

# Forage species diversity and composition, and carrying capacity of rangelands in Teluk Wondama Regency, West Papua, Indonesia

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**Abstract.** *Lekitoo MN, Lekitoo T, Santoso B, Saragih EW, Yoku O, Hariadi BT, Iyai DA, Sonbait LY. 2026. Forage species diversity and composition, and carrying capacity of rangelands in Teluk Wondama Regency, West Papua, Indonesia. Biodiversitas 27 (1): d270111. <https://doi.org/10.13057/biodiv/d270111>. Rangelands and natural pastures serve as the backbone of livestock feed. However, there is limited empirical data on their productivity and capacity to sustain livestock populations in lesser-known regions, such as Papua. The study aims to assess the botanical diversity and composition of forage in natural rangeland in Teluk Wondama Regency, West Papua, Indonesia, and to evaluate its carrying capacity. Botanical sampling was conducted by establishing 30 sample plots measuring 1×1 m<sup>2</sup> in areas of 64 ha within the Warayaro natural rangelands. Forage productivity was estimated based on botanical composition, fresh forage, dry matter, and total digestible nutrients. The findings reveal that the rangeland in Warayaro is a heterogeneous pasture comprising 5 types of fodder, including 4 grasses and 1 legume species. Non-native species from 3 families dominated the pasture, namely *Paspalum dilatatum*, followed by *Paspalum conjugatum*, *Centrosema pubescens*, *Eleusine indica*, and *Cyperus rotundus*. The botanical composition consisted of 86.7% grasses and 13.3% legumes. Average forage yield is 2.0 t FM, 0.4 t ha<sup>-1</sup> and 1.02 t ha<sup>-1</sup> TDN. The existing Warayaro forage has a carrying capacity for cattle of 0.4 AU ha<sup>-1</sup> yr<sup>-1</sup> (FM), 0.3 AU ha<sup>-1</sup> yr<sup>-1</sup> (DM) and 0.8 AU ha<sup>-1</sup> yr<sup>-1</sup> (TDN). The Warayaro natural pasture has low production potential (264.7 kg TDN per 100 kg of livestock body weight) and moderate nutritional quality, with a protein content of only 11.2%. The Warayaro pasture is more suitable for growing young stock to reach a body weight of 182 kg. The carrying capacity of the rangeland for cattle and goat is 32 head yr<sup>-1</sup> is 320 head yr<sup>-1</sup>, respectively. Key ecological recommendations include increasing the proportion of legumes through reseeding, implementing rotational grazing, and monitoring and controlling *C. rotundus* to prevent competitive exclusion of forage species.*

**Keywords:** Carrying capacity estimation, grazing management, tropical pasture ecology, West Papua rangeland

## INTRODUCTION

Rangelands, covering over 80 million km<sup>2</sup> globally, are foundational to ecological integrity and socio-economic resilience. They sustain nearly 1 billion livestock units, support 2 billion people, and provide essential ecosystem functions, including carbon sequestration, biodiversity conservation, grazing-based livelihoods, and cultural services (Maestre et al. 2024). Briske et al. (2020) highlighted that sustainably managed pastoral systems deliver ecosystem services, including nutrient cycling and cultural heritage, comparable in value to those of temperate forests.

Livestock production supports rural livelihoods, food security, and regional economies across Indonesia (Khairiyakh and Mulyo 2015; Maylinda et al. 2019), including in Teluk Wondama Regency, West Papua Province, Indonesia. In 2022, Teluk Wondama supported approximately 679.1 animal units (AU), comprising 652 AU from beef cattle and 27.1 AU from goats; thus, cattle dominate (~96%) while goats contribute a small share (~4%) (BPS Teluk Wondama 2025). Production is largely traditional (extensive) to semi-intensive, where animals depend heavily on natural grazing and limited feed inputs.

Sustainability of the livestock sector depends on the availability and quality of natural forages (Abdullah et al. 2017; Hau et al. 2023), which are the primary feed resources for grazing animals such as cattle, goats, and sheep (Rasouli and Amiri 2016; Accatino et al. 2017; Rahmawati et al. 2020). Forage quantity and quality determine pasture carrying capacity, defined as the maximum number of animals that can graze an area without causing ecological degradation. Low-quality or sparse forage limits intake (Lüscher et al. 2020), slows growth (Salguero-Gómez et al. 2016), reduces reproductive performance (Reswati et al. 2021), and increases the risk of overgrazing when demand exceeds plant regrowth.

As climate variability, land-use change, and ecological degradation affect forage availability, it becomes increasingly important to quantify and monitor carrying capacity to avoid overgrazing, land degradation, and reduced livestock productivity (Se'u et al. 2015; Maylinda et al. 2019; Prasetyo and Heryanto 2021). However, empirical data from Teluk Wondama remain scarce on botanical composition, forage yield, nutritional quality, and sustainable carrying capacity. This lack of localized evidence hinders tailored

land-use policies, grazing strategies, and restoration plans (Sutedi et al. 2025).

Teluk Wondama comprises grasslands, forests, and agricultural mosaics used for communal grazing (Hilmiati et al. 2021). Productivity can be limited when livestock numbers exceed available feed under climate variability and land-use change (Asindu et al. 2017; Rojas-Downing et al. 2017; Maylinda et al. 2019). This imbalance can reduce forage quantity and quality (Abdullah et al. 2017; French 2017) and cause ecological and economic losses (Hilmiati et al. 2021; Nair et al. 2021). Therefore, improvements should start with an ecological assessment to guide local stocking and management (Zahra et al. 2015; Reed et al. 2022; Munson et al. 2024).

Recent Indonesian studies in other settings reported native grass dominance and limited legume cover, which constrain protein content, emphasizing legume enrichment (Daru et al. 2023; Iyai et al. 2023; Setiawan et al. 2024). Sutedi et al. (2025) showed that rotational grazing improved biomass yield and carrying capacity compared with continuous grazing. Yet these findings may not reflect Wondama's ecological diversity and seasonal dynamics.

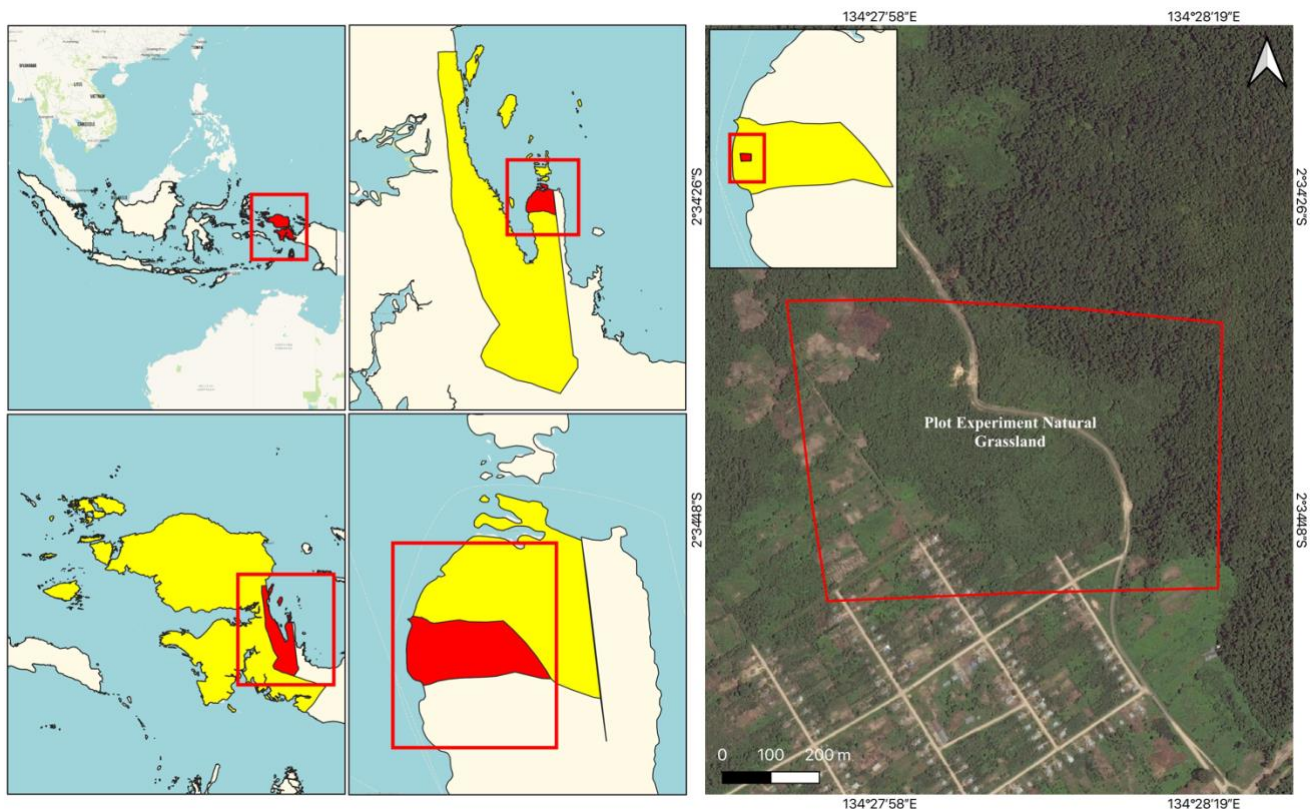
This study fills the local gap by quantifying botanical composition and dominance, forage yield (fresh matter, dry matter, and Total Digestible Nutrients, TDN), and protein content in Warayaro, a natural grazing area in Teluk Wondama, and translating these measurements into carrying capacity estimates ( $\text{AU ha}^{-1} \text{yr}^{-1}$ ). We hypothesize that

Warayaro's native pasture has low to moderate productivity, with carrying capacity below the national standard for Indonesian rangelands, and that high dominance with low evenness may reduce forage diversity and resilience. The novelty lies in integrating forage production, botanical composition, and nutritional quality to identify the most suitable livestock production system (breeding, fattening, or rearing) for Wondama's inland rangelands.

## MATERIALS AND METHODS

### Study area and period

This research was conducted in the natural grazing pasture of Warayaro, Sobey Village, Teluk Duari District, Teluk Wondama Regency, West Papua, Indonesia (Figure 1), for a period of two months, from January 11 to March 11, 2023. Teluk Wondama Regency was once part of Manokwari Regency and includes island areas, mostly located on the mainland of Papua Island. The regency comprises 13 districts, 75 villages, and 1 urban village, covering a total area of 14,953.8 km<sup>2</sup>. Teluk Wondama Regency lies between the coordinates 132°35'-134°45' E and 0°15'-3°25' S. As a tropical region like much of Indonesia, Teluk Wondama Regency features a topography that includes coastal areas, lowlands, and mountainous regions, and it borders several other regencies.



**Figure 1.** Map of study area and sampling plots in natural rangelands of Warayaro, Sobey Village, Teluk Duari District, Teluk Wondama Regency, West Papua Province, Indonesia

The administrative boundaries of Teluk Wondama Regency are to the North bordered by Ransiki District of Manokwari Regency and Cenderawasih Bay, to the South bordered by Yaur District of Nabire Regency, to the West bordered by Kuri and Idoor Districts of Teluk Bintuni Regency and to the East bordered by Yaur District of Nabire Regency and Cenderawasih Bay (BPS Teluk Wondama 2025).

The regency has a humid tropical climate, with a minimum temperature of 23.42°C and a maximum of 31.94°C. Based on the Schmidt and Ferguson climate classification and rainfall data, Teluk Wondama falls into Category B, with a Q value of 0.219, indicating a wet climate. Average rainfall is 110.25 mm per month, average humidity is 83.33%, and sunlight intensity is 59.66% (BPS Teluk Wondama 2025). The livelihoods of residents in Warayaro, Sobey Village, Teluk Duari District, Teluk Wondama Regency, include farming, fishing, and livestock raising.

## Data collection

### Research materials and tools

The materials used in this study included forages collected in the pasture, plastic bags, newspaper, raffia rope, and aluminum foil. The equipment used included a GPS device, measuring tape, compass, 2-m wooden stakes, 1x1 m quadrants, machete, cutter knife, pruning scissors, caliper (phi band), altimeter, 2 kg capacity analytical balance, electric oven, scissors, digital camera, 30 cm ruler, hand lens, measuring tape, and plant identification book (Lazier and Ahmad 2016; Muchugi et al. 2023).

### Techniques and methods

This study used a descriptive method with survey techniques and direct field observation. Sampling followed the method recommended by French (2017). The area of the natural pasture was measured using GPS and a measuring tape. The number of samples was determined by the forage sampling requirement: for a 65-ha grazing area, 100 samples are required. If the area is smaller or larger than 65 ha, the number of samples is adjusted using the formula below:

$$\text{Number of samples} = \frac{\text{Land area (ha)}}{65 \text{ (ha)}} \times 100 \text{ (ha)}$$

Samples of 30 points (1×1 m<sup>2</sup>) were taken systematically (Figure 1) by creating representative transects using the line intercept method (French 2017). All forages within the sampling plot were cut as close to the ground as possible, including parts of tree species potentially consumed by livestock (up to 1.5 m height). Fresh weight was measured, and the samples were bagged. Yield per square meter was recorded. To ensure regrowth, a portion of the plants was left uncut based on the Proper Use Factor (PUF), which varies depending on field conditions, animal type, plant species, climate, and season, i.e., light use of 25-30%, moderate use of 40-45%, and heavy use of 60-70%.

### Field-measured variables

Each forage species within the sampling plot (1×1 m<sup>2</sup>) was identified and described morphologically, including growth type, height, stem diameter, bark appearance, leaf composition, general leaf shape, leaf arrangement, and floral and fruit characteristics, based on Se'u et al. (2015). Botanical composition was calculated based on the wet weight of each species, categorized into grasses, legumes, and other forages (Prihantoro et al. 2023) as follows:

$$\text{Species X (\%)} = \frac{\text{Wet weight of species X } \left(\frac{\text{g}}{\text{m}^2}\right)}{\text{Total sample wet weight } \left(\frac{\text{g}}{\text{m}^2}\right)} \times 100\%$$

Carrying capacity was estimated based on forage production using Voissin's method (Se'u et al. 2015; Prihantoro et al. 2023):

$$\text{Fresh forage production (kg/m}^2\text{)} \times 10,000 = \text{kg/ha.}$$

$$\text{Available forage} = \text{PUF} \times \text{fresh forage production.}$$

$$\text{Land area required per month (AU ha}^{-1}\text{)} = \frac{\text{Forage requirement/month}}{\text{Available forage}}$$

$$\text{Land area required per year} = \text{Y} \times \text{monthly requirement}$$

$$\text{Y} = \{\text{R} \mid \text{S}\} + 1$$

Where, R: 70R: 70 (rest days), S: 30S: 30 (grazing days) and Y: 3.3Y: 3.3. Livestock Unit (LU): 1 cow weighing 455 kg (Accatino et al. 2017).

The carrying capacity formula was computed as:

$$\text{CC (AU ha}^{-1}\text{)} = \frac{1 \text{ (ha)}}{\text{Annual land requirement } \left(\frac{\text{ha}}{1.11}\right)}$$

### Laboratory analysis

Sun-dried samples were then oven-dried at 105°C for 24 hours to determine dry matter yield.

$$\text{Dry forage production (kg/m}^2\text{)} \times 10,000 = \text{kg/ha.}$$

$$\text{Dry matter available} = \text{PUF} \times \text{dry forage production}$$

$$\text{Feed requirement per month} = 3\% \text{ of body weight}$$

Land area and carrying capacity were calculated for fresh forage.

TDN was calculated using Bain et al. (2016), Rizali et al. (2018), and Cattalam et al. (2018)s' formula as follows:

$$\% \text{TDN} = -54.572 + 6.796(\text{SK}) - 51.083(\text{L}) + 1.851(\text{BETN}) - 0.334(\text{PK}) - 0.049(\text{SK})^2 + 3.384(\text{L})^2 - 0.086(\text{SK})(\text{BETN}) + 0.687(\text{L})(\text{BETN}) + 0.942(\text{L})(\text{PK}) - 0.112(\text{L})^2(\text{PK})$$

Where, SK: Crude Fiber, L: Fat, PK: Crude Protein, BETN: Nitrogen-Free Extract, Annual TDN requirement for one LU: 1.2045 tons (Nell and Rollinson 1974).

Carrying capacity based on TDN (Abdullah et al. 2017; Accatino et al. 2017; Maylinda et al. 2019) was calculated as follows:

$$\text{Carrying Capacity} = \frac{a (\text{TDN})}{\text{Akt}}$$

Where, a: grazing land area, TDN: TDN: forage TDN production, Akt: livestock TDN requirement.

Determining the beef cattle production method was based on forage TDN. High Potential (HP) is  $\geq 650$  kg TDN/100 kg BW, Moderate Potential (MP) is 450 kg TDN/100 kg BW, and Low Potential (LP) is 325 kg TDN/100 kg BW. Protein quality was classified as: High Quality (HQ) ( $>12\%$  protein), Moderate Quality (MQ) (9-12% protein), and Low Quality (LQ) ( $<9\%$  protein).

Production strategy is grouped by category as presented in Table 1: I-III emphasize fattening, breeding, or rearing; IV-VI focus on rearing; and VII-IX are preferred for breeding over rearing (Nuswantara et al. 2023).

### Data analysis

All data were analyzed using descriptive statistics, i.e., average, standard deviation, range, rank, and proportion (Rao 2018). The analyzed data were presented in tabular form using tables and figures.

## RESULTS AND DISCUSSIONS

### Forage production vs national average

Forage production and carrying capacity of the natural grazing pasture of Warayaro, West Papua, Indonesia, are presented in Table 2. Table 2 shows that the fresh forage production in the natural grazing pasture of Warayaro is  $2.0 \text{ t ha}^{-1}$  with an estimated carrying capacity of  $0.4 \text{ AU ha}^{-1} \text{ yr}^{-1}$  (for cattle weighing 455 kg), or equivalent to  $1 \text{ AU ha}^{-1} \text{ yr}^{-1}$  for cattle with a body weight of 182 kg. In other words, to meet the needs of  $1 \text{ AU ha}^{-1} \text{ yr}^{-1}$  with a body weight of 455 kg, fresh forage production of  $5.0 \text{ t ha}^{-1}$  is required. Thus,

the Warayaro natural grazing pasture can accommodate 16 AU  $\text{yr}^{-1}$ .

Forage productivity in Warayaro is extremely low, with DM yield ( $0.4 \text{ t ha}^{-1}$ ) far below the Indonesian standards ( $6-8 \text{ t ha}^{-1}$  for improved pasture). Carrying capacity ( $0.3-0.4 \text{ AU ha}^{-1} \text{ yr}^{-1}$ ) is only a fraction of the national benchmark ( $1.0-2.0 \text{ AU}$ ), highlighting severe limitations in supporting livestock under current conditions. TDN yield ( $1.02 \text{ t ha}^{-1}$ ) is inadequate for high-producing animals (dairy/beef finishing) and suitable only for maintenance of young stock or low-performance animals. The deficit compared to Indonesian standards is primarily due to low species diversity, ty dominated by grasses with low protein content (Abdullah et al. 2017; Rahmawati et al. 2020; Daru et al. 2023), no fertilization or improvement measures, and lastly, soil fertility and climatic constraints typical of Wondama's coastal ecosystem. Therefore, interventions are needed to introduce legumes (e.g., *Centrosema*, *Stylosanthes*), implement rotational grazing, liming, and fertilization to boost DM and TDN yields.

When compared with the results of several studies on carrying capacity estimates in Papua, the carrying capacity value obtained in the Warayaro natural pasture is relatively higher than that in the natural grazing areas in Yapen Regency, which was  $0.56 \text{ AU ha}^{-1} \text{ yr}^{-1}$  for cattle with a body weight of 300 kg, or equivalent to  $0.37 \text{ AU ha}^{-1} \text{ yr}^{-1}$  for cattle weighing 455 kg. However, compared with the results of research in the Kebar natural pasture, which reported an estimated carrying capacity of  $1.78 \text{ AU ha}^{-1} \text{ yr}^{-1}$  for 300 kg cattle (Iyai et al. 2023), or  $1.17 \text{ AU ha}^{-1} \text{ yr}^{-1}$  for 455 kg cattle, the carrying capacity in Warayaro is still lower.

**Table 1.** Matrix for production recommendation

	High potential	Moderate potential	Low potential
High quality	I	II	III
Medium quality	IV	V	VI
Low quality	VII	VIII	IX

**Table 2.** Forage production and estimated carrying capacity of the natural grazing pasture of Warayaro, Teluk Wondama, West Papua, Indonesia

Parameter	Warayaro (This study)	Indonesian standards*	Gap and remarks
Fresh forage:			
Production ( $\text{AU t ha}^{-1} \text{ yr}^{-1}$ )	2.0	30-40 $\text{t ha}^{-1} \text{ yr}^{-1}$ for improved pasture (Hilmiati et al. 2021)	Warayaro is only ~5-7% of the national standards, indicating severe underproduction
Carrying capacity ( $\text{AU ha}^{-1} \text{ yr}^{-1}$ )	0.4		
Dry matter forage (DM):			
Production ( $\text{AU t ha}^{-1} \text{ yr}^{-1}$ )	0.4	6-8 $\text{t ha}^{-1} \text{ yr}^{-1}$ for managed grass-legume pastures (Sutedi et al. 2025)	Warayaro is ~6% of productive systems
Carrying capacity ( $\text{AU ha}^{-1} \text{ yr}^{-1}$ )	0.3		
TDN production:			
Production ( $\text{AU t ha}^{-1} \text{ yr}^{-1}$ )	1.02	4.5-6 $\text{t ha}^{-1} \text{ yr}^{-1}$ for improved tropical pasture (Widyaningrum et al. 2021)	Very low energy yield; requires supplementation
Carrying capacity ( $\text{AU ha}^{-1} \text{ yr}^{-1}$ )**	0.8	1.0-2.0 AU under improved systems (Daru et al. 2023)	Current carrying capacity is only 15-30% of standard

Note: \*SNI and National Guidelines, \*\*Based on DM and FM

The low productivity of fresh forage in the Warayaro pasture is due to the dominance of field grasses, which have high growth potential but low productivity. This aligns with Accatino et al. (2017), Nasehi (2018), Gopar et al. (2019) and Pangestu et al. (2019), who found that forage productivity is positively correlated with the carrying capacity of a grazing area. The higher the forage productivity, the higher the livestock carrying capacity of the grazing area, and vice versa if the forage productivity is low.

Table 2 also shows that the dry matter forage production and estimated carrying capacity in the Warayaro natural grazing pasture is  $0.4 \text{ t ha}^{-1}$ , with an estimated carrying capacity of  $0.3 \text{ AU ha}^{-1} \text{ yr}^{-1}$  (for cattle weighing 455 kg), or equivalent to  $1 \text{ AU ha}^{-1} \text{ yr}^{-1}$  for cattle with a body weight of 136.5 kg. When compared with the study by Se'u et al. (2015) in East Nusa Tenggara Province and Utami and Pujiawati (2019) in Bali for natural grazing pasture, the estimated carrying capacity based on dry matter was  $3.05 \text{ AU ha}^{-1} \text{ yr}^{-1}$ . Thus, the carrying capacity based on dry matter in Warayaro is lower than that of the Kebar pasture. This lower value is due to most of the forage in the Warayaro natural grazing area having a relatively high moisture content (around 79%). In contrast, forage in the Kebar pasture has a lower moisture content (66%). This condition is related to climatic factors (rainfall), habitat types, and the different forage species found in both areas. The Warayaro grazing area is dominated by *Paspalum conjugatum* and also includes other forage types such as *Merremia peltata*, which have high water content. In contrast, the Kebar pasture is dominated by *Imperata cylindrica*, which has lower water content.

The dry matter content of a forage species is defined as the difference between the fresh forage weight and its water content. The water content percentage is strongly influenced by sunlight intensity, nutrient content, plant species, and plant age. According to Gopar et al. (2019) and Se'u et al. (2015), the dry matter production of a forage species is highly influenced by cutting intervals and frequency, fertilization, plant age, plant type, management practices, and the leaf-to-stem ratio.

Forage in the Warayaro natural grazing pasture produces Total Digestible Nutrients (TDN) of  $1.02 \text{ t ha}^{-1}$  with a TDN value of 51%, and a carrying capacity of  $0.8 \text{ AU ha}^{-1} \text{ yr}^{-1}$ . The TDN value in the Warayaro pasture still falls within the typical range for tropical forages, which is between 41.4-59.9%. Compared with the study by Iyai et al. (2023), which estimated a carrying capacity of 3.37 AU/ha/year based on TDN, the Warayaro pasture still has relatively low TDN. This is likely due to differences in forage species composition between the two grazing areas. The TDN-based Carrying Capacity is  $0.8 \text{ AU ha}^{-1} \text{ yr}^{-1}$ , and assuming  $1 \text{ AU} \approx 100 \text{ kg}$  of body weight, then the availability of TDN per 100 kg of body weight calculated is  $1.275 \text{ t yr}^{-1}$ .

Since this value significantly exceeds the threshold for high potential (650 kg TDN/100 kg body weight), the feed potential is classified as high potential. However, because the data only present the TDN value and not the crude protein content, it is assumed that although the TDN is

high, the protein level may not be correspondingly high. As such, the feed quality is most likely moderate or low. Without evidence of  $\text{CP} > 12\%$ , we cannot confidently classify the feed as high quality. Taking a conservative approach, we assume the feed has moderate quality, given that in natural pasture systems, CP levels typically range from 9-12%. Conclusion within the nine feed condition patterns, i.e., combining the high potential and moderate quality yields pattern II in the 3x3 feed condition matrix.

### Species composition and dominance

In terms of species richness and composition, the pasture consists of five main forage species, dominated by grasses from the family Poaceae (Graminae) with three species and one species each from Cyperaceae and legume (Fabaceae) (Table 3). Grasses dominate botanical composition (86.7%), while legumes contribute only 13.3%, indicating a monocot-dominant system with limited nitrogen-fixing capacity. In terms of dominance and community structure, *Paspalum dilatatum* (Dallis grass) is the most dominant species (49.70%), showing it is the key structural species in the community. *P. conjugatum* and *C. pubescens* have moderate dominance (12.79% and 10.46%), contributing significantly to forage availability and diversity. Other species, such as *Eleusine indica* (8.43%) and *Cyperus rotundus* (8.35%) (Table 4), have lower dominance, indicating they are secondary species in the community.

In line with functional group balance, grasses account for 86.7% of the cover, creating a system heavily reliant on grass species. Legume cover (13.3%) is relatively low (Table 3), which may limit soil nitrogen enrichment and reduce crude protein content in forage. This imbalance suggests a need for legume enrichment to improve pasture quality and sustainability. Based on ecological implications, high grass dominance indicates strong competition for nutrients and light, potentially reducing legume persistence if not managed. Low species evenness, i.e., one species (*P. dilatatum*) occupies nearly half of the community, reducing ecological stability and resilience to disturbances (e.g., drought, grazing pressure).

The estimated carrying capacity in the Warayaro natural grazing area (based on fresh forage production, dry matter, and TDN) indicates that the area has low forage potential when compared to the ideal carrying capacity of a well-managed pasture. According to Maylinda et al. (2019) and Prasetyo and Heryanto (2021), a good carrying capacity for a grazing area is  $2.5 \text{ AU ha}^{-1} \text{ yr}^{-1}$ . The total carrying capacity was  $32 \text{ AU yr}^{-1}$ , calculated as  $0.8 \text{ AU ha}^{-1} \text{ yr}^{-1} \times 40 \text{ ha}$ . Since 1 head of cattle equals 1 AU, this capacity corresponds to 32 head of cattle per year. For goats, assuming 1 goat: 0.1 AU (i.e., 10 goats: 1 AU), the same carrying capacity is equivalent to  $32 \text{ AU} \times 10$ : 320 goats per year. This condition can be further improved by introducing various leguminous species and high-yielding cut-and-carry grasses, such as elephant grass (*Pennisetum purpureum*), which is already present in the Warayaro natural pasture but in very limited quantities (Table 4).

### Nutritional value of forage

The Warayaro natural grazing pasture provides favorable conditions for the growth and development of elephant grass (*P. purpureum*), which is well adapted to tropical regions, especially in hot, humid, and dry areas. In less fertile areas, fertilization is necessary to achieve better yields (Noor 2015; Clough et al. 2016; Teague and Kreuter 2020). Therefore, elephant grass is suitable to be introduced in the Warayaro natural pasture as part of efforts to improve forage production in the area.

The results presented in Table 5 suggest that the forage nutritional quality in the natural grazing pasture of Warayaro, Teluk Wondama Regency, is moderate. The average crude protein content is 11.2%, which is considered adequate for basic ruminant feed, especially for maintenance and growth. However, the crude fiber content is relatively high (31.5%), which reduces digestibility. The corrected Total Digestible Nutrients (TDN) average is only 51%, indicating moderate energy value. Ideally, TDN should be above 55-60% for high-quality feed. Dominant species such as *P. dilatatum* contribute the most to total TDN (27.1%), even though its TDN value is relatively low (54.6%). Legume species like *C. pubescens* have high protein content (16.8%), but contribute minimally to overall TDN (6.1%). Carrying capacity indicates low status. A carrying capacity of 0.8 AU ha<sup>-1</sup> yr<sup>-1</sup> means that one hectare can only support approximately 1 head of cattle every 1.25 years. This reflects low to moderate biomass productivity and forage quality, as well as suboptimal forage quantity (Accatino et al. 2017; Maylinda et al. 2019; Utami and Pujiawati 2019; Prasetyo and Heryanto 2021; Daru et al. 2023). Improving natural rangelands with limited legumes and low DM yield requires intervention strategies. This can be done by

introducing improved forages and high-TDN, low-fiber forage grasses such as *Brachiaria decumbens*, *Panicum maximum* (currently often updated as *Megathyrsus maximus*), and *Setaria sphacelata*.

### Implication for management

Based on the analysis, the average crude protein and TDN content in the Warayaro natural grazing pasture are 11.2% and 51%, respectively. These results indicate that the forage quality in the Warayaro grazing area falls into the moderate-quality category, with protein content ranging from 9-12% (Setiawan et al. 2024). Based on the available forage potential in the Warayaro grazing pasture, there is 264.7 kg of TDN available for every 100 kg of livestock body weight. This indicates that the feed potential in the Warayaro grazing area falls under the low potential category, according to Nuswantara et al. (2023) classification.

**Table 3.** Species group composition of the natural grazing pasture of Warayaro, Teluk Wondama, West Papua, Indonesia

Family/Species	Common name	Forage class
Poaceae (Graminae)		
<i>Paspalum conjugatum</i>	Carabao grass	Grass
<i>Eleusine indica</i>	Indian goose grass	Grass
<i>Paspalum dilatatum</i>	Dallis grass	Grass
Cyperaceae		
<i>Cyperus rotundus</i>	Purple nutsedge	Grass
Fabaceae		
<i>Centrosema pubescens</i>	Centro (Pueru)	Legumes

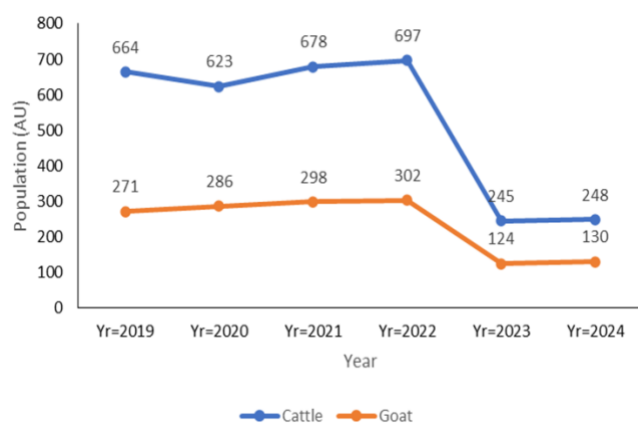
**Table 4.** Dominance and botanical composition of the natural grazing pasture of Warayaro, Teluk Wondama, West Papua, Indonesia

Common name	Dominance (%)	Botanical composition (%)	Category	References
Carabao grass	12.79	86.7	Moderate Common	Mabberley 2017
Indian goose grass	8.43		Rare/Less Common	Mabberley 2017
Dallis grass	49.70		Very common/Dominant	FAO 2023
Purple nutsedge	8.35		Rare/Less common	Hutchinson and Dalziel 2019
Centro (Pueru)	10.46	13.3	Moderately common	Mabberley 2017

**Table 5.** Nutritional value and TDN of forage species of the natural grazing pasture of Warayaro, Teluk Wondama, West Papua, Indonesia

Forage species	Component (%)					Corrected TDN***
	Crude protein	Fat	Crude fiber	NFE*	TDN**	
<i>Paspalum conjugatum</i> *	8.29	1.01	31.28	45.75	59.40	7.60
<i>Eleusine indica</i> *	9.98	1.10	32.73	42.36	60.10	5.10
<i>Paspalum dilatatum</i> *	10.82	2.32	32.54	41.34	54.60	27.10
<i>Cyperus rotundus</i> *	10.24	0.95	27.94	46.55	61.00	5.10
<i>Centrosema pubescens</i> **	16.80	4.04	33.20	36.50	58.20	6.10
Average±Stdv	11.23±3.25	1.9±1.33	31.5±2.13	42.5±4.01	58.66±2.49	10.20±9.50
TDN (tons)						1.02
Carrying capacity (AU ha <sup>-1</sup> Yr <sup>-1</sup> )						0.8

Note: \*NFE: Nitrogen-Free Extract, \*\*TDN: Total Digestible Nutrients (calculated), \*\*\* Corrected based on species dominance



**Figure 2.** Cattle and goat population in Teluk Wondama, West Papua, Indonesia (Source: BPS Teluk Wondama 2025)

**Table 6.** Current condition and improvement recommendation

Aspect	Current condition	Recommended improvement
Forage quality	Fair (moderate protein, high fiber, low-moderate TDN)	Introduce improved varieties, more legumes
Carrying capacity	Low (0.8 AU ha <sup>-1</sup> yr <sup>-1</sup> )	Fertilization, rotation system, irrigation
Species dominance	Grass-dominant, minimal legumes	Increase forage species diversity

Compared with the study in Manokwari, which reported an average crude protein content of 4.03% (low quality) and 451 kg of TDN available per 100 kg of body weight (high potential), the Warayaro pasture has better forage quality but lower feed potential than the Kebar grazing area. This is because the forage species in the Warayaro pasture are dominated by *P. dilatatum* and *P. conjugatum*, grasses typically found in low-productivity but high-nutritional-quality grasslands. In contrast, the Kebar pasture is dominated by *I. cylindrica*, which has high productivity but lower nutritional quality. *I. cylindrica* is only consumed by livestock when young and is generally disliked due to its coarse texture and sharp leaf edges, which can irritate the animals' mouths (Tolera and Abebe 2007). Given the conditions of low feed potential and moderate forage quality (classified as condition VI), the Warayaro natural grazing area is best suited for beef cattle fattening or breeding operations, particularly for raising young cattle (feeders) to a body weight of 182 kg.

The population experienced slight fluctuations but generally increased, from 664 AU (2019) to 697 AU (2022). There was a sharp decline to 245 AU (2023), followed by a slight increase to 248 AU (2024). This drastic decrease may indicate a major disruption to the cattle farming system, such as reduced feed availability, livestock diseases, and changes in land-use policies (Figure 2). In 2019-2022, the goat population showed a relatively steady increase from 271 AU (2019) to 302 AU (2024). A trend similar to that of cattle, although the values are lower. This may indicate

external factors affecting the entire livestock farming system in the region, such as policy, climate, or economic conditions (Iyai et al. 2020, 2023).

To strengthen ecological sustainability, one priority is to expand the use of high-quality legumes, such as *C. pubescens* and *Stylosanthes* spp., to increase forage protein levels (Table 6) while also improving soil nitrogen inputs through biological nitrogen fixation. A second approach involves fertilization and land enhancement, for example, by applying organic amendments or urea to promote the growth of protein-rich forages. The third strategy is improved grazing management, particularly rotational grazing, which helps prevent pasture degradation and provides sufficient recovery time for optimal regrowth (Clough et al. 2016; Mahlobo 2016; Teague and Kreuter 2020; Bremer et al. 2023).

Overgrazing shall be avoided, which can worsen carrying capacity and reduce forage diversity. Fourthly is by watering and drainage management (Table 6). This stage is done by ensuring an adequate water supply to support forage growth. Even simple irrigation systems can significantly boost biomass production. Increasing biomass production aims to increase TDN production from 1.02 t ha<sup>-1</sup> to at least 2 t ha<sup>-1</sup>, thereby raising livestock capacity to 1.5-2.0 AU ha<sup>-1</sup> yr<sup>-1</sup>.

#### Existing feed quality

The quality of animal feed is a critical factor for livestock health, growth, and production. It is influenced by the nutritional content of the forages and by their ability to meet the livestock's nutritional needs, especially during critical periods such as the dry season. Feed potential is classified into three categories: high ( $\geq 650$  kg TDN/100 kg body weight), medium (450-649 kg TDN/100 kg body weight), and low (<450 kg TDN/100 kg body weight). Feed quality is based on protein content: high (>12% crude protein), medium (9-12% crude protein), or low (<9% crude protein). Using data from the Warayaro pasture, the TDN production is 1.02 t ha<sup>-1</sup>, and the carrying capacity is 0.8 AU ha<sup>-1</sup> yr<sup>-1</sup>. This indicates a high feed potential for the area, which contributes to a high feed quality when associated with the proper crude protein (CP) content. Changes in rainfall patterns and temperature could impact the availability of high-quality forage. During the dry season, forage quality may decrease, leading to reduced protein content (Priyanto et al. 2015).

The carrying capacity of pastures refers to the number of livestock units (AU) that a pasture can sustain over a year without degradation. It is influenced by factors such as forage production, soil quality, and management practices. Warayaro pasture shows fresh forage production, i.e., 2.0 t ha<sup>-1</sup>, and carrying capacity, i.e., 0.4 AU ha<sup>-1</sup> yr<sup>-1</sup> for fresh forage, and AU ha<sup>-1</sup> yr<sup>-1</sup> for dry matter forage. This gives an idea of how much livestock the land can support based on the available forage. Forage productivity in tropical rangelands is strongly constrained by climatic variability, soil fertility, and grazing management (Zhang et al. 2023; Maestre et al. 2024; Sutedi et al. 2025). In many Indonesian rangelands, low soil nutrient availability, particularly nitrogen and phosphorus, limits biomass production and

reduces protein content of forage species (Daru et al. 2023). Rainfall seasonality also influences growth patterns, with dry periods reducing biomass yield by up to 40% compared to wet seasons (Sumarga et al. 2016; Danso-Abbeam et al. 2021). Poor grazing practices, such as continuous grazing without rest, further degrade pasture quality by promoting dominance of unpalatable or weedy species (Briske et al. 2020).

As feed quality improves over the next decade (through better forage types, improved pasture management, and supplement feeding), livestock productivity is expected to increase. This means that the carrying capacity may not only increase in terms of numbers but also in terms of animal health and production (Malo-Bulu et al. 2015; Adeniji et al. 2019; Marandure et al. 2020). Pasture quality is closely tied to species diversity and functional group balance, especially between grasses and legumes (Setiawan et al. 2024). Legumes such as *C. pubescens* enhance crude protein content and improve digestibility, whereas grass-dominated pastures tend to have higher fiber and lower nitrogen concentration, reducing overall nutritional value (French 2017; Rahmawati et al. 2020). Daru et al. (2023) observed that integrated systems with higher legume cover provided better forage quality compared to monoculture grasslands. Conversely, rangelands dominated by species such as *P. dilatatum* may produce higher biomass but lower protein content, requiring strategic supplementation to meet livestock nutritional needs (Sutedi et al. 2025). With improved feed quality and land management, the population of beef cattle and other ruminants may increase significantly in areas like West Papua. This will depend on market demands, government support (Chau et al. 2017; Romjali 2019; Qian et al. 2020), and the availability of suitable grazing land (Hilmiasi et al. 2021; Lase et al. 2024).

Based on the data and projections for 2024-2034, we can expect improvements in feed quality, especially if management practices such as cover crop integration (Syed 2018; Toh et al. 2018; Ngaiwi et al. 2023), forage conservation (French 2017; Corlett 2020), and supplementary feeding (Bell et al. 2018) are implemented. However, quality may still fluctuate due to seasonal variations and climate change impacts (Rojas-Downing et al. 2017; Shirsath et al. 2017; Twine 2020; Unc et al. 2021; Waaswa et al. 2021). Biomass and carrying capacity estimates vary widely across Indonesian rangelands due to differences in ecology and management. Sutedi et al. (2025) reported a carrying capacity of 0.8-1.2 AU ha<sup>-1</sup> yr<sup>-1</sup> under improved grazing in Java, while Maylinda et al. (2019) documented only 0.3-0.5 AU ha<sup>-1</sup> yr<sup>-1</sup> in degraded pastures of Nusa Tenggara. In East Kalimantan, Daru et al. (2023) found forage yields of 6.5 t DM ha<sup>-1</sup> yr<sup>-1</sup> in integrated oil palm systems, significantly higher than 0.4 t DM ha<sup>-1</sup> recorded in our Wondama study. Similar trends are reported in other tropical regions, where natural savannas in Africa typically sustain 0.2-0.6 AU ha<sup>-1</sup> yr<sup>-1</sup> under rainfed conditions (van Oudtshoorn 2016), underscoring the productivity limitations of unimproved tropical pastures and the importance of management interventions. There is potential to increase carrying capacity through better land management, crop-livestock integration, and improved grazing systems (Corson

et al. 2022). However, this will need to be balanced with sustainable land-use practices to prevent overgrazing and pasture degradation.

In conclusion, Warayaro is a heterogeneous pasture that consists of five types of fodder, including four grasses and one legume species. Non-native species from 3 families dominate the pasture, namely *P. dilatatum*, followed by *P. conjugatum*, *C. pubescens*, *E. indica*, and *C. rotundus*. The Warayaro pasture has a botanical composition of 86.7% grasses and 13.3% legumes. Average forage yield is 2.0 t FM, 0.4 t ha<sup>-1</sup> and 1.02 t ha<sup>-1</sup> TDN. The Warayaro pasture has carrying capacity for cattle of 0.4 AU ha<sup>-1</sup> yr<sup>-1</sup> (FM), 0.3 AU ha<sup>-1</sup> yr<sup>-1</sup> (DM) and 0.8 AU ha<sup>-1</sup> yr<sup>-1</sup> (TDN). The Warayaro natural pasture has low production potential (264.7 kg TDN per 100 kg of livestock body weight), and the nutritional quality of the forage is moderate (a protein content of 11.2%). Based on the potential and quality of the forage, the Warayaro pasture is more suitable for growing young stock (weaners) until they reach a body weight of 182 kg. Based on the findings, the carrying capacity of cattle is 32 head yr<sup>-1</sup> and for goats, 320 head yr<sup>-1</sup>. Key ecological recommendations are increasing legume proportion through reseeded, implementing rotational grazing, and monitoring and controlling *C. rotundus*. Therefore, future research should focus on conducting longitudinal studies to understand how climate change and seasonal shifts affect forage biomass and nutritional value, develop predictive models of forage availability across different climate scenarios, and evaluate the performance and sustainability of various grazing systems.

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