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Potential for Increasing Ruminant Livestock Population Based on Forage Availability in East Kutai Regency

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ABSTRACT

The availability of adequate feed resources is an important factor determining the potential development of ruminant livestock in a region. This study aimed to estimate the availability of forage resources, total feed supply, carrying capacity, and the potential capacity for increasing the ruminant livestock population in East Kutai Regency, East Kalimantan. A quantitative descriptive approach was applied using secondary data obtained from the Central Statistics Agency of East Kutai Regency for 2024. Feed resources were estimated from plantation areas, agricultural land, and crop residues and expressed as dry matter (DM). The carrying capacity was calculated from total feed availability based on a dry matter requirement of 6.25 kg DM livestock unit^{-1} day^{-1}, while the potential capacity for increasing the ruminant livestock population (KPPTR) was determined by subtracting the existing livestock population from the estimated carrying capacity. The results indicated that plantation areas contributed 412,448.81 Mg DM year^{-1}, while agricultural crop residues contributed 20,180.04 Mg DM year^{-1}. Agricultural land provided an additional 4,037.38 Mg DM year^{-1}. Consequently, total feed availability varied substantially among subdistricts, with Muara Wahau, Bengalon, Kongbeng, Sandaran, and Karangan among the areas with relatively high feed resources. The estimated carrying capacity of East Kutai Regency reached 193,074.67 livestock units (AU), compared with an existing ruminant population of 16,975.48 AU, resulting in a theoretical KPPTR of 176,099.19 AU. Muara Wahau recorded the highest KPPTR, whereas Sangatta Utara and Sangatta Selatan showed negative values. These findings indicate considerable feed-based potential for ruminant livestock development, although actual expansion should consider forage accessibility, seasonal availability, feed quality, land-use conditions, and farmer socioeconomic factors.

Keywords: *carrying capacity; crop residues; East Kutai; forage resources; ruminants; livestock development*

INTRODUCTION

The development of ruminant livestock production requires an adequate, good-quality, and sustainable supply of feed resources. Feed is a major component of livestock production systems because it supports maintenance requirements, growth, reproduction, and animal production. In production systems that rely on locally available resources, the availability of forage and plant-based feed materials is an important factor determining the capacity of a region to support livestock populations. Therefore, feed carrying capacity should be assessed to ensure that livestock development is aligned with the available feed resources. The balance between feed supply and livestock requirements can be used to identify feed-surplus and feed-deficit conditions within a particular region (Rahimi et al., 2021).

Feed resources for ruminants are not limited to grazing areas or specifically cultivated forage. Agricultural and plantation lands can also provide substantial biomass that may be utilized as livestock feed, including crop by-products and residues. Rice straw, maize biomass, root-crop residues, and other agricultural residues can serve as feed resources when they are available in sufficient quantities and can be effectively utilized. Studies in Indonesia have indicated that agricultural by-products can contribute substantially to the carrying capacity of ruminant livestock, particularly in areas with intensive agricultural activities (Harahap & Harahap, 2022). The utilization of these resources may also improve resource-use efficiency by integrating crop and livestock production while reducing competition between food production and feed supply (Sandström et al., 2022).

Nevertheless, the availability of plant biomass does not directly represent the amount of feed that can be utilized by livestock. Feed carrying capacity assessments should consider dry matter production, the proportion of biomass that can be effectively utilized as feed, and the dry matter requirements of livestock. Feed availability may also vary among regions depending on land area and land-use patterns, crop productivity, commodity types, and the livestock population to be supported. Therefore, an inventory of available feed resources and an assessment of the balance between feed supply and demand are essential for determining opportunities for rational livestock population development. This approach can be used to identify areas with feed surpluses or deficits and to support livestock development planning based on locally available resources (Rahimi et al., 2021; Duncan et al., 2023).

East Kutai Regency is one of the regions in East Kalimantan with considerable agricultural and plantation activities involving various crop commodities. Regional statistical data indicate that agricultural activities in East Kutai encompass food crops and plantation commodities distributed across several subdistricts (BPS East Kutai Regency, 2025). These activities generate plant biomass that has potential as a livestock feed resource, including forage available within plantation areas and crop residues generated from food-crop production. However, the presence of these resources alone does not adequately indicate the actual feed supply capacity without quantitative estimates of biomass production and its potential utilization. Therefore, further analysis is required to determine the contribution of these plant resources to feed carrying capacity and the ability of the region to support ruminant livestock populations.

Based on these conditions, an inventory and assessment of forage availability and agricultural residues are necessary to determine the actual capacity of East Kutai Regency to provide feed for ruminant livestock. Information on feed availability and livestock requirements can subsequently be used to compare the carrying capacity of the region with the existing livestock population. This comparison can provide an indication of areas that still have potential for livestock population expansion and those where feed resources may be limiting. Therefore, this study aimed to analyze the availability of forage resources from plantation areas and agricultural residues and to estimate the potential for increasing the ruminant livestock population based on feed carrying capacity in East Kutai Regency.

MATERIALS AND METHODS

Methods

This study employed a quantitative descriptive approach using secondary data. The study area encompassed all subdistricts in East Kutai Regency, East Kalimantan Province, Indonesia. The data analyzed consisted of regional statistical data, with the observed variables including the potential availability of forage resources, ruminant livestock population, carrying capacity, and the potential for increasing the ruminant livestock population (KPPTR). The data were obtained from the Central Statistics Agency (BPS) of East Kutai Regency for the year 2024.

Data Analysis

1. Potential Forage Resources

The data were presented in tabulated form at the subdistrict level. Forage resource availability was assessed based on the potential supply of forage using the approach of Nell and Rollinson (1974). This approach estimates forage production based on the recorded land area or harvested area obtained from statistical data and subsequently converts the estimated production into dry matter (DM). The forage resources considered in this study included plantation areas, paddy fields, upland agricultural land, and agricultural residues or by-products from food crops that have potential for use as livestock feed. Forage production from each source was expressed in Mg DM year^{-1} to standardize the data and facilitate comparison with livestock dry matter requirements.

Following the approach of Nell and Rollinson (1974), permanent pasture was used as a reference standard, assuming a production of 15 Mg DM year^{-1}. The potential forage supply from different land-use types was subsequently estimated based on the corresponding land area and conversion coefficients representing their equivalent forage production relative to permanent pasture. The assumed production values for agricultural residues and forage resources, together with their equivalent conversion coefficients, are presented in Tables 1 and 2. For several types of crop residues for which production assumptions were not provided by Nell and Rollinson (1974), production estimates were based on data reported by the Directorate General of Livestock Services and the Faculty of Animal Science, Gadjah Mada University (1982).

Table 1. Assumed Production Values of Agricultural Crop Residues (HHSP).

HHSP material	Production (Mg)	Dry matter (%)
Lowland rice straw[1]	3.86	92.5
Upland rice straw[1]	2.76	92.5
Maize straw[2]	10.00	80.3
Cassava leaves[2]	5.00	26.0
Sweet potato leaves[2]	15.00	20.0
Soybean straw[2]	3.00	88.9
Peanut leaves[2]	4.00	90.0

Source: [1] Directorate General of Livestock Services and Faculty of Animal Science, Gadjah Mada University (1982); [2] Nell and Rollinson (1974).

Table 2. Forage Resources and Equivalent Conversion Values.

Forage resource	Equivalent conversion value to standard source	Description
Permanent pasture (Prp) as the standard source	-	Production of 15 Mg DM $year^{-1}$
Fallow paddy fields (Sb)	10% of Sb area = Prp	Assumption: 20% of paddy field area is left fallow
Paddy field bunds (Gs)	100% of Gs area = Prp	Bund area = 3% of total paddy field area
Cultivated forest/similar forest (Hb)	5% of Hb area = Prp	-
Secondary forest (Hs)	2% of Hs area = Prp	-
Upland/dry agricultural land (Tg)	1% of Tg area = Prp	-
Plantation (Pk)	5% of Pk area = Prp	-

Source: Nell and Rollinson (1974).

The equations used to analyze the potential availability of forage resources were as follows:

a) Dry Matter Production from Plantation Areas

The potential forage supply from plantation areas was estimated based on the available plantation area in each subdistrict. The plantation commodities considered included oil palm, coconut, rubber, coffee, and cocoa. Forage dry matter production from plantation areas was estimated assuming that 5% of the plantation area could be utilized as a forage source and converted to its equivalent permanent pasture area, with a standard production of 15 Mg DM ha^{-1} $year^{-1}$. The calculation was performed using the following equation:

$$\text{Plantation DM production} = \text{plantation area} \times 5\% \times 15 \text{ Mg DM ha}^{-1} \text{ year}^{-1}$$

The total plantation area was calculated as the sum of the areas of all plantation commodities in each subdistrict. The estimated DM production from all plantation sources was then summed to obtain the total potential forage supply from plantations, expressed as Mg DM $year^{-1}$.

b) Dry Matter Production from Agricultural Crop Residues

The production of forage from agricultural crop residues (HHSP) was estimated based on the harvested area of each food crop and the assumed dry matter production values used in the approach of Nell and Rollinson (1974). The food crops considered included rice, maize, cassava, sweet potato, peanut, and soybean.

$$HHSP = \Sigma (LP_i \times P_i \times DM_i)$$

where:

HHSP = forage from agricultural crop residues (Mg DM $year^{-1}$)

LP_i = harvested area of crop i (ha)

P_i = assumed residue production of crop i (Mg ha^{-1})

DM_i = assumed dry matter content of crop i (%)

c) Dry Matter Production from Agricultural Land

The potential forage supply from agricultural land was estimated from forage sources consisting of upland/dry agricultural land, fallow paddy fields, and paddy field bunds. Permanent pasture was used as the standard reference, with a production of 15 Mg DM ha^{-1} $year^{-1}$, following the approach of Nell and Rollinson (1974).

In this study, the area of upland/dry agricultural land was estimated from the total harvested area of food crops other than rice, namely maize, cassava, sweet potato, peanut, and soybean. Dry matter production from upland/dry agricultural land was estimated assuming that 1% of the area was equivalent to the standard forage source. The equation was:

$$\text{Upland/dry agricultural land DM} = \text{upland/dry agricultural land area} \times 1\% \times 15 \text{ Mg DM ha}^{-1} \text{ year}^{-1}$$

The area of fallow paddy fields was assumed to represent 20% of the rice harvested area. Dry matter production from fallow paddy fields was estimated assuming that 10% of the fallow area was equivalent to the standard forage source. The equation was:

$$\text{Fallow paddy field DM} = \text{rice harvested area} \times 20\% \times 10\% \times 15 \text{ Mg DM ha}^{-1} \text{ year}^{-1}$$

Dry matter production from paddy field bunds was estimated assuming that bunds accounted for 3% of the rice harvested area and that 100% of this area was equivalent to the standard forage source. The equation was:

$$\text{Paddy field bund DM} = \text{rice harvested area} \times 3\% \times 100\% \times 15 \text{ Mg DM ha}^{-1} \text{ year}^{-1}$$

The total dry matter production from agricultural land was calculated by summing the DM production from upland/dry agricultural land, fallow paddy fields, and paddy field bunds:

$$\text{Agricultural land DM production} = \text{upland/dry agricultural land DM} + \text{fallow paddy field DM} + \text{paddy field bund DM}$$

d) Forage Resources and Total Feed Availability

Forage resources (SDH) represent the total dry matter production derived from plantation and agricultural land. In this study, SDH was calculated as the sum of forage DM production from plantation areas and agricultural land. The equation was:

$$\text{SDH (Mg DM year}^{-1}) = \text{plantation DM} + \text{agricultural land DM}$$

Total feed availability was calculated as the sum of forage resources (SDH) and forage derived from agricultural crop residues (HHSP):

$$\text{Total feed availability (Mg DM year}^{-1}) = \text{SDH} + \text{HHSP}$$

2. Ruminant Livestock Population, Carrying Capacity, and Potential Capacity for Increasing Ruminant Livestock Population (KPPTR)

The ruminant livestock population, comprising beef cattle, buffaloes, goats, and sheep, was converted into livestock units (AU) to standardize the population according to feed requirements. The conversion coefficients used were 1 adult beef cattle and 1 adult buffalo equivalent to 1 AU each, whereas 1 goat and 1 sheep were each equivalent to 0.14 AU (Directorate General of Livestock Services, 1998). Carrying capacity (CC) was calculated based on the total available feed dry matter and the dry matter requirement of one livestock unit, using the following equation:

$$CC = (\text{Total feed availability} \times 1{,}000) / (6.25 \times 365)$$

where:

Total feed = available feed dry matter (Mg DM $year^{-1}$)

1,000 = conversion factor from Mg to kg

6.25 = daily dry matter requirement (kg DM AU^{-1} day^{-1})

365 = number of days per year

The potential capacity for increasing the ruminant livestock population (KPPTR) represents the capacity of a given area to accommodate additional ruminant livestock based on the availability of forage resources. KPPTR was calculated using the following equation:

$$\text{KPPTR} = \text{CC} - \text{Current livestock population (AU)}$$

A positive KPPTR value indicates a theoretical capacity for increasing the livestock population based on feed availability, whereas a negative value indicates that the existing livestock population exceeds the estimated carrying capacity based on available feed resources. The KPPTR values for each subdistrict were subsequently ranked from the highest to the lowest value to describe differences in the potential capacity for increasing the ruminant livestock population among subdistricts.

RESULTS AND DISCUSSION

Potential Forage Resources

a) Dry Matter Production from Plantation Areas

The estimation results showed that plantation areas in East Kutai Regency made a substantial contribution to forage resource availability. Based on the assumptions of Nell and Rollinson (1974), Muara Wahau Subdistrict had the highest estimated forage resource production from plantation areas, reaching 50,703.00 Mg DM year^{-1}, followed by Sandaran at 43,978.76 Mg DM year^{-1} and Bengalon at 42,366.03 Mg DM year^{-1}. In contrast, the lowest production was recorded in Sangatta Utara, with 312.75 Mg DM year^{-1} (Table 3).

Table 3. Dry Matter Production of Forage Resources from Plantation Areas (Mg DM year^{-1})

Subdistrict	Oil palm	Coconut	Rubber	Coffee	Cocoa	Total
Muara Ancalong	26,939.36	92.25	621.75	0.75	153.00	27,807.11
Busang	9,747.26	12.75	603.79	-	1,322.63	11,686.42
Long Mesangat	9,262.96	20.31	473.06	-	-	9,756.33
Muara Wahau	50,609.21	4.50	89.29	-	-	50,703.00
Telen	38,363.30	9.75	458.25	-	4.50	38,835.80
Kongbeng	39,639.24	15.00	154.50	-	12.00	39,820.74
Muara Bengkal	15,182.09	5.08	257.09	-	1.50	15,445.75
Batu Ampar	2,914.84	18.75	909.90	6.19	-	3,849.68
Sangatta Utara	69.00	7.50	233.25	-	3.00	312.75
Bengalon	41,977.53	0.75	387.00	-	0.75	42,366.03
Teluk Pandan	1,547.25	51.00	266.70	8.06	35.68	1,908.69
Sangatta Selatan	366.23	30.83	635.25	4.50	3.08	1,039.88
Rantau Pulung	19,833.45	35.25	379.50	0.00	3.75	20,251.95
Sangkulirang	29,785.94	276.38	4,643.75	1.50	54.75	34,762.32
Kaliorang	8,572.01	59.25	64.88	3.75	27.00	8,726.89
Sandaran	41,860.73	218.81	1,526.07	9.00	364.16	43,978.76
Kaubun	24,605.02	20.48	105.00	3.38	94.13	24,827.99
Karangan	35,426.34	3.00	829.14	-	110.25	36,368.73
Total	**396,701.75**	**881.62**	**12,638.16**	**37.13**	**2,190.17**	**412,448.81**

The substantial contribution of plantation areas to forage resources indicates that plantations serve not only as areas for the production of major commodities but also have the potential to provide forage biomass that can be utilized in crop–livestock integration systems. However, these values represent estimates derived from conversion factors and therefore should not be interpreted as the total actual biomass available or as biomass that can be directly consumed by livestock. Based on the assumptions of Nell and Rollinson (1974), the total estimated dry matter production from plantation areas reached approximately 412,448.81 Mg DM year^{-1}. This contribution was dominated by oil palm plantations, which occupied a relatively larger area than the other plantation commodities.

These findings are consistent with the study of Daru et al. (2023) on cattle–oil palm integration systems in East Kalimantan. Their study demonstrated that understory vegetation in oil palm plantations exhibited diversity, nutrient content, and biomass production that could support forage provision for livestock. Thus,

oil palm plantations can be viewed not only as areas for producing the main commodity but also as potential sources of feed within crop–livestock integration systems.

Nevertheless, a large plantation area does not automatically indicate that all understory forage biomass is available for livestock utilization. Understory vegetation production is influenced by plant age, canopy shading, weed management, soil conditions, and the intensity of land utilization. Sutedi et al. (2025) reported differences in understory forage production beneath oil palm stands according to plantation age and environmental conditions. Their findings indicate that changes in light intensity resulting from canopy development can affect both forage composition and production.

b) Dry Matter Production from Agricultural Crop Residues

In addition to plantation areas, crop residues represent an important source of feed biomass. The estimated agricultural crop residue forage (HHSP) in this study included rice straw, maize straw or biomass, cassava residues, sweet potato residues, peanut residues, and soybean residues. Based on data from all subdistricts, the total estimated HHSP reached approximately 20,180.04 Mg DM year^{-1}. The estimated dry matter production of agricultural crop residue forage (HHSP) is presented in Table 4.

Table 4. Dry Matter Production of Agricultural Crop Residue Forage (HHSP) (Mg DM year^{-1})

Subdistrict	Rice	Maize	Cassava	Sweet potato	Peanut	Soybean	Total
Muara Ancalong	–	209.58	16.25	–	29.52	–	255.35
Busang	2,214.85	94.75	0.91	2.37	0.07	–	2,312.96
Long Mesangat	978.39	128.48	–	7.50	2.70	–	1,117.07
Muara Wahau	439.35	48.18	1.30	6.00	–	–	494.83
Telen	153.50	–	0.00	–	–	–	153.50
Kongbeng	3,001.43	94.75	34.52	9.60	18.61	–	3,158.91
Muara Bengkal	363.05	57.01	1.91	8.85	4.32	–	435.14
Batu Ampar	303.49	118.84	7.02	–	–	–	429.36
Sangatta Utara	92.65	78.29	24.05	14.25	13.14	0.67	223.05
Bengalon	1,115.17	24.09	2.60	90.00	1.80	–	1,233.66
Teluk Pandan	573.32	648.42	19.50	74.40	43.20	–	1,358.84
Sangatta Selatan	1,581.45	81.50	11.86	17.25	18.36	0.80	1,711.22
Rantau Pulung	379.33	212.80	9.43	33.00	22.50	–	657.05
Sangkulirang	733.42	297.11	13.00	10.50	18.00	1.33	1,073.36
Kaliorang	436.07	140.53	13.00	48.00	–	–	637.59
Sandaran	296.35	281.05	6.76	–	–	–	584.16
Kaubun	3,648.80	–	7.93	7.35	18.54	–	3,682.62
Karangan	513.58	136.51	2.28	–	9.00	–	661.37
Total	**16,824.20**	**2,651.91**	**172.30**	**329.07**	**199.76**	**2.80**	**20,180.04**

The highest HHSP production was recorded in Kaubun Subdistrict at 3,682.62 Mg DM year^{-1}, followed by Kongbeng at 3,158.91 Mg DM year^{-1} and Busang at 2,312.96 Mg DM year^{-1}. In contrast, Telen had the lowest estimated HHSP production, at 153.50 Mg DM year^{-1}. These differences were primarily associated with the harvested area and types of food crops cultivated in each subdistrict.

The dominance of rice straw indicates that food crop production, particularly rice, is directly associated with the potential availability of feed resources for ruminants. This condition provides an opportunity to strengthen integration between the crop and livestock subsectors. Biomass generated from crop production should not necessarily be regarded solely as waste, as a portion can be returned to livestock production after considering its nutritional value, utilization rate, seasonal availability, and processing requirements. This finding is consistent with Harahap and Harahap (2022), who reported that agricultural residues can make a substantial contribution to dry matter availability and the carrying capacity of ruminant livestock. Their study used secondary data and a descriptive approach to estimate feed potential from agricultural residues, making its analytical approach relatively comparable to that used in the present study in East Kutai Regency.

Therefore, the substantial contribution of agricultural crop residues indicates an opportunity to integrate food crop production with livestock production. Crop residues previously regarded as by-products can be utilized as feed resources, allowing a portion of the biomass generated by agricultural systems to be returned to livestock production. This concept is consistent with the integrated crop–livestock system approach, which positions crop residues as one component of more circular resource utilization. Swastika et al. (2024) explained that crop–livestock integration can improve resource-use efficiency through the utilization of crop residues as livestock feed and the return of livestock by-products to agricultural systems.

c) Dry Matter Production from Agricultural Land

The potential forage supply from agricultural land in this study was derived from upland/dry agricultural land, fallow paddy fields, and paddy field bunds. The estimates showed considerable variation among subdistricts, with the highest value recorded in Kaubun at 771.52 Mg DM year^{-1}, followed by Kongbeng at 654.09 Mg DM year^{-1} and Busang at 479.96 Mg DM year^{-1}. The lowest value was recorded in Muara Ancalong at 38.30 Mg DM year^{-1} (Table 5).

Table 5. Dry Matter Production from Upland Agricultural Land, Fallow Paddy Fields, and Paddy Field Bunds (Mg DM year^{-1})

Subdistrict	Upland/dry agricultural land	Fallow paddy fields	Paddy field bunds	Total
Muara Ancalong	38.30	-	-	38.30
Busang	14.72	186.10	279.14	479.96
Long Mesangat	20.80	82.21	123.31	226.32
Muara Wahau	8.32	36.92	55.37	100.61
Telen	0.00	12.90	19.35	32.24
Kongbeng	23.62	252.19	378.28	654.09
Muara Bengkal	10.81	30.50	45.76	87.07
Batu Ampar	18.88	25.50	38.25	82.63
Sangatta Utara	19.56	7.79	11.68	39.02
Bengalon	17.77	93.70	140.55	252.02
Teluk Pandan	117.83	48.17	72.26	238.26
Sangatta Selatan	19.47	132.88	199.31	351.66
Rantau Pulung	41.66	31.87	47.81	121.34
Sangkulirang	50.99	61.62	92.43	205.05
Kaliorang	30.23	36.64	54.96	121.83
Sandaran	43.17	24.90	37.35	105.42
Kaubun	5.07	306.58	459.87	771.52
Karangan	22.17	43.15	64.73	130.05
Total	**503.38**	**1,413.60**	**2,120.40**	**4,037.38**

Compared with plantation-based sources, the contribution of agricultural land was relatively small. This can be explained by the use of conversion factors that assume only a proportion of the total land area serves as a forage source equivalent to permanent pasture. Such an approach allows feed resources from different land-use types to be compared using a common dry matter unit, but it is not intended to represent the actual forage production of the entire land area.

The presence of paddy field bunds and fallow paddy fields remains important despite their relatively smaller aggregate contribution. These two sources can provide locally available forage in close proximity to farming operations and may support cut-and-carry feeding systems. However, their utilization is strongly dependent on planting and harvesting schedules, land conditions, accessibility, and crop management practices. Therefore, forage resources from agricultural land are more appropriately viewed as part of the regional feed resource portfolio rather than as the sole basis for livestock development.

d) Forage Resources and Total Feed Availability

In this study, forage resources were derived from the combined potential forage supply of plantation areas and agricultural land, while total feed availability was calculated by adding agricultural crop residue forage (HHSP).

Table 6. Forage Resources (SDH) and Total Feed Availability (Mg DM year^{-1})

Subdistrict	Forage resources (SDH) (Mg DM year^{-1})	Total feed availability (Mg DM year^{-1})
Muara Ancalong	27,845.42	28,100.77
Busang	12,166.37	14,479.33
Long Mesangat	9,982.65	11,099.72
Muara Wahau	50,803.61	51,298.44
Telen	38,868.05	39,021.54
Kongbeng	40,474.83	43,633.74
Muara Bengkal	15,532.82	15,967.96
Batu Ampar	3,932.30	4,361.66
Sangatta Utara	351.77	574.83
Bengalon	42,604.29	43,837.95
Teluk Pandan	2,260.35	3,619.18
Sangatta Selatan	1,161.21	2,872.43
Rantau Pulung	20,457.00	21,114.05
Sangkulirang	34,884.15	35,957.51
Kaliorang	8,832.31	9,469.90
Sandaran	44,750.28	45,334.44
Kaubun	24,958.04	28,640.66
Karangan	40,406.11	41,067.47

The calculations at the subdistrict level revealed substantial variation among areas. Muara Wahau, Bengalon, Kongbeng, Sandaran, and Karangan had relatively high levels of dry matter availability, whereas Sangatta Utara, Sangatta Selatan, Teluk Pandan, and Batu Ampar had comparatively lower values (Table 6).

This pattern indicates that the potential for ruminant livestock development in East Kutai Regency cannot be assessed solely using the regency-wide average. Differences in land-use structure result in the concentration of feed resources in particular areas. Subdistricts with extensive plantation areas may have high forage potential despite relatively limited contributions from food crops. Conversely, areas with more intensive food crop production may obtain additional feed resources from agricultural residues. From a regional planning perspective, these conditions indicate the importance of a subdistrict-based approach. Subdistricts with high feed availability may have greater potential to accommodate additional livestock populations, whereas areas with lower availability may require strategies to increase forage productivity, process agricultural residues, or obtain feed from other areas.

Crop–livestock integration can be one strategy for improving the utilization of these resources. Swastika et al. (2024) reported that crop–livestock integration can support a circular economy through the utilization of crop residues as livestock feed and the reuse of livestock by-products within agricultural systems. However, implementation requires appropriate knowledge, technology, institutional support, and policy frameworks.

Ruminant Livestock Population, Carrying Capacity, and Potential Capacity for Increasing Ruminant Livestock Population (KPPTR)

The ruminant livestock population analyzed in this study consisted of beef cattle, buffaloes, goats, and sheep, which were converted into livestock units (AU). This conversion was necessary to enable different livestock species to be compared based on a common feed requirement unit. The conversion results showed that the total ruminant livestock population in East Kutai Regency in 2024 reached 16,975.48 LU. Data on livestock population, carrying capacity, and the Potential Capacity for Increasing Ruminant Livestock Population (KPPTR) are presented in Table 7.

Table 7. Ruminant livestock population, carrying capacity, and Potential Capacity for Increasing Ruminant Livestock Population (KPPTR) in East Kutai Regency.

Subdistrict	Carrying Capacity (AU)	Ruminant Livestock Population (AU)	KPPTR (AU)	Rank
Muara Ancalong	12,318.15	365.46	11,952.69	8
Busang	6,347.10	9.72	6,337.38	12
Long Mesangat	4,865.63	448.88	4,416.75	13
Muara Wahau	22,486.99	879.00	21,607.99	1
Telen	17,105.33	330.38	16,774.95	5
Kongbeng	19,127.12	2,250.42	16,876.70	4
Muara Bengkal	6,999.66	437.20	6,562.46	11
Batu Ampar	1,911.96	395.54	1,516.42	15
Sangatta Utara	251.98	349.70	−97.72	18
Bengalon	19,216.64	893.98	18,322.66	3
Teluk Pandan	1,586.49	1,072.52	513.97	16
Sangatta Selatan	1,259.15	1,325.78	−66.63	17
Rantau Pulung	9,255.47	1,480.60	7,774.87	10
Sangkulirang	15,762.19	1,653.28	14,108.91	7
Kaliorang	4,151.19	2,028.60	2,122.59	14
Sandaran	19,872.63	199.48	19,673.15	2
Kaubun	12,554.81	2,338.22	10,216.59	9
Karangan	18,002.18	516.72	17,485.46	6
Total	**193,074.67**	**16,975.48**	**176,099.19**	

Based on the total dry matter availability and a feed requirement of 6.25 kg DM AU^{-1} day^{-1}, the theoretical carrying capacity of East Kutai Regency reached 193,074.67 AU. The analysis of carrying capacity and KPPTR revealed substantial differences among subdistricts in their theoretical capacity to support additional ruminant livestock. Based on the KPPTR values, Muara Wahau ranked first with 21,607.99 AU, followed by Sandaran with 19,673.15 AU and Bengalon with 18,322.66 AU. The relatively high KPPTR values in these areas indicate that their estimated carrying capacity remains considerably greater than the existing ruminant livestock population. Thus, differences in KPPTR rankings are determined not only by the amount of available feed resources but also by the number of livestock already utilizing those resources in each subdistrict.

This pattern is evident in Kongbeng, which had a carrying capacity of 19,127.12 AU but ranked fifth in terms of KPPTR, with a value of 16,876.70 AU. This condition was associated with its relatively large existing livestock population of 2,250.42 AU. In contrast, Sandaran had a carrying capacity of 19,872.63 AU and an existing livestock population of only 199.48 AU, resulting in a KPPTR of 19,673.15 AU and a second-place ranking. These findings demonstrate that a high carrying capacity does not necessarily result in the same KPPTR ranking because KPPTR represents the difference between carrying capacity and the existing livestock population.

Subdistricts with high KPPTR rankings theoretically have greater capacity to accommodate additional livestock based on the estimated availability of feed resources. Muara Wahau, for example, had a high availability of feed resources, particularly from plantation areas, resulting in a carrying capacity of 22,486.99 AU. After accounting for the existing livestock population, the resulting KPPTR was 21,607.99 AU. This condition indicates that the estimated feed resource potential in the area has not been fully matched by the existing livestock population. However, this value should be interpreted as a theoretical capacity because feed availability in this study was estimated using land-resource conversion factors and does not represent the entire biomass that is actually accessible and consumable by livestock. Similar approaches to carrying-capacity assessment indicate that the balance between feed supply and livestock requirements should be considered together with the spatial and temporal characteristics of feed resources (Rahimi et al., 2021).

A positive KPPTR value indicates that, based on the assumptions regarding dry matter availability and livestock feed requirements used in this study, the theoretical carrying capacity of an area remains greater than its existing livestock population. Conversely, a negative KPPTR value indicates that the existing livestock population has exceeded the estimated theoretical carrying capacity based on the available feed

resources. In this study, negative KPPTR values were observed in Sangatta Selatan and Sangatta Utara, with values of −66.63 and −97.72 AU, respectively. These values indicate that, based on the estimated dry matter availability, the existing livestock population in these two subdistricts exceeds their theoretical carrying capacity. However, this does not necessarily indicate an actual feed shortage in the field. Rather, it suggests that any future increase in livestock population in these areas would need to be accompanied by additional feed resources or improved efficiency in utilizing existing resources.

Differences in KPPTR rankings also indicate that the potential for livestock development in East Kutai Regency has a distinct spatial dimension. Subdistricts with high KPPTR values do not necessarily have more developed livestock production systems; rather, they have a larger difference between estimated feed-supply capacity and the existing livestock population. Conversely, subdistricts with low or negative KPPTR values may require greater attention to feed availability if livestock population expansion is to be pursued. Therefore, the KPPTR ranking can serve as an initial indicator for identifying areas that warrant further assessment for livestock development, but it should not be used as the sole basis for establishing livestock population expansion targets.

These findings further emphasize the importance of a spatially based approach to livestock development. Surplus feed capacity identified in one subdistrict cannot necessarily be directly utilized to meet livestock feed requirements in another subdistrict because of differences in location, accessibility, transportation costs, land-use patterns, and the physical form of available feed resources. The utilization of locally available feed resources through crop–livestock integration may provide an approach for improving resource-use efficiency. Swastika et al. (2024) reported that crop–livestock integration enables crop residues to be utilized as livestock feed while also facilitating the recycling of livestock by-products within agricultural systems. Therefore, KPPTR rankings should be regarded as an initial basis for identifying areas with potential for livestock development, followed by further assessment using actual forage production data, feed quality, seasonal availability, accessibility, and the socioeconomic conditions of livestock farmers.

CONCLUSION

The assessment demonstrates that East Kutai Regency possesses substantial feed resources that can support the development of ruminant livestock. Plantation areas constituted the largest estimated source of dry matter, contributing 412,448.81 Mg DM year^{-1}, followed by agricultural crop residues at 20,180.04 Mg DM year^{-1} and agricultural land at 4,037.38 Mg DM year^{-1}. The contribution of these resources varied considerably among subdistricts, reflecting differences in plantation area, food-crop production, and land-use patterns.

Based on the estimated feed supply and a dry matter requirement of 6.25 kg DM AU^{-1} day^{-1}, the theoretical carrying capacity of East Kutai Regency was 193,074.67 AU. The existing ruminant population was estimated at 16,975.48 AU, resulting in a theoretical KPPTR of 176,099.19 AU. Muara Wahau had the highest estimated KPPTR at 21,607.99 AU, followed by Sandaran at 19,673.15 AU and Bengalon at 18,322.66 AU. In contrast, Sangatta Utara and Sangatta Selatan had negative KPPTR values of −97.72 and −66.63 AU, respectively.

The results indicate that the potential for ruminant livestock development is spatially heterogeneous across East Kutai Regency. Therefore, KPPTR values should be used as an initial indicator for identifying areas with feed-based development potential rather than as a direct target for livestock population expansion. Further assessment involving actual forage biomass, nutritional quality, seasonal variation, accessibility, feed processing requirements, transportation, and socioeconomic conditions is required before determining practical livestock development capacity. Strengthening crop–livestock integration and improving the utilization of plantation vegetation and agricultural residues may provide additional opportunities to increase the efficiency of locally available feed resources.

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