

Population Dynamics and Diversity Patterns of Grassland Plants in West Papua: Insights from iNEXT and PCA

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Abstract: Natural grazing is the dominant system, understanding the composition and characteristics of available vegetation becomes essential for maintaining productivity and ecological balance. This study aims to analyze and identify the types of forages and non-forages found on natural livestock ranches in Teluk Wondama Regency, West Papua. Through field surveys, direct observations, and sample analysis, the research categorized plant species into forage and non-forage groups based on their palatability, nutritional content, and potential use for livestock. We applied Chi-square, Cramers' V, PCA, and k-Means cluster test to measure association of plants and locations of the samples. However, we also predicted the additional population species projection using iNext software. The results revealed Warayaro's natural rangeland is a heterogenic pasture that consists of 15 types of fodder which include 9 grasses, 1 legume, and 5 types of other fodder, either of native and nonnative origin (14 genuses from 8 families) dominated by *Paspalum dilatatum* Poir. The botanical composition of the natural pasture in Warayaro consists of 86.7% grasses, 10.5% legumes and 2.8% other forages. If other forages are excluded, the botanical composition is 89.2% grasses and 10.8% legumes. CF (Closed to Forest) shows the highest projected species richness. There is no significant association between the number of forage plant species and the location. The Cramér's V indicates that the strength of the relationship between location and species count is weak. Therefore, the distribution of forage plant species tends to be uniform across the plot locations and does not show statistically consistent differences. However, a significant proportion of the vegetation consisted of non-palatable or low-nutrient species, indicating a need for improved pasture management and enrichment. This study provides crucial baseline data for resource planning, livestock development programs, and ecological conservation in the area.

Keywords: Plant species, Fodder, Grass, Leguminosae, Natural Rangeland

Introduction

Livestock production plays a vital role in supporting food security, income generation, and rural livelihoods in many parts of Indonesia (Suwanto and Prihantoro 2020; Widyaningrum et al. 2021; Clough et al. 2016), including the Teluk Wondama Regency in West Papua. One of the most critical components of sustainable livestock systems is the availability and quality of natural forages. In regions like Wondama, where natural grazing is the dominant system, understanding the composition and characteristics of available vegetation becomes essential for maintaining productivity and ecological balance.

Teluk Wondama Regency is endowed with vast areas of natural grassland and forest margins, often used for extensive grazing. These natural pastures consist of a variety of plant species, both palatable and unpalatable. However, there has been limited documentation on the botanical composition of these rangelands. Without a clear understanding of which species constitute optimal forage (Tulu et al. 2023; Brewer and Gaudin 2020; Alemayehu et al. 2012) and which are considered non-forage or invasive (Zhang et al. 2014; Accatino et al. 2014; Abdullah et al. 2017; Accatino et al. 2017a), efforts to improve livestock productivity remain suboptimal. Furthermore, the dynamic between forage quality and livestock performance is well established. High-quality forages contribute to better animal health (Dumont et al. 2018; Ilatsia et al. 2012), faster weight gain (Ghimire 2024; Rostini et al. 2014; Paris 2002; Owens et al. 2014), and higher milk or meat yields (Sraïri and Kiade 2005; Getachew et al. 2010; Rochfort et al. 2008; De Moraes et al. 2014; Karimuna et al. 2020). In contrast, low-nutrient or toxic plants can reduce productivity and pose health risks (Primatika et al. 2022; Ilatsia et al. 2012; Correia-Gomes et al. 2017). Despite its significance, the region lacks comprehensive data on species identification, forage classification, and nutritional assessments.

Natural livestock grazing is the dominant practice in Wondama Regency. Rangelands in the area are under pressure from overgrazing, seasonal variability, and climate change (Accatino et al. 2017b, 2017a; Abdullah et al. 2017; Ilatsia et al. 2012; Cortner et al. 2019). Previous studies in other regions show that up to 40% of pasture species in natural ranches may be non-palatable or invasive (Abdullah et al. 2017). Local farmers often lack formal training or guidance on identifying beneficial forage species. Nutritional deficits in livestock diets are a common challenge reported in remote rural areas (Tolera and Abebe 2007; Thomas et al. 2002; Rojas-Downing et al. 2017; Kristensen, Søgaard, and Kristensen 2005; Sun et al. 2020).

Research gaps consisted of lack of botanical inventory (L. Qian et al. 2020; Lüscher et al. 2020; Yang et al. 2020; Maroyi 2009; Corlett 2020). No comprehensive study exists that identifies and classifies forage and non-forage species in Teluk Wondama's natural rangelands. Absence of forage quality evaluation, i.e. nutritional values of native species which remain largely unknown or unquantified. Unclear spatial distribution occurred when the patterns and spread of forage versus non-forage

species across different landscapes (Acebes et al. 2021; Reiss-Woolever et al. 2021; Asubonteng et al. 2021) in the region are not mapped. Limited local capacity is frequently exist when there is insufficient extension support to help communities manage and enrich their rangelands based on ecological evidence (Teague and Kreuter 2020; Stark et al. 2016; Garrett et al. 2017). Natural livestock grazing systems in Teluk Wondama face increasing challenges due to unregulated land use, climate shifts, and lack of forage management. While livestock numbers may continue to grow, the forage base is not necessarily expanding in quality or quantity.

The absence of baseline data on which plants are beneficial or harmful to livestock limits any effort to improve pasture productivity. Farmers often rely on traditional knowledge, which may not be sufficient to manage evolving ecological conditions. Without scientific analysis and identification of forages and non-forages, policy interventions and sustainable grazing practices remain hindered. This research, therefore, aims to fill a critical knowledge gap and offer evidence-based recommendations for better livestock and land resource management.

Materials and Methods

Materials

This research was conducted in the natural grazing pasture of Warayaro, Sobey Village, Teluk Duari District, Teluk Wondama Regency, for a period of two (2) months, from January 11 to March 11, 2023. Teluk Wondama Regency is a result of the administrative expansion of Manokwari Regency. Its territory consists of islands, with the majority located on the mainland of Papua Island. Teluk Wondama Regency includes 13 districts, 75 villages, and 1 subdistrict, covering an area of 14,953.8 km². The coordinates of Teluk Wondama Regency are 132°35' - 134°45' East Longitude (E) and 0°15' - 3°25' South Latitude (S). As a tropical region, similar to other areas in Indonesia, the topography of Teluk Wondama Regency includes coastal areas, lowlands, and mountains that border other regencies. The boundaries of Teluk Wondama Regency are: to the North: Ransiki District, Manokwari Regency, and Cendrawasih Bay, to the South: Yaur District, Nabire Regency, To the West: Kuri District and Idoor District, Teluk Bintuni Regency, and to the East: Yaur District, Nabire Regency, and Cendrawasih Bay (BPS-Kabupaten Teluk Wondama 2025).

Teluk Wondama Regency has a tropical wet climate with a minimum temperature of 23.42°C and a maximum temperature of 31.94°C. According to Schmidt and Ferguson's classification of rainfall data, the climate of Teluk Wondama Regency falls into category B, with a Q value of 0.219, classifying it as a wet climate. The average rainfall in Teluk Wondama Regency is 110.25 mm per month, with an average humidity of 83.33% and solar radiation intensity of 59.66% (BPS-Kabupaten Teluk Wondama 2025). The main livelihoods of the people of Warayaro village, Sobey, in Teluk Duari District, Teluk Wondama Regency are farming, fishing, and animal husbandry.

The materials used in this study included forages found in the pasture, plastic bags, newspaper, raffia rope, and aluminum foil. The equipment used included a GPS device, measuring tape, compass, 2-meter wooden stakes, 1x1 meter 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.

Methods

This study used a descriptive method with survey techniques and direct field observation. Data collection was conducted in the natural grazing pasture of Warayaro, Sobey Village, Teluk Duari District, TelukWondama Regency. Sampling followed the method recommended by Marini et al. (2007) and Crane (2020). The area of the natural pasture was measured using GPS and a measuring tape. The number of samples taken was based on the forage sampling requirement: for a 65-hectare grazing area, 100 samples are required. If the area is smaller or larger than 65 hectares, the number of samples is adjusted using the formula:

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

Samples were taken systematically by creating representative transects using the line intercept method (Harrison et al. 2012; Abdullah et al. 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).

Measured Variables

Each forage species within the sampling plot 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 Yang et al. (2020), Critchley et al. (2002), Palm (2021), and Tolera and Abebe (2007). Botanical composition was calculated based on the wet weight of each species, categorized into grasses (G), legumes (L), and other forages (O) (Baderan et al. 2021; L. S. Qian et al. 2020).

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

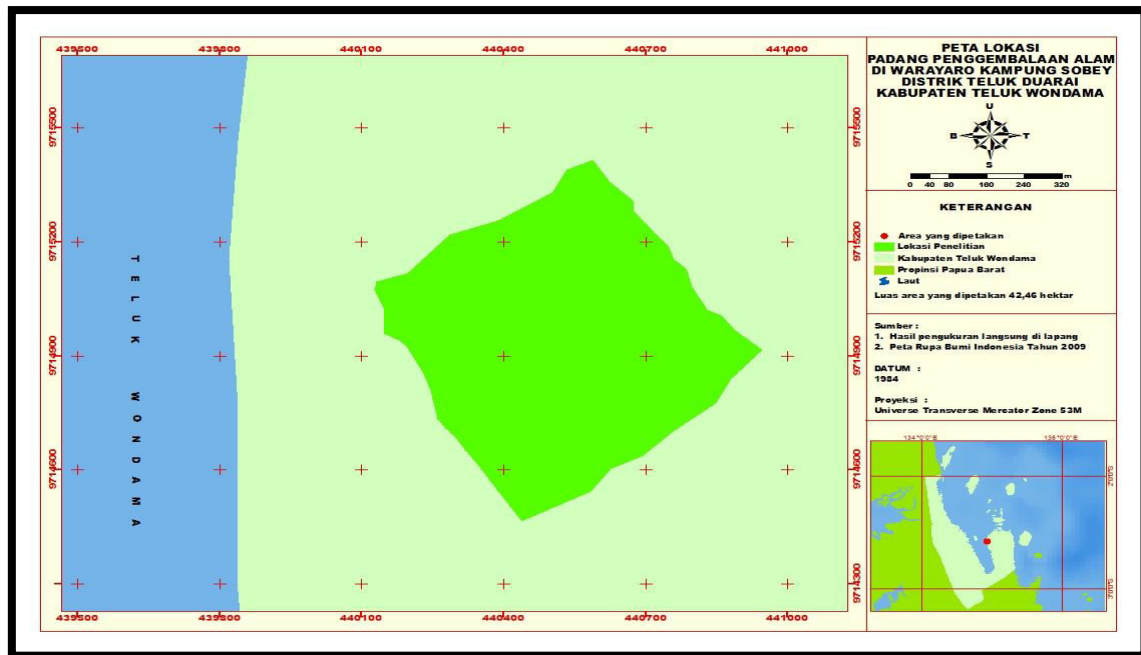


Figure 1. Site of field research where plot samples were taken in natural rangelands, TelukWondama rency, West Papua

Data Analysis

All data were analysed using descriptive and inferential statistic (Saizen et al. 2010). Data then were presented in the form of tables and figures. In inferential statistic, we applied Chi-Square (χ^2) test, which is used to test independent between two categorical variables in contingency table (Bolowe et al. 2022). $\chi^2 = \sum \frac{(O_{ij} - E_{ij})^2}{E_{ij}}$, O_{ij} = observed frequency in cell (i,j), E_{ij} =expected frequency in cell (i,j), calculated as; $E_{ij} = \frac{(\text{row total } i) \times (\text{column total } j)}{\text{grand total}}$. Cramer's V is a measure of association between two nominal variables, it ranges from 0 (no association) to 1 (perfect association) (Córdoba et al. 2019). $V = \sqrt{\frac{\chi^2}{n \cdot (k-1)}}$, χ^2 =Chi-square statistic, n =total number of observations, k =smaller of (number of rows, number of columns). Principal component analysis (PCA) is used for dimensionality reduction while preserving variance in the dataset (Far and Yakhler 2015). Step-by-step core formula: Center the data: $X_c = X - \mu$, Compute covariance matrix= $C = \frac{1}{n-1} X_c^T X_c$, Solve the eigen value equation= $Cv = \lambda v$, and Project data onto principal component: $Z = X_c \cdot W$, where W is a matrix of selected eigenvectors. k-Means clustering is an unsupervised learning algorithm that partitions data into k clusters. $J = \sum_{i=1}^k \sum_{x_j \in C_i} \|x_j - \mu_i\|^2$, where k =number of clusters, x_j = data point, μ_i = centroid of cluster C_i , and $\|x_j - \mu_i\|^2$ =squared Euclidean distance. In projecting the increasing of plant species population, we applied iNext tool, i.e. the pattern of species population growth. The iNEXT tool applies two types of statistical analyses grounded in Hill numbers to assess species diversity. The first is a non-

asymptotic method that uses interpolation and extrapolation techniques, while the second is an asymptotic method aimed at estimating diversity at its asymptotic limit (Chao et al. 2016).

Results and Discussions

Identification and Description of Forage Types

The results of the identification of forage types found in the natural grazing field of Warayaro Village, Sobey, Teluk Duari District, Teluk Wondama Regency, are presented in Table 1.

Table 1. Results of Identification of Forage Types in the Natural Grazing Field of Warayaro Village, Sobey, Teluk Duari District, Teluk Wondama Regency.

No.	Forages species	Classification
1.	<i>Paspalum conjugatum</i> Berg	Grass
2.	<i>Ischaemum</i> cf. <i>timorense</i> Kth	Grass
3.	<i>Eleusine indica</i> Gaertn	Grass
4.	<i>Imperata cylindrica</i> L	Grass
5.	<i>Paspalum dilatatum</i> Poir	Grass
6.	<i>Pennisetum purpureum</i> Schum & Thonn	Grass
7.	<i>Digitaria insularis</i> Scop	Grass
8.	<i>Cyperus rotundus</i> L	Sedge
9.	<i>Scirpus grossus</i> L.	Sedge
10.	<i>Centrosema pubescens</i> Benth	Liana/Vine
11.	<i>Meremipeltata</i>	Liana/Vine
12.	<i>Ludwigia adscandens</i>	Shrubs
13.	<i>Passiflora foetida</i> L	Liana/Vine
14.	<i>Fluggea racemosa</i> L.	Shrubs
15.	<i>Dryopteris</i> sp.	Ferns

These types of forage are generally exotic species (not native) to Indonesia or Papua, as they primarily originate from South America (Latin) and Africa. Only three species are native (indigenous) to Indonesia, namely *Fluggea racemosa*, *Meremipeltata*, and *Dryopteris* sp. These forage species can be described as follows:

1. *Paspalum Conjugatum* Berg

General Description. A perennial grass that typically forms clumps without creeping runners, reaching a height of 20-100 cm (usually less than 1 meter). The stems are flat and round in shape, generally hollow. The leaf blades are linear with a rough edge. The leaf length is 10-25 cm and the width is 0.5-1.8 cm. The flowering is in the form of a panicle or an incomplete spike, consisting of 2-14 spikelet that are spaced apart. The length of the spikelet is 1.5-10 cm, and the individual spikelet are arranged

on both sides of the spike's stem, with a length of 2-3.5 mm. A depiction of this plant is shown in Figure 1.



Figure 1. Paspalum Conjugatum- A: Appearance; B: Leaf; C: Flower

1. *Ischaemum Timorense* Kth

General Description: A perennial grass that grows in clumps, with creeping and strongly rooted basal stems; height ranges from 0.4 to 1 meter. The stem is flattened and round, covered with dense white hairs. The leaf blades are lanceolate-linear, hairy, with rough edges, measuring 10–25 cm in length and 0.3–1.5 cm in width. The inflorescence is in the form of a panicle, 2–8 cm long. The spikelets are needle-like and hairy, measuring 5–8 mm in length. This plant species is shown in Figure 2.

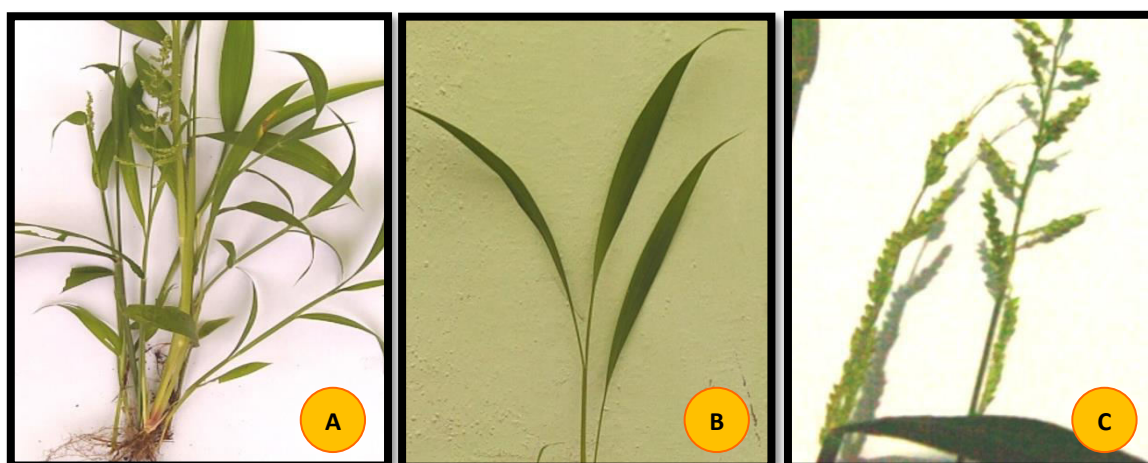


Figure 2. Ischaemumtimorense- A: Appearance; B: Leaf; C: Flower

2. *Eleusine indica* Gaertn.

General Description. A short-lived (annual) grass that grows in clumps, with a height ranging from 0.1 to 0.9 meters. Occasionally, roots emerge from the lower nodes. The stem is flattened and round, and usually branched. The leaf blades are linear with rough edges; the leaf base is hairy, with a length of 10–20 cm and a width of 0.1–1 cm. The inflorescence is a panicle, with spikelets measuring 2.5–17 cm in length. The spikelets are solitary, densely arranged on both sides of the axis, and measure 4–7 mm in length. This plant species is shown in Figure 3.



Figure 3. *Eleusine indica*- A: Appearance; B: Leaf and root; C: Flower

3. *Imperata cylindrica* L

General Description. A perennial grass with creeping shoots, growing to a height of 0.2–1.5 meters. The stem is oval and round in shape. The leaf blades are lanceolate-linear, measuring 12–100 cm in length and 0.8–5 cm in width. The leaf edges are very rough, with the base generally having long hairs, and a broad, pale white midrib. The inflorescence is a panicle or compound spike, ranging from 7–30 cm in length. The spikelets are about 4 mm long, pale or purplish in color. This plant species is shown in Figure 4.

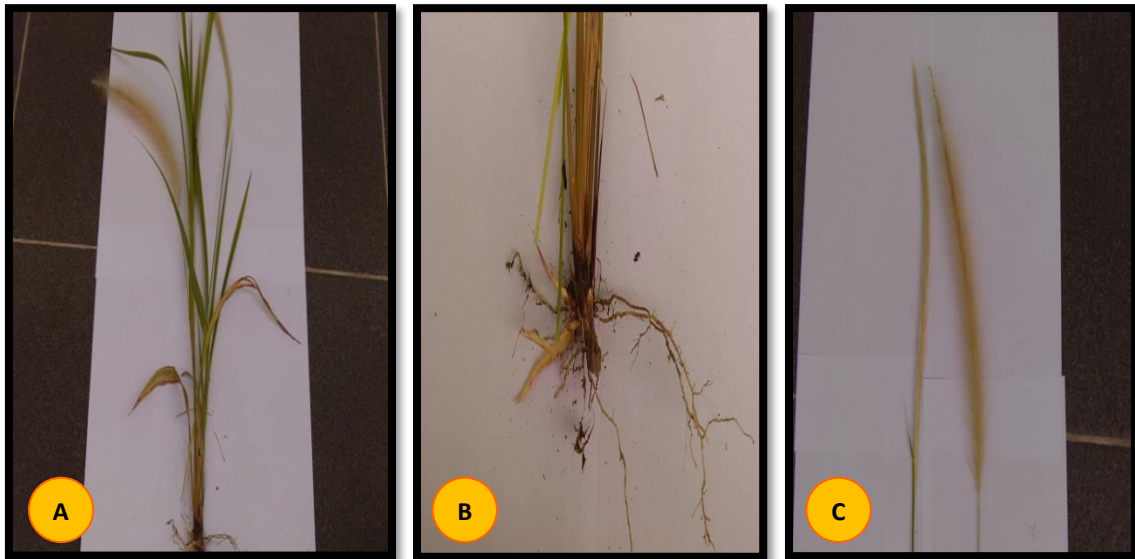


Figure 4. *Imperata Cylindrica*- A: Appearance; B: Root; C: Flower

4. *Paspalum dilatatum* Poir.

General Description. A perennial grass that typically forms large clumps without creeping shoots, growing to a height of 20–180 cm (usually less than 1 meter). The stem is flattened and round, and hollow. The leaf blades are linear with rough edges, measuring 10–25 cm in length and 0.5–1.8 cm in width. The inflorescence is a spike or an incomplete panicle with two branches, consisting of 2–18 spikelets. Each spikelet is 1.5–10 cm long, with individual spikelets arranged on both sides of the spike stem, measuring 2–3.5 mm in length. This plant species is shown in Figure 5.



Figure 5. *Paspalum Dilatatum*- A: Performance; B: Leaf; C: Flower

6. *Pennisetum Purpureum* Schumacher & Thonn

General Description. A perennial grass with creeping rhizome-shaped shoots, growing to a height of 1.5–3 meters. The stem is oval and round, with both upright and leaning forms, hard in texture, sometimes branched, and often covered with a white, flour-like powder. The leaf blades are generally somewhat stiff, lanceolate-linear in shape, measuring 16–150 cm in length and 5–15 cm in width. The leaf edges are very rough, with the base typically having long hairs, and a broad, pale white midrib. The inflorescence is a panicle or compound spike, 12–35 cm in length. The spikelets are 5–6 mm long, yellow in color, and bear long hairs about 1 cm in length. This plant species is shown in Figure 6.

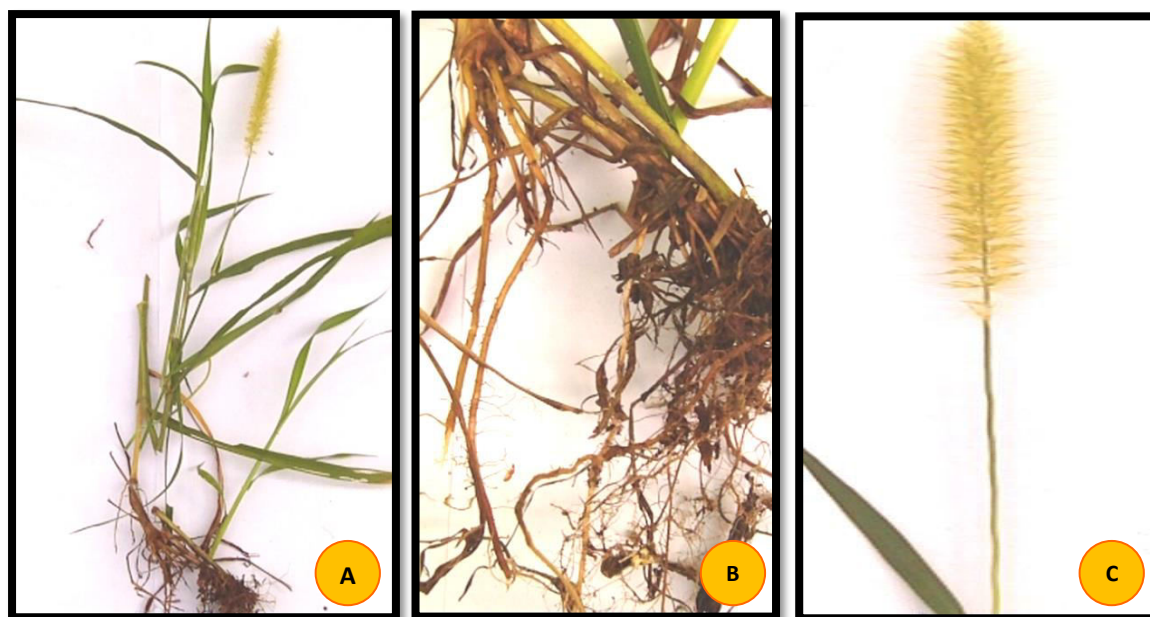


Figure 6. *Pennisetum Purpureum*- A: Appearance; B: Root; C: Flower

7. *Digitaria insularis* Scop.

General Description. A perennial grass that grows in clumps, reaching a height of 1–1.2 meters. The stem is flattened and round, with a hollow base. The leaf sheath is attached to the stem, with a very short ligule. The leaf blades are lanceolate-linear with rough edges, measuring 10–20 cm in length and 0.3–1.1 cm in width. The inflorescence is a panicle with 2–22 spikelets per flower cluster, positioned at varying heights. The spikelets are 2–21 cm long, with individual spikelets alternately arranged on both sides of the spike stem, each measuring 2–4 mm in length. This plant species is shown in Figure 7.



Figure 7. *Digitaria Insularis*- A: Appearance; B: Leaf and root; C: Flower

8. *Cyperus rotundus* L.

General Description. A perennial herb, growing to a height of 0.1–0.8 meters. The main stem is blunt to sharply three-angled. There are 4–10 leaves arranged at the base of the stem, with the leaf sheaths embedded in the soil. The leaf blades are linear, measuring 10–25 cm in length and 0.2–0.6 cm in width. The inflorescence is a panicle composed of small spikelets; the flowers are brown, with each flower measuring 1–3 cm in length and 2 mm in width. This plant species is shown in Figure 8.



Figure 8. *Cyperus Rotundus*- A: Root and leaf; B: Flower

9. *Scirpus grossus* L.

General Description. A sturdy, perennial herb that grows upright in strong clumps, with creeping shoots; height ranges from 0.8 to 2 meters. The leaves are crowded at the base of the stem, measuring 15–30 cm in length and 0.5–2 cm in width. The inflorescence is in the form of a spike, 3–5 cm long, bearing numerous flowers that

are 4–9 mm in size, with a reddish-brown color. This plant species is shown in Figure 9.



Figure 9. Scirpus grossus- A: Performance; B: Leaf and root; C: Fruits

10. Centrosema pubescens Benth

General description. Liana is woody and climbs or twines by forming roots, with a length of 1–10 m. The stem is cylindrical, with a diameter of 5–8 mm, and the stem has white hairs. The tendrils are located at the leaf axils, with a length of 3–5 cm and circular, per-like tips. The leaves are compound, palmate, alternate, measuring 5–12 x 3–8 cm. The leaflets are oval-shaped with a heart-shaped base and a pointed tip, the edges of the leaves are sometimes serrated, and the surface of the leaves and young parts are generally covered with dense white hairs. Flowering usually occurs at the leaf axils. The fruit is pod-shaped with a smooth, hairy surface, measuring 5–10 cm in length and 0.6–1 cm in width. When young, it is green, and when mature, it turns yellow-orange to black. This plant species is shown in Figure 10.



Figure 10. Centrosema Pubescens- A: Leaf; B: Flower and fruit

11. *Meremia peltata*

General description. A woody liana and climbing plant that forms roots, with a length of 3-20 m. The stem is cylindrical, with a diameter of approximately 0.5-1 cm, generally producing a very thick white sap. The tendril is located at the leaf axil, with a length of 3-7 cm and a curled tip in the form of a hook. The leaves are simple, arranged alternately, with a length of 10-30 cm and a width of 8-24 cm. The leaves are oval-shaped with a heart-shaped base and a pointed tip, the leaf edges are sometimes serrated, and the surface of the leaves and the young parts are generally hairless. Flowering usually occurs at the tip of the shoot or leaf axil. The fruit is oval or egg-shaped, with a diameter of 1-2 cm, green when young and turning orange-yellow to black when mature. This type of plant is shown in Figure 11.



Figure 11. Merremiapeltata- A: Young leaf; B: Mature leaf

12. *Ludwigia scandens*

General Description. A perennial shrub that grows with strong roots and typically forms clumps. It can reach a height of 75-150 cm. The main stem is cylindrical and covered with bark that is generally somewhat rough to coarse. The plant usually has 3

to 5 branches. The leaves are simple, with blade shapes that are lanceolate; 2–4 cm in length and 1.5–2.5 cm in width. The flowers are trumpet-shaped, yellow in color, and typically found in the leaf axils or at the ends of branches. The fruit is a capsule measuring 2–3 cm in length and 0.4–0.7 cm in width. It produces a large number of very small seeds. This plant species is shown in Figure 12.

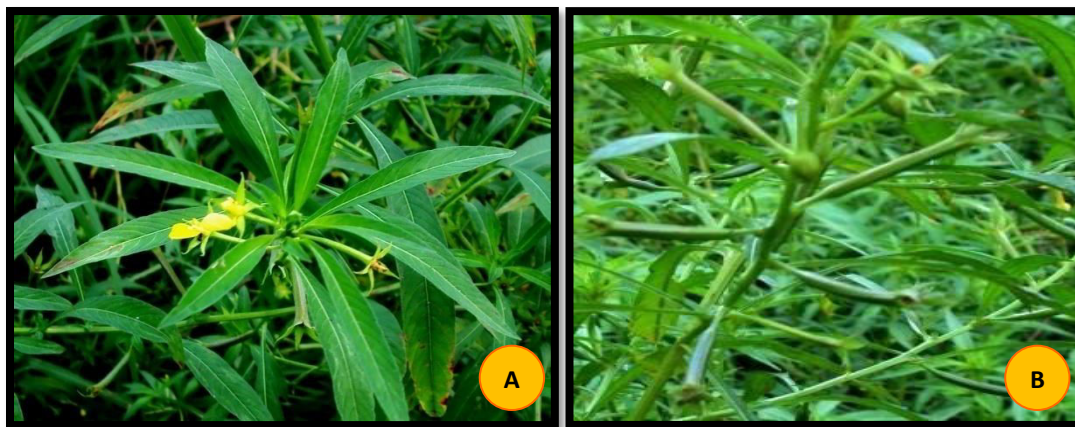


Figure 12. Ludwigia adscendens – A: leaf and flower; B: fruit

13. *Passiflora foetida* L

General Description. A woody liana and climbing plant that typically twines using root formation, with a length of 4–7 meters. The stem is cylindrical, very small in diameter (4–6 mm), and covered with fine white hairs. Tendrils are found in the leaf axils, measuring 6–9 cm long, with coiled, spring-like tips. The leaves are simple, alternate, 4–8 cm long and 2–6 cm wide, heart-shaped, often with three lobes. Leaf edges are serrated, and the surface is generally covered with fine white hairs. This plant species is shown in Figure 13.



Figure 13. Passiflora foetida– A: Leaf; B: Young fruit; C: Mature fruit

Flowering usually occurs in the leaf axils. The fruit is enclosed in a dense, cage-like structure made of fine hairs. It is round or oval in shape, green when young, and turns yellow-orange when mature, with a length of 1.5–2 cm.

14. *Fluggea racemosa*

General Description. A small to medium-sized tree, reaching a height of 15–20 meters. The main trunk is cylindrical, grooved, and sometimes fluted or twisted. It is branch-free up to 7–10 meters with a diameter at breast height of approximately 50 cm. It may or may not have buttresses; when present, they are small, around 80 cm high and 100 cm wide. The outer bark surface is rough, fissured, scaly, and peels off in small flakes, with a light yellow or pale grayish-brown color. The bark incision typically reveals a bark thickness of 10–14 mm and does not produce sap. The inner bark ranges from soft to hard, with an orange-yellow or yellowish-brown color.

Leaves are simple, arranged alternately, stalked, with leaf blades that are elliptical to elongated in shape, with rounded bases and shortly pointed tips, 6–10 cm long and 3–6 cm wide. The petiole is 8–10 mm long. Flowering occurs in panicles, 1–2 cm long, and hairy. Flowers have 4–5 petals and are white or pale yellow. The fruit is round or slightly elongated, arranged in a circle, 2–4 cm in diameter, green when young and yellow when mature. Each fruit contains 1–2 seeds. This plant species is shown in Figure 14.



Figure 14. *Fluggea Racemosa*– A: Stem appearance; B: Leaves; C: Fruits

15. *Dryopteris* sp

General Description. A terrestrial fern, though sometimes epiphytic, without a main stem, featuring an upright rhizome with dense and closely packed leaves. The leaf stalk (petiole) ranges from 10–70 cm long, generally glabrous at the base or covered with scales. The leaves are simple compound, with leaf blades measuring 15–50 cm in length and 5–16 cm in width, typically stiff and upright. This plant species is shown in Figure 15.

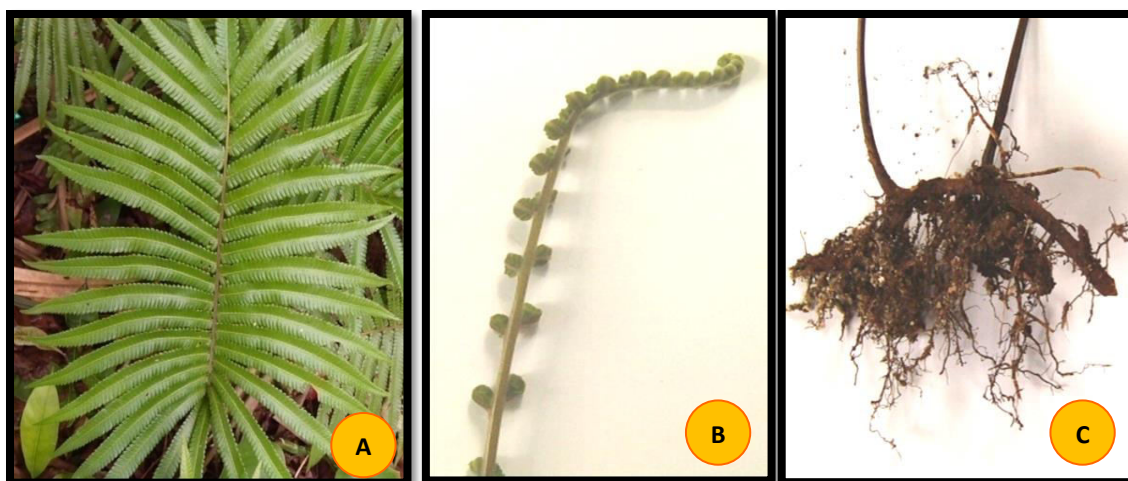


Figure 15. *Dryopteris* sp. – A: General appearance; B: Young leaf; C: Roots

The leaflets are generally sessile or nearly sessile, usually with hairy scales. The base of the leaflets is blunt, and the tips taper to a point. The leaflets are crescent-shaped and serrated. Spores are typically found on the underside of the leaf, on the densely arranged leaflets, located in the notches of the serrated edges.

Forage Species, Dominance, and Botanical Composition

The forage species, along with their local names, common names, and plant families, are presented in Table 3.

Table 3. Forage Species on the Natural Pastureland of Warayaro, Teluk Duari District, TelukWondama Regency

No.	Forage species	General name/Local	Family
A. Grass			
1.	<i>Paspalum conjugatum</i> Berg	JampangPahit (Sunda), Rumput Kerbau	Poaceae (Graminae)
2.	<i>Ischaemun</i> cf. <i>timorensis</i> Kth	Rumput Sarang Buaya (Malaysia), Rumput Apet (Sumbawa)	Poaceae (Graminae)
3.	<i>Eleusine indica</i> Gaertn.	Rumput Angsa (Inggris)	Poaceae (Graminae)
4.	<i>Imperata cylindrica</i> L.	Alang-alang	Poaceae (Graminae)
5.	<i>Paspalum dilatatum</i> Poir.	Rumput Australia	Poaceae (Graminae)
6.	<i>Pennisetum purpureum</i>	Rumput Gajah	Poaceae (Graminae)
7.	Schumacher & Thonn.	Rumput Asam (Inggris)	Poaceae (Graminae)
8.	<i>Digitaria insularis</i> Scop.	Rumput Kacang	Cyperaceae
9.	<i>Cyperus rontodus</i> L.	Rumput Bawang	Cyperaceae
.	<i>Scirpusgrossus</i> L.		
B. Leguminosae			
1.	<i>Centrosema pubescens</i> Benth.	Sentro	Fabaceae
C. Non-Forage			
1.	<i>Meremipeltata</i>	Tali kuskus/Waiviria (Wondama)	Convolvulaceae

2.	Ludwigiaadscandens L.	Krangkong (Indonesia)	Onagraceae
3.	Passiflora foetidaL.	Buah Putri (Papua)	Passifloraceae
4.	Flugea racemosa L.	Katok Hutan (Papua)/ Aiki (Wondama)	Euphorbiaceae
5.	Dryopteris sp	Paku/Makumu Rau (Wondama)	Polypodiaceae

The data in Table 3 show that in the natural pasture of Warayaro, there are 15 forage species that can be utilized as livestock feed. These forages consist of grasses, legumes, and other forages, originating from 14 genera and 8 families. When compared to findings from other studies, Warsono and Nuhayanan (1998) in Kebar identified 26 forage species from 25 genera and 6 families. Junaidi and Sawen (2010) in Yapen Regency found 22 forage species from 21 genera and 12 families. Furthermore, research by Sawen and Junaidi (2011) in Sorong and Fak-fak Regencies recorded 28 forage species from 25 genera and 13 families in Sorong, and 9 species from 9 genera and 6 families in Fak-fak. A study by Iyai et al. (2023) in Prafi found more than 22 forage species from 21 genera and 11 families. Thus, overall, the forage species composition in the natural pasture of Warayaro, Teluk Duari District, TelukWondama Regency, is considered low.

The low number of forage species found in the Warayaro pasture is suspected to be due to the area being newly opened. As a result, the overall composition of forages is still limited, since the natural succession process is still in its early stages. A key indicator that the area was recently opened is the presence of *Merremiapeltata* and *Flueggea racemosa* in the pasture. These two species are among the first to invade newly cleared forest land. Their invasion marks the beginning stage of secondary succession (Brown et al. 2007; Kamau 2004; Ramakrishnan 2007; Midgley and Woodward 2013).

The forage dominance and botanical composition of the Warayaro natural pasture observed in this study are presented in Figure 16.

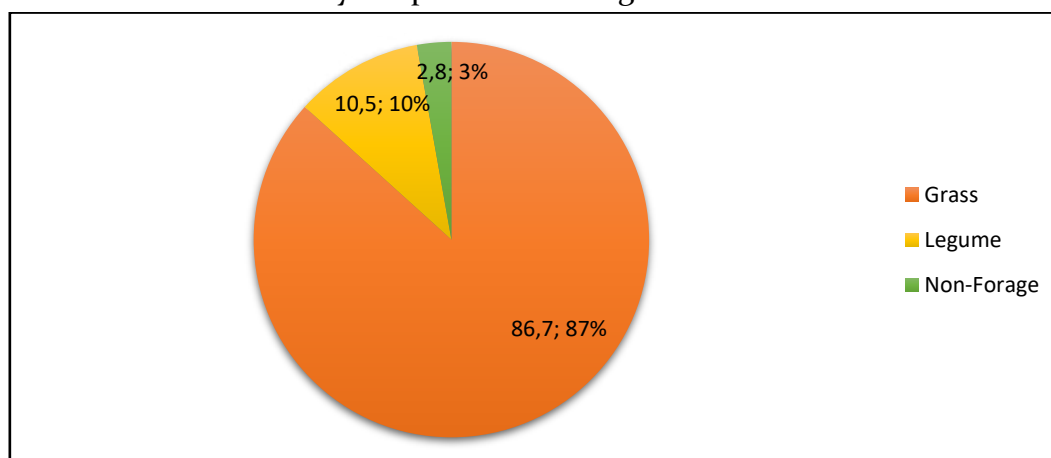


Figure 16. Botanical Composition of Forage in the Natural Grazing Field of Warayaro, Sobey Village, Teluk Duari District, TelukWondama Regency

In Figure 16, it can be seen that the botanical composition of the natural pasture in Warayaro consists of 86.7% grasses, 10.5% legumes, and 2.8% other forages. If other forages are excluded, the botanical composition is 89.2% grasses and 10.8% legumes. This indicates that the forage composition in Warayaro's natural pasture is not yet ideal for a good-quality grazing pasture, as grasses dominate the area. According to Hilmiati et al. (2021), Ghimire (2024), and Kocu et al. (2017), one of the criteria for a good pasture is a botanical composition of 60% grasses and 40% legumes.

The category of an ideal pasture requires a balanced composition of grasses and legumes to ensure sufficient nutrient availability through the balance between the two (Kristensen et al., 2005; Norton et al. 2016; Rostini et al. 2014; Gopar et al. 2019; Paggasa 2017). In addition, legumes contribute to soil nutrient availability, thereby supporting the growth of other forage types. Legumes are forage crops with higher nutritional value than grasses, being rich in protein, phosphorus, calcium, molybdenum, and are more palatable to livestock. Moreover, legumes enhance soil fertility by fixing nitrogen from the air at rates of 370–450 kg/ha/year (Bourke 2001; Ojiem et al. 2006; Lüscher et al. 2020).

To improve the botanical composition of the natural pasture in Warayaro, the introduction of superior leguminous species can be carried out (Kamau 2004). The soil in Teluk Wondama Regency is generally acidic ($\text{pH} < 4.5$) and contains low organic matter with poor nutrient content (N, P, K) (BPS-Kabupaten Teluk Wondama 2025). Under such acidic and nutrient-poor conditions, Mahlobo (2016), and Syed (2018) recommend introducing leguminous plants that easily form symbiosis with Rhizobium bacteria, have high persistence, and can thrive in acidic soils. Several leguminous species recommended for development in acidic and nutrient-deficient soils include: *Cassia siamea* Lamk (johar), *Sesbania glandiflora* Pers (turi), *Erythrina variegata* L (dadap), and *Stylosanthes guyanensis* (stylo).

Research on the botanical composition of forage in several pastures in Papua shows suboptimal conditions. Junaidi and Sawen (2010) found that natural pastures in Yapen Regency were dominated by other forages (54%), grasses (44%), and legumes (2%). Junaidi and Sawen (2010) in Sorong reported a composition of other forages (50%), grasses (39%), and legumes (11%), while in Fak-fak, grasses dominated (56%), followed by legumes (33%) and other forages (11%). Furthermore, Warsono and Nuhuyan (1998) in the Kebar natural pasture showed grass domination at 96% and legumes at only 4%.

From these studies, it can be concluded that the natural pastures in Papua are generally not yet ideal in terms of botanical composition.

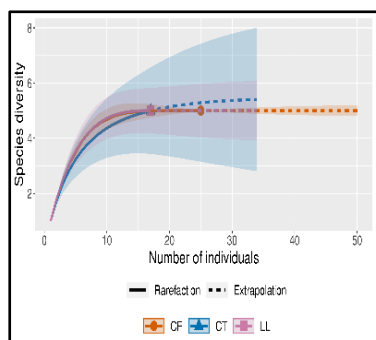


Figure 17. Increasing plant species population estimation Using iNext under natural pasture TelukWondama, West Papua. Diversity order $q=0$. CF=Closed to forest ecosystem, CT=Coastal, LL=Lowland

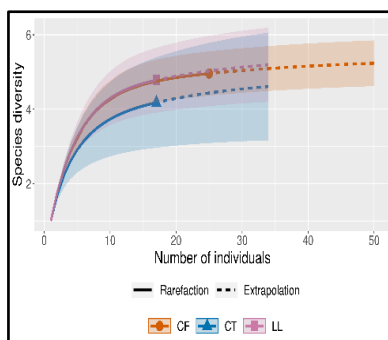


Figure 18. Increasing plant species population estimation Using iNext under natural pasture TelukWondama, West Papua. Diversity order $q=1$. CF=Closed to forest ecosystem, CT=Coastal, LL=Lowland

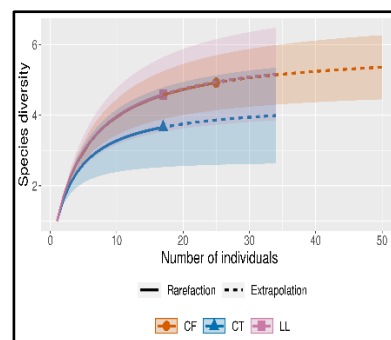


Figure 19. Increasing plant species population estimation Using iNext under natural pasture TelukWondama, West Papua. Diversity order $q=2$. CF=Closed to forest ecosystem, CT=Coastal, LL=Lowland

Based on species diversity estimation using the iNEXT method under different ecosystems in TelukWondama, West Papua, the analysis corresponds to the diversity orders $q = 0, 1, \text{ and } 2$, which represent different perspectives on biodiversity. Figure 17, i.e. species richness ($q = 0$). This order reflects species richness only, without considering species abundance (all species are weighted equally). CF (Closed to Forest) shows the highest projected species richness. CT (Coastal) and LL (Lowland) have fewer species detected and estimated, indicating lower richness. Forest-adjacent pastures (CF) support more diverse plant communities. Coastal and lowland pastures may be under more environmental stress or have undergone more disturbance, limiting species presence. Figure 18 is Shannon Diversity ($q = 1$). This diversity order takes both richness and species abundance into account, giving moderate weight to common species. CF still ranks highest in diversity, indicating not only a higher number of species but also a more even distribution. Lowland and Coastal show moderate diversity, suggesting that a few dominant species may be more prevalent. CF ecosystem supports a balanced community structure. Diversity in CT and LL is possibly skewed toward dominant species, reducing ecological evenness. Figure 19 shows Simpson Diversity ($q = 2$). This measure emphasizes dominant species, reducing the influence of rare species. The gap in diversity between CF, CT, and LL becomes more pronounced. CF still leads, meaning it not only has more species but also less dominance by any single species. CT and LL show lower diversity, suggesting that dominant species significantly shape the ecosystem.

CF is ecologically more stable and diverse. CT and LL are likely more homogeneous, possibly due to grazing pressure, salinity (in CT), or anthropogenic impact. The Closed to Forest (CF) ecosystem exhibits the highest and most stable

diversity across all orders ($q = 0$ to 2). Coastal (CT) and Lowland (LL) ecosystems are more vulnerable and possibly degraded or monopolized by dominant species. Conservation of CF areas should be prioritized as biodiversity reservoirs. Restoration or enrichment planting in CT and LL with native or adaptive species may improve species diversity and resilience. Rotational grazing or grazing exclusion zones could help recover plant diversity, especially in degraded LL zones.

Proceeding iNext analysis (Figure 17, 18, and 19), we proceeded our statistical analyses with Chi-square and Cramer's V tests. Based on the Chi-square and Cramer's V analysis of 5 plots from 3 locations (Coastal=5 plots, Lowland =5 plots, and Close Forest =5 plots, in total 15 plots), a chi-square value (χ^2) of 4.20 was obtained with 8 degrees of freedom (df) and a p-value of 0.838. Since $p > 0.05$, there is no significant association between the number of forage plant species and the location. The Cramer's V value of 0.189 indicates that the strength of the relationship between location and species count is weak. Therefore, the distribution of forage plant species tends to be uniform across the plot locations and does not show statistically consistent differences.

Multivariate Interpretation of Forage Plant Species Distribution

In addition, Principal component analysis and KMeans cluster test was applied. Principal Component Analysis (PCA) and KMeans Clustering were conducted to evaluate the distribution patterns of forage plant species across three location types in the natural rangelands of Wondama Regency, namely Coastal, Lowland, and Close Forest. The dimensionality reduction result from PCA showed that the three locations were projected far apart in a two-dimensional space (PC1 and PC2), which represents the greatest variance in the data.

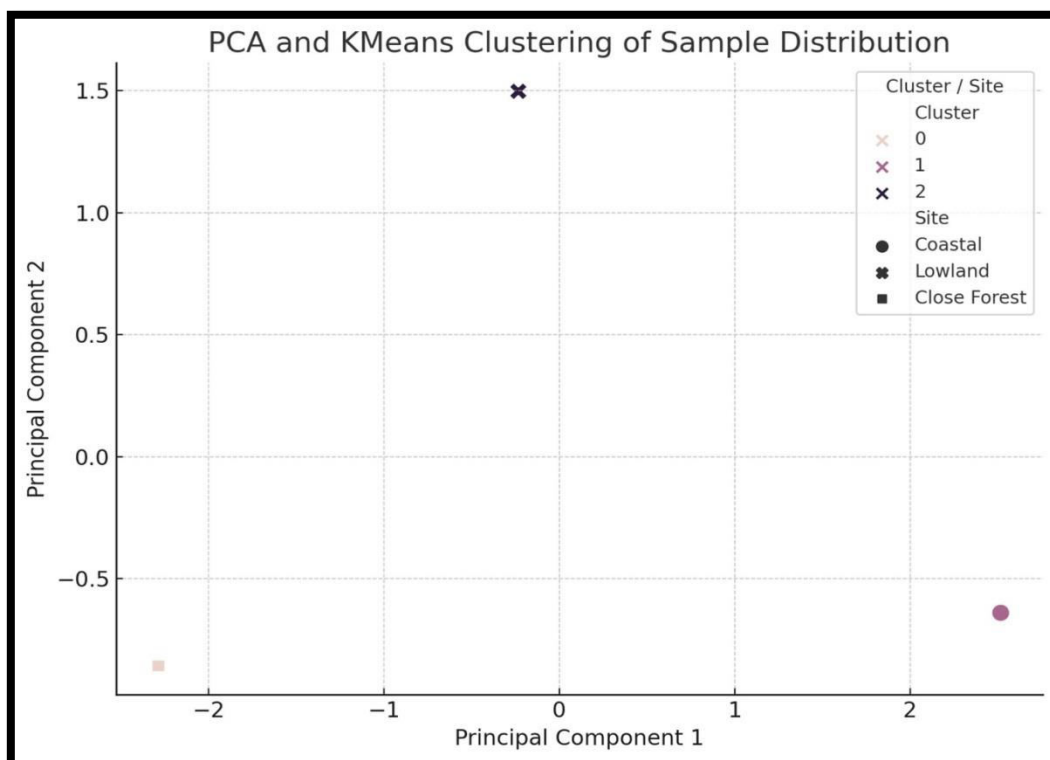


Figure 20. PCA and KMeans clusters of the forage plants under natural rangelands

The clustering result using the KMeans algorithm ($k = 3$) showed that each location fell into a different cluster, indicating a notable difference in species distribution patterns among them. The Coastal and Close Forest locations appeared to have highly contrasting distribution characteristics, as evidenced by their extreme positions along the PC₁ axis. This indicates that, although the previous Chi-square test did not reveal statistically significant differences, there is a latent structure in the data that distinguishes each location based on the composition or number of recorded species. Thus, multivariate approaches such as PCA and clustering provide additional insight into the potential ecological differences among locations (Zahra et al. 2015; Brewer and Gaudin 2020; Freitas and Pinard 2008; Lüscher et al. 2020), which may not be detected through conventional univariate or categorical analyses. These results highlight the importance of incorporating exploratory data-based analysis in vegetation studies of natural rangelands and in the sustainable management of forage resources for livestock (Sharifian et al. 2023; Rasouli and Amiri 2016; Dady et al. 2018; Zhang et al. 2014; Suarna et al. 1970).

Table 4. Dominance and Botanical Composition of Forage in the Natural Grazing Field of Warayaro, Sobey Village, Teluk Duari District, Teluk Wondama Regency

No	Forages species	Dominants (%)	Botanical composition (%)
A. Grass			
1	<i>Paspalum dilatatum</i> Poir	49,70	86,7
2	<i>Paspalum conjugatum</i> Berg	12,79	
3	<i>Eleusine indica</i> Gaertn	8,43	
4	<i>Cyperus rontudus</i> L	8,35	
5	<i>Ischaemun cf. timorensis</i> Kth	6,07	
6	<i>Digitaria insularis</i> Scop	1,06	
7	<i>Imperata cylindrical</i> L	0,21	
8	<i>Pennisetum purpureum</i> Schumacher & Thonn	0,07	
9	<i>Scirpus grossus</i> L.	0,04	
B. Leguminosae			
1	<i>Centrosema pubescens</i> Benth	10,46	10,5
C. Non-Forages			
1	<i>Ludwigia adscandens</i>	2,53	2,8
2	<i>Dryopteris</i> sp	0,15	
3	<i>Flugea racemosa</i>	0,08	
4	<i>Merremia peltata</i>	0,04	
5	<i>Passiflora foetida</i> L	0,02	
Total		100	100

The climate of TelukWondama Regency supports the vigorous growth of *Paspalum dilatatum*Poir due to its classification as a wet tropical climate (BPS-Kabupaten Teluk Wondama 2025), and because the natural pastureland of Warayaro is located 2–5 meters above sea level. According to Diwyanto et al. 2010; Nahlunnisa et al. 2016; Syarifuddin et al. 2017), *Paspalum dilatatum*Poir originates from subtropical regions of South America and naturally grows in both tropical and subtropical areas, including Indonesia. It is estimated to have been introduced to Australia around 1870, where it is now considered naturalized. This grass thrives in humid subtropical areas with annual rainfall of no less than 890–1,000 mm and in coastal areas with maritime climates. It grows well in heavy, moist soils. *Paspalum dilatatum*Poir is a palatable forage favoured by livestock, nutritionally rich during its young growth stage, and resistant to heavy grazing and trampling due to its strong underground root system.

Conclusions

Warayaro is a heterogenic pasture that consists of 15 types of fodder which include 9 grasses, 1 legume, and 5 types of other fodder, either of native and nonnative origin (14 genres from 8 families) dominated by *Paspalum dilatatum*Poir. The botanical composition of the natural pasture in Warayaro consists of 86.7% grasses, 10.5% legumes, and 2.8% other forages. If other forages are excluded, the botanical composition is 89.2% grasses and 10.8% legumes. CF (Closed to Forest) shows the highest projected species richness. CT (Coastal) and LL (Lowland) have fewer species detected and estimated, indicating lower richness. Shannon Diversity ($q = 1$), this diversity order takes both richness and species abundance into account, giving moderate weight to common species. CF still ranks highest in diversity, indicating not only a higher number of species but also a more even distribution. There is no significant association between the number of forage plant species and the location. The Cramér's V indicates that the strength of the relationship between location and species count is weak. Therefore, the distribution of forage plant species tends to be uniform across the plot locations and does not show statistically consistent differences.

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