled to crop production. Agricultural by-products are important components of the Indonesian ruminant feed base (Ilham, 2015; Edi, 2020), and the pattern is consistent with the regional importance of maize biomass reported for North Sulawesi (Paat et al., 2021). Maize stover nevertheless varies in feeding value with maturity, plant fraction, processing, and storage, and crop residues may also have competing uses (Jaleta et al., 2015; Shah et al., 2025). Natural pasture made a relatively small contribution, while its 7.50 t DM ha⁻¹ yr⁻¹ study value lies within the range reported for natural pastures in South Sulawesi (Khaerani et al., 2024; Sema et al., 2025). Cocoa pod husk contributed less than 1% of the feed balance, consistent with its supplementary role and known constraints from lignin, tannins, and theobromine (Puastuti & Susana, 2014).



Source: authors' calculations.

Figure 2. Composition of available dry matter and dry-matter requirement by village, 2025

The theoretical carrying capacity of 4,532.02 LU is a dry-matter-based estimate of annual feed quantity. Its management value therefore lies in identifying the relative balance between feed supply and livestock demand across villages; decisions on herd expansion also require information on feed quality, seasonal continuity, accessibility, and farm-level feasibility.

Village Comparison of Feed Capacity and Source Dependence

At subdistrict level, CCI was 3.50 in 2023, rose to 6.06 in 2024, and fell to 4.71 in 2025, remaining above 1 in every year and every village (Table 4). Village CCI ranged from 2.33 to 4.25 in 2023 and from 3.33 to 8.36 in 2024. Pancakarsa II had the lowest CCI in all three years, which indicates a persistent rather than incidental feature: its herd is large relative to its crop-residue base.

Table 4. Carrying capacity index by village, 2023–2025

Village	2023	2024	2025
Kalimas	3.93	8.36	5.61
Makarti Jaya	4.25	6.20	5.44
Malango	4.25	6.75	5.22
Pancakarsa I	3.85	6.33	4.83
Pancakarsa II	2.33	3.33	2.96
Puncak Jaya	3.53	6.68	4.66
Tirto Asri	2.98	6.53	5.09
Available DM, Taluditi (t yr ⁻¹)	8,797.38	13,027.12	10,338.67
Livestock units, Taluditi	1,101.50	942.00	961.50
Taluditi CCI	3.50	6.06	4.71

Source: authors' calculations from official 2023–2025 records using one parameter set.

The interannual changes were driven mainly by supply. On the log-ratio decomposition, changes in available dry matter accounted for 71.5% of the absolute change in subdistrict CCI between 2023 and 2024 and 91.9% between 2024 and 2025, with the remainder associated with changes in livestock units. Maize harvested area increased from 9,386 ha in 2023 to 14,297 ha in 2024 and then declined to 10,315 ha in 2025, closely tracking the CCI series. In a residue-based feed system, carrying-capacity estimates can therefore fluctuate with cropping decisions made primarily for crop production, a pattern consistent with the distribution and seasonal-access constraints reported by Fathurohman et al. (2026).

A second temporal shift is visible in the composition of the feed base. Paddy harvested area increased from 407 ha in 2023 to 1,076 ha in 2025, and rice-straw dry matter rose from 487.0 to 1,287.5 t. Over the same period, the subdistrict Shannon index increased from 0.47 to 0.58 and the maize-excluded index from 0.40 to 0.81, indicating a broader non-maize contribution by 2025. These changes represent short-term variation over three years rather than a long-term trend.

Because maize stover dominated supply, its utilization factor had the largest influence on the carrying-capacity estimate. Under the primary sensitivity values UMS = 0.40, 0.50, and 0.56, subdistrict CCI was 3.93, 4.71, and 5.18, respectively, and every village remained in quantitative surplus. The deterministic stress test then reduced UMS from 0.50 to 0 in 0.10 increments (Table 5). At UMS = 0.10, subdistrict CCI remained 1.59 and each village was at or above balance after rounding. Only 416.20 t of the 17,122.90 t of potential maize-stover dry matter, equivalent to a break-even utilization of 2.4%, was required for subdistrict CCI to reach 1 when non-maize resources were retained. Village break-even factors ranged from 0.052 in Pancakarsa I to 0.100 in Pancakarsa II; Kalimas, Makarti Jaya, and Tirto Asri were already above balance without maize stover. The classification was also insensitive to the livestock-unit coefficients: because age-class proportions were nearly uniform, the ratio of livestock units to head ranged only from 0.732 to 0.738 among villages, and counting every animal as one livestock unit would still leave the lowest village CCI at 2.17 (Pancakarsa II).

The maize-excluded diagnostic reveals a different dimension of the feed balance. Four villages fall below balance without maize stover: Pancakarsa I (0.56), Pancakarsa II (0.51), Puncak Jaya (0.37), and Malango (0.26), while the subdistrict index falls to 0.81 (Table 6). Makarti Jaya remains only slightly above balance (1.03); excluding cocoa pod husk as well reduces its index to 0.81. Thus, the non-maize balance is strongest in Kalimas and Tirto Asri, borderline in Makarti Jaya, and insufficient in the remaining four villages.

Table 5. Deterministic stress test of the carrying capacity index under reduced maize-stover utilization, 2025

Village	U = 0	0.10	0.20	0.30	0.40	0.50*	U* _{MS}
Kalimas	1.53	2.34	3.16	3.98	4.80	5.61	≤ 0
Makarti Jaya	1.03	1.91	2.80	3.68	4.56	5.44	≤ 0
Malango	0.26	1.25	2.25	3.24	4.23	5.22	0.074
Pancakarsa I	0.56	1.41	2.27	3.12	3.98	4.83	0.052
Pancakarsa II	0.51	1.00	1.49	1.98	2.47	2.96	0.100
Puncak Jaya	0.37	1.23	2.08	2.94	3.80	4.66	0.073
Tirto Asri	1.56	2.26	2.97	3.67	4.38	5.09	≤ 0
Taluditi	0.81	1.59	2.37	3.15	3.93	4.71	0.024

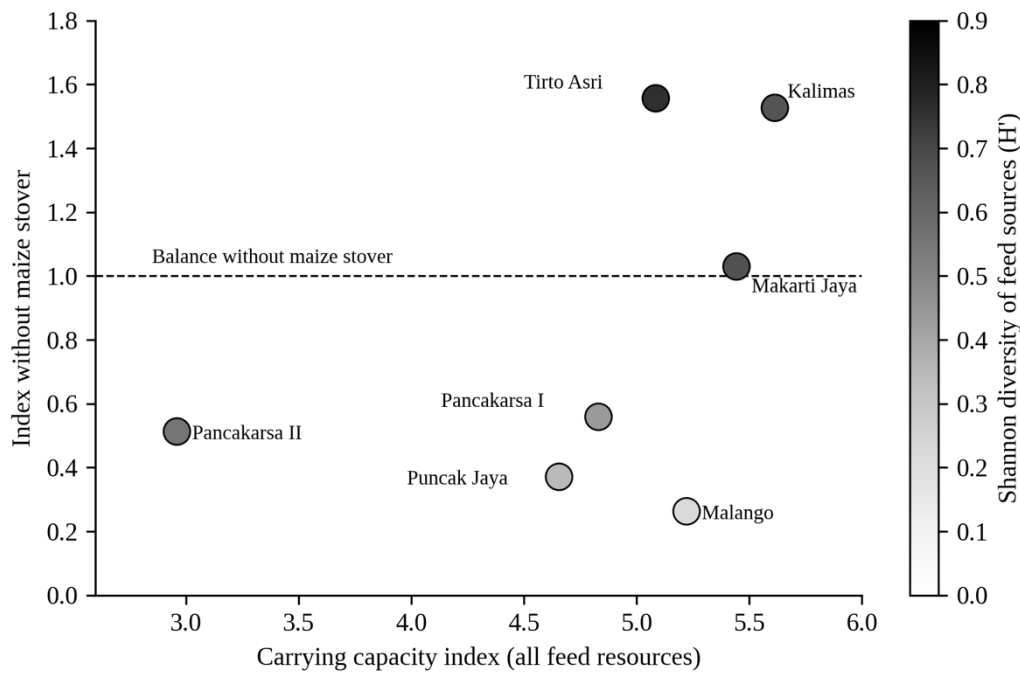
*Baseline. U = 0 is equivalent to the maize-excluded index. U*_{MS} = break-even utilization factor; ≤ 0 indicates balance without maize stover. The primary sensitivity analysis also included U = 0.56. Pancakarsa II at U = 0.10 is 1.00 after rounding (break-even = 0.100).

Table 6. Structural indicators of village feed balances

Village	Maize stover (%)	Rice straw (%)	H'	CCI- _{MS} 2023	CCI- _{MS} 2024	CCI- _{MS} 2025
Kalimas	72.8	25.2	0.67	0.59	1.11	1.53
Makarti Jaya	81.1	10.2	0.68	0.63	0.74	1.03
Malango	95.0	0.5	0.22	0.24	0.25	0.26
Pancakarsa I	88.4	7.5	0.44	0.27	0.32	0.56
Pancakarsa II	82.7	13.6	0.56	0.26	0.29	0.51
Puncak Jaya	92.0	1.3	0.35	0.31	0.39	0.37
Tirto Asri	69.4	26.5	0.76	0.57	0.96	1.56
Taluditi	82.8	12.5	0.58	0.40	0.54	0.81

Shares and H' refer to 2025. H' = Shannon diversity of the four feed sources (maximum 1.386). CCI-_{MS} = carrying capacity index without maize stover; for Makarti Jaya in 2025 it falls to 0.81 if cocoa pod husk is also excluded. Source: authors' calculations.

The two dimensions rank villages differently (Figure 3). Malango ranks third by CCI (5.22) but last by the maize-excluded index (0.26), because 95.0% of its estimated supply comes from maize stover. Tirto Asri ranks fourth by CCI (5.09) but first by the maize-excluded index (1.56), with rice straw contributing 26.5% of its feed dry matter. Feed-source diversity follows the same compositional pattern: Tirto Asri and Kalimas combine the highest Shannon values with the strongest non-maize balances, whereas Malango and Puncak Jaya show low diversity and weak non-maize balances. The contrast demonstrates that villages with similar overall CCI can differ markedly in the structure of their feed base.



Source: authors' calculations.

Figure 3. Carrying capacity index with and without maize stover, shaded by feed-source diversity, 2025

This pattern held over time. In 2023 no village had a maize-excluded index above 1; in 2024 only Kalimas did (1.11); in 2025 Kalimas, Makarti Jaya, and Tirto Asri did. Malango remained between 0.24 and 0.26 in all three years and Puncak Jaya between 0.31 and 0.39 (Table 6), so their single-source dependence is persistent rather than incidental.

A resilience perspective helps interpret why Malango appears more exposed to single-source disruption despite its high CCI. In resilience terms, the CCI expresses the size of the feed buffer, whereas feed-source diversity expresses its redundancy, that is, whether the feed function rests on more than one component (Holling, 1973). Malango combines the third-largest buffer with almost no redundancy: maize stover supplies 95.0% of its dry matter, so any disturbance that removes stover from feeding, such as the interval between maize harvests, open burning, or a shift away from maize cropping, removes nearly the entire feed base at once and leaves an index of 0.26. Tirto Asri holds a slightly smaller buffer (5.09) but also draws on rice straw from a separate cropping system, so a disturbance confined to maize still leaves its balance at 1.56. This contrast follows the portfolio logic described by Komarek et al. (2022), in which diversified feed sources reduce exposure to single-source shocks at some cost, and it parallels the stabilizing effect of crop diversity on national food production reported by Renard and Tilman (2019). The CCI and the structural diagnostics therefore describe two different properties of the same feed system, its capacity and its redundancy, and should not be expected to rank villages identically. Because resilience itself was not measured, these diagnostics are interpreted as indicators of exposure to single-source disruption rather than as a resilience index.

These results refine the earlier subdistrict assessment (Diko & Dunggio, 2025) and complement studies emphasizing spatial heterogeneity (Fraval et al., 2024; Lessmann et al., 2024; Qi et al., 2025). Variation in surplus magnitude mattered less for classification because all villages remained in surplus across the primary sensitivity range. Feed-source structure, however, separated villages whose annual non-maize resources could meet dry-matter demand from those whose balance depended on maize stover.

Residue-Use Practices in the Field

Interviews confirmed that crop residues are an established part of feeding practice in all seven villages. All 14 informants named natural grass as a feed source and 12 named maize residue, and 12 reported using maize residue after harvest always or often. Seven informants combined grazing with confinement and five kept cattle confined with cut-and-carry feeding, so residue use depends largely on labor for cutting, transport, and storage. Informants' descriptions matched the village feed structures: in Kalimas, rice straw was described as a reserve or abundant feed; in Pancakarsa I and Makarti Jaya, maize stover carried to the pen was the most frequent feed; and in Malango, maize residue was used once the harvest had passed, with grass under cocoa used at other times, illustrating how stover supply is concentrated around harvest. Cocoa pod husk was used by 11 informants at varying frequencies, most often in small portions, in line with its supplementary role.

All 14 informants reported that feed availability differs between seasons and that the dry season is the most difficult period; 12 responded by using crop residues and 7 by searching for feed farther away. The annual surplus therefore does not guarantee feed sufficiency throughout the year, and the findings point to collection, storage, and seasonal timing as important practical constraints despite the large annual biomass surplus, consistent with the low break-even utilization factor. Field observation also documented that stover not used as feed was burned or left to decompose in the field. The interviews further qualify the structural diagnostics: informants in Malango, Puncak Jaya, and Tirta Asri frequently described forage growing under plantation trees or on slopes, which the administrative natural-pasture area does not fully capture. Non-maize balances in these villages may therefore be underestimated, and the maize-excluded index is best read as a conservative indicator of exposure rather than as a predicted deficit.

Environmental Sustainability Implications

Open burning of crop residues generates air pollution and health costs and forgoes the recycling of nutrients to the soil (Krishna & Mkondiwa, 2023). Because the subdistrict balance required only 2.4% of potential maize-stover dry matter, and at most 10% in any village, feed recovery can focus first on stover that would otherwise be burned. Feed recovery and environmental protection can therefore be complementary when collection targets residues that would otherwise be burned while sufficient biomass is retained for soil cover and organic-matter return. The size of this co-benefit could not be quantified, because the shares of stover burned and retained were observed but not measured.

Policy Implications

The findings carry three policy implications. First, livestock-development programs should be targeted by village feed structure rather than by the aggregate surplus: maize-dependent villages (Malango, Puncak Jaya, and Pancakarsa I) need support for stover collection, preservation, and storage (Alimi et al., 2024), whereas diversified villages (Tirta Asri and Kalimas) have a stronger non-maize feed buffer, although any herd-expansion decision there still requires verification of feed quality, seasonal continuity, ecological land suitability, and spatial-planning constraints. Second, the calculated surplus should not be used as a basis for automatic herd expansion. Third, residue fates and dry-season feed shortages should be recorded routinely so that future decisions can rest on monthly rather than annual feed balances. Inter-village exchange of feed biomass may complement local storage where transport costs and organization are feasible (Martin et al., 2016; Fathurohman et al., 2026).

The novelty of this study lies in reporting surplus magnitude alongside dependence on the dominant feed source. Combining the maize-excluded index, break-even utilization factor, and feed-source diversity distinguishes villages with similar CCI values but different

feed structures. This additional structural information provides a clearer basis for targeting residue collection, storage, and diversification strategies while retaining the conventional carrying-capacity index as the core measure of annual dry-matter balance.

CONCLUSION

Conclusion

Taluditi had a large quantitative dry-matter surplus in 2025: estimated available dry matter was 4.71 times the requirement of the existing 961.50 livestock units, and all seven villages were in surplus, with CCI values of 2.96–5.61. Interannual variation from 2023 to 2025 was driven mainly by maize-associated biomass. The surplus remained above balance across the primary sensitivity range and required only 2.4% of potential maize-stover dry matter, yet source dependence differed sharply among villages: four villages fell below balance in the maize-excluded diagnostic, while villages with more diversified feed portfolios retained stronger non-maize balances. Read through resilience theory, the carrying capacity index captures the size of the feed buffer, whereas feed-source structure captures its redundancy. Most interviewed farmers used maize residue routinely after harvest and all reported greater feed difficulty during the dry season, while field observation recorded open burning of unused stover; these findings point to residue collection and storage as important practical constraints. Recovering stover that would otherwise be burned offers a potential co-benefit for feed security and the environment, and livestock programs should be targeted by village feed structure rather than by the aggregate surplus.

Limitations

The analysis is based on annual dry-matter quantity; nutrient quality, monthly seasonality, accessibility, storage losses, and competing residue uses were not quantified. The maize-excluded case is a diagnostic source-removal scenario rather than a measured seasonal feed balance. Forage under plantation trees and on slopes, reported by informants, is not fully represented in the administrative natural-pasture area. The cocoa pod husk coefficient is based on a dry-matter fraction near the upper end of reported values; lower values would reduce cocoa pod husk supply but would not change any village's carrying-capacity status. The interviews covered 14 informants and are descriptive rather than representative, and residue fates were recorded qualitatively, so the proportions burned, fed, or retained in fields and the associated emissions could not be estimated. Several feed coefficients were literature- or study-derived, and the seven-village, three-year dataset supports descriptive spatial and temporal interpretation rather than broad statistical generalization.

Recommendations

The Pohuwato Regency Agriculture Office should prioritize stover collection, preservation, and storage in maize-dependent villages and link any herd-expansion program to verified feed quality and seasonal continuity rather than to the aggregate surplus. The Taluditi Agricultural Extension Center could add residue fates (fed, burned, or left in the field) and dry-season feed shortages to its routine reporting. Local institutions may facilitate collective residue storage and inter-village feed exchange where economically feasible. At the regency level, feed-based carrying capacity should be integrated with ecological land suitability and the regional spatial plan before livestock-development locations are designated. Future research should quantify residue recovery, competing uses, and under-tree forage, construct monthly feed balances that include nutritional quality, and evaluate environmental trade-offs among burning, field retention, and feed use.

Author Contributions

Abdullah Kadir Diko contributed to conceptualization, data collection, data curation, formal analysis, and preparation of the original manuscript. Sukirman Rahim and Marini Susanti Hamidun contributed to research supervision, methodological refinement, interpretation, and manuscript revision. Dewi Wahyuni K. Baderan and Syamsul Bahri contributed critical academic review and substantive input to the environmental and livestock-feed components of the study. All authors read and approved the final version of the manuscript.

AI Disclosure Statement

During preparation of this manuscript, the first author used ChatGPT (OpenAI) and Claude (Anthropic) for manuscript organization, English-language editing, and consistency checks. All data, calculations, methodological decisions, interpretations, references, and final wording were reviewed by the authors, who take responsibility for the content of the manuscript.

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