

Original Research Paper

Botanical Composition and Yields of Forages in Natural Pastures Using Principal Component Analysis and Cluster Dendrogram in South Sulawesi, Indonesia

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Abstract: This study aims to identify the composition and yields of forages in natural pastures using principal component analysis and cluster dendrogram in Gilireng and Majauleng subdistricts, Wajo regency, South Sulawesi, Indonesia. Pasture plants were collected using 20 randomly sampled quadrats to observe the botanical composition and yields of forages. The collected data regarding legume classification is analyzed by Multivariate Analysis of Variance (MANOVA) with PCA and dendrogram clustering by using R version 4.2.2. The botanical composition of natural pastures was majored by grasses, followed by legumes and weeds in both Subdistricts and the pasture total dry yields were 9.01 and 5.20 t/ha in Gilireng and Majauleng subdistricts, respectively, to show the carrying capacity at 2.56 and 1.44 animal unit/ha, respectively. Principal component analysis for the biplot between the subdistricts and villages revealed the superior extensiveness of dimension 1 to dimension 2, but only a few types of outlier plants remained. Dimension 1 has a high kurtosis of 66.2%, while dimension 2 has a variance accounting for 26.5%. Furthermore, dendrogram analysis indicated that the agglomerative coefficient's combination between plants and environments was approximated at 0.84 and the dissimilarity value accounted for 30%. This indicates a high level of similarity or cohesion to the grouping between legumes and sampling locations in Wajo district, South Sulawesi. The use of Principal Component Analysis (PCA) contributed effectively and quickly to the recognition and classification of legumes present in the study.

Keywords: Botanical Composition, Cluster Dendrogram, Forage Yield, Natural Pasture, Principal Component Analysis

Introduction

Pasture land is globally predicted to represent 26% of land and 70% of the agricultural area (Anderson *et al.*, 2019; Cardoso *et al.*, 2020). However, it is primarily cultivated in areas with lower fertility levels (Godfray *et al.*, 2010; Hasan *et al.*, 2019). During the rainy season in pasture areas, forage crops are plentiful, whereas they are few during the dry season. The insufficient supply of forages throughout the year offers a significant obstacle to advancing cattle production in Indonesia (Horne and Stur, 1999).

Challenges related to natural pasture encompass lower efficiency, insufficient nutrient composition and

limitations in growth (Utomo and Widjaja, 2012). Botanical composition is frequently regarded as a key indicator of the quality of natural pasture.

It can be identified by detecting the composition of grasses, legumes and weeds (Skaer *et al.*, 2013). Botanical composition can also be used to indicate the occurrence of disturbance in a vegetation community by observing vegetation distribution patterns (Smith, 2002; Jayanegara *et al.*, 2009). However, there is little information available on pasture vegetation characteristics collected from farmers. Vegetation studies at small spatial scales are important to understand the importance of vegetation variability (Pornaro *et al.*, 2019;

Durán and Delgado-Baquerizo, 2020; Foerster *et al.*, 2020). Numerous factors, including climate, plant diseases, parasites, species, plant fraction, growth phase and soil, substantially impact forage quality (Tanner *et al.*, 2001; Arzani *et al.*, 2012). These issues indirectly affect the growth of livestock responses (Moore *et al.*, 2020; Lai *et al.*, 2021). To meet the nutritional requirements of grazed livestock, pasture quality and forage optimization are thus important (Kusmiyati *et al.*, 2019). Research in certain developed countries has led to new advances in biomass measurement, pasture remote sensing technology and associated pasture modeling and analysis. Nevertheless, implementing the technologies in Indonesia remains challenging due to the demand for substantial time and financial resources.

An alternative approach that can be used in investigating forage variance in pastures, is to use multivariate analysis with Principal Component Analysis (PCA) and dendrogram clustering. Despite its simplicity and lack of accuracy compared to the previously mentioned advanced methodologies, it provides a great opportunity to analyze a large amount of data by explaining the original variables to form a simple data presentation (Wang and Du, 2000; Zhang *et al.*, 2014). It is also a linear combination of the original variables that are useful in analyzing large sets of correlated data (Hasan and Abdulazeez, 2021) and is widely applied to classify phenotypic traits of plant germplasm based on their similarity. This technique can be applied to classify forages based on their intrinsic traits. In this context, it is very interesting to collect different types of forage with good quality (Jayanegara *et al.*, 2009). Therefore, this study aimed to identify fodder forage crop production and botanical composition of natural grasslands using PCA and cluster dendrogram.

Materials and Methods

Research Site

This research was conducted from October to December 2020 at three and two villages in Gilireng and Majauleng subdistricts, respectively, in the regency of Wajo, South Sulawesi Province ($3^{\circ} 54' 11''$ S- $4^{\circ} 0' 48''$ S and $120^{\circ} 5' 33''$ E- $120^{\circ} 13' 19''$ E) (Fig. 1) The annual temperature was estimated to range from 23-33°C, the humidity from 55-90% and annual precipitation of 8000 mm.

Sampling and Measurements

The botanical component analysis was performed by "measuring the quantity of vegetation," which was proposed by Mannetje and Haydock (1963) to estimate the botanical composition of natural pasture. The natural pastures in Gilireng and Majauleng Subdistricts of Wajo regency, as the research location, were selected

homogeneously in terms of vegetation structure and composition. The homogeneity of each area was visually assessed based on the herbaceous component, presence of trees and shrubs, terrain slope and rock outcrops. A number of sampling points were included in each area, with a total of 20 sampling points.

The positions of these points were determined in the field using a GPS device (Topcon GMS-2). At each point, a botanical survey was conducted using the linear quadrat method, recording the plant species touching the steel needle for each quadrat point. At each point, soil depth was measured by striking an iron rod with a hammer until it reached bedrock and herbaceous mass was collected by cutting vegetation in a 100×100 cm area at a height of 1 cm using a handheld brush cutter. Samples of forages in each quadrat were cut at 5-10 cm from the soil surface or at a similar sward height consumed by grazing livestock (Junaidi and Sawen, 2010). Forages obtained from the research quadrant plots were pooled to provide one representative sample per pasture, then weighed and divided into two sub-samples. The first (125 g fresh material) was stored at 20°C and used to characterize botanical composition. The second subsample was dried-oven at 60°C for 72 h to assess the Dry Matter (DM) content. As for the determination of botanical composition, each sample was sorted into fresh forage based on the type of forage (grasses, legumes and weeds). The botanical composition of the fresh forage was then determined by manually sorting the samples into species. Subsamples dried-oven at 65°C for 72 h were then weighed to determine total DM.

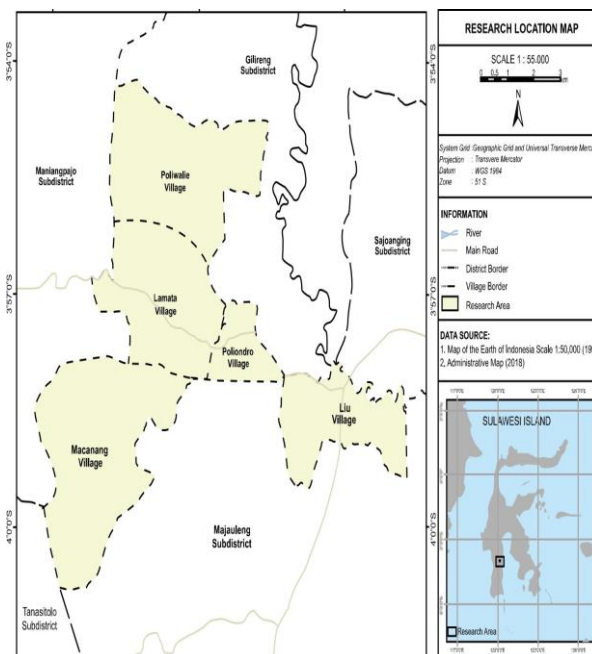


Fig. 1: Research map for the location of Gilireng and Majauleng subdistricts, Wajo Regency, South Sulawesi

Measurement of forage production was performed by employing the "actual weight estimate" method at 1×1 m area. Positioning of the measured plot in the pasture was performed randomly.

The botanical composition was calculated in percentage (%) with the following formula:

$$\text{Botanical composition} = (\text{DM}_{\text{sample}} / \text{DM}_{\text{total}}) \times 100\%$$

As forage DM requirement is 3.0% of body weight (300 kg) and the carrying capacity was calculated according to the following formula. Carrying capacity = forage DM production/forage DM requirement.

Statistical Analysis

The collected data regarding legume classification is analyzed by MANOVA with PCA and dendrogram clustering by using R version 4.2.2, which were applied to the chlorophyll content, fresh weight and dry weight of forages derived from the two, Gilireng and Majauleng subdistricts in Wajo Regency, South Sulawesi province.

Results

Forage Yield and Percentage of Dry Matter

Forage production records analyzed among the villages in the Gilireng and Majauleng subdistricts are presented in Table 1.

Table 1: Fresh and dry weights and dry matter percentage in some villages in Gilireng and Majauleng subdistricts, Wajo regency, South Sulawesi, Indonesia (Mean ± standard error, n = 20)

Sub-district	Village	Yield (g/m ²)/ %	Type of forages				
			Grass	Legume	Weeds	Total	
Gilireng	Lamata	Fresh weight	2396.67±003.33	180.00±90.18	271.00±29.51	2847.67±065.25	
		Dry weight	377.00±004.40	51.00±26.40	52.00±03.06	0480.00±023.84	
		Dry matter	15.73±000.16	28.33±09.67	19.19±01.29	0016.86±010.50	
	Poliwalie	Fresh weight	1446.33±019.94	72.00±18.15	74.00±07.47	1592.67±016.71	
		Dry weight	204.00±004.00	15.33±06.39	24.00±04.16	0243.33±007.80	
		Dry matter	14.10±000.15	21.29±04.06	32.43±07.50	0015.28±008.40	
	Poliondro	Fresh weight	1022.00±006.93	252.33±24.44	7.00±07.00	1281.33±016.50	
		Dry weight	152.33±013.95	25.33±02.90	1.00±01.00	0178.66±011.98	
		Dry matter	14.91±001.26	10.04±00.41	14.28±04.76	0013.94±050.80	
	Average	Fresh weight	1621.67±406.40	168.11±52.40	117.33±79.23	1907.11±478.77	
		Dry weight	244.44±067.93	30.55±10.62	25.67±14.74	0300.66±091.59	
		Dry matter	14.91±000.47	19.89±05.32	21.97±05.42	0015.36±000.84	
Majauleng	Macanang	Fresh weight	643.00±015.82	235.00±117.6	150.00±32.15	1028.00±132.06	
		Dry weight	203.33±011.67	87.33±43.76	50.00±16.77	0340.66±047.48	
		Dry matter	31.62±001.05	37.16±12.39	33.33±04.55	0033.13±105.24	
	Liu	Fresh weight	611.30±052.54	130.00±85.05	107.30±55.02	0848.60±021.43	
		Dry weight	166.30±029.33	23.00±14.22	26.00±13.08	0215.30±028.66	
		Dry matter	27.20±002.46	17.69±06.21	24.23±08.06	0025.37±008.29	
	Average	Fresh weight	627.15±015.85	182.50±52.50	128.65±21.35	0938.30±089.70	
		Dry weight	184.81±018.51	55.17±32.17	38.00±12.00	0277.98±062.68	
		Dry matter	29.46±002.21	30.23±09.73	29.54±04.55	0029.62±003.88	
	Average	Dry weight	214.63±029.81	42.86±12.30	31.83±06.17	0289.32±011.34	
	Total percentage			064.04	21.00	14.60	1.00

Source: Processed primary data in 2021

Table 1 indicates that Lamata village (16.86%) has the largest percentage of DM in the Gilireng subdistrict and Poliondro village (13.94%) has the lowest percentage. Meanwhile, in Majauleng subdistrict, Macanang village has the largest percentage of dry matter at 33.13%, while Liu Village has the lowest percentage at 25.37%. However, when compared between the two subdistricts, the highest percentage of DM was shown in the Majauleng subdistrict where the percentage of grasses, legumes and weeds dominated compared to the Gilireng Subdistrict. In total percentage, grasses occupied the highest at 64.4%, followed by legumes and the lowest in weeds at 14.6%.

Botanical Composition of Forages

The botanical composition of the classification of forage and species was determined by calculating the proportion of DM, as indicated in Table 1. The botanical composition of forage species in natural grasslands in the Gilireng and Majauleng subdistricts is presented in Table 2. Based on the classification in Table 2, nineteen forage species were identified in the Gilireng subdistrict, where the botanical composition identified the highest in grasses (81.3%), followed by legumes (10.1%) and other weeds (8.6%). In Majauleng subdistrict, the botanical composition included the highest in grasses (64.4%), followed by legumes (21.0%) and weeds (14.6%). In contrast to the trend observed in the percentage of DM, the percentages of botanical composition in both subdistricts are mainly dominated by grass species, compared to legumes and weeds.

Table 2: Botanical composition of forage species in natural pastures of Gilireng and Majauleng subdistricts, South Sulawesi, Indonesia (Mean \pm standard error, n = 3 and 2, respectively)

Forage type	Forage species	Botanical composition (%)	
		Gilireng subdistrict	Majauleng subdistrict
Grass	Signal grass (<i>Brachiaria decumbens</i>)	29.00 \pm 000.67	22.00 \pm 000.50
	Elephant grass (<i>Pennisetum purpureum</i>)	16.70 \pm 000.22	05.40 \pm 000.90
	Para grass (<i>Brachiaria mutica</i>)	09.31 \pm 000.84	03.43 \pm 000.85
	Carabao grass (<i>Paspalum conjugatum</i>)	08.90 \pm 004.57	11.35 \pm 000.05
	Setaria grass (<i>Setaria sphacelata</i>)	06.50 \pm 000.50	-
	Dwarf Napier grass (<i>Pennisetum purpureum cv. Mott</i>)	04.73 \pm 002.47	01.32 \pm 001.30
	Spear grass (<i>Heteropogon contortus</i>)	02.40 \pm 001.21	-
	Coco-grass (<i>Cyperus rotundus</i>)	01.40 \pm 001.40	00.60 \pm 000.50
	Lesser spear grass (<i>Chrysopogum ariculatus</i>)	01.20 \pm 001.20	15.42 \pm 001.60
	Indian goosegrass (<i>Eleusine indica</i>)	01.02 \pm 000.16	00.65 \pm 000.45
	Mexicana grass (<i>Muhlenbergia Mexicana</i>)		03.71 \pm 002.11
	Subtotal		081.16
Legume	Desmodium (<i>Desmodium inrtortum</i>)	08.37 \pm 000.89	12.60 \pm 002.60
	Sun hemp (<i>Chrotalaria triflorum</i>)	01.70 \pm 000.92	-
	Hyacinth bean (<i>Lablab purpureus</i>)	00.17 \pm 000.17	02.97 \pm 001.23
	Quickstick (<i>Gliricidia sepium</i>)		05.60 \pm 001.40
	Subtotal	010.24	021.17
Weeds	Lesser roundweed (<i>Hiptis brevipes</i>)	04.00 \pm 000.11	05.70 \pm 002.00
	West Indian Lantana (<i>Lantana camara</i>)	01.80 \pm 000.94	04.25 \pm 00.75
	Redflower ragleaf (<i>Crassocephalum crepidioides</i>)	01.80 \pm 000.89	-
	Shameplant (<i>Mimosa pudica</i>)	01.00 \pm 000.40	05.00 \pm 000.95
	Subtotal	008.60	014.95
Total		100.00	100.00

Source: Processed primary data in 2020 and 2021 for Gilireng and Majauleng subdistrict, respectively

Table 3: Forage production, dry matter requirement and carrying capacity in Gilireng and Majauleng subdistricts, Wajo Regency, South Sulawesi

Parameter	Unit	Subdistrict	
		Gilireng	Majauleng
Forage fresh matter production	ton/ha	57.21	18.25
Forage dry matter production	ton/ha	09.01	05.20
Available forage dry matter production	ton/ha	02.19	01.23
Feed dry matter requirement (3% of body weight)	kg/day	09.00	09.00
Dry weight requirement (in 30 days, a month)	kg/month	270.00	0270.00
Carrying capacity	AU/ha	2.56	01.44

Source: Primary data in 2021

Forage Production and Carrying Capacity

The sustainability of natural pastures in Wajo Regency can be ensured by determining forage production and carrying capacity. Forage production and carrying capacity are also essential for maintaining a healthy forage. Forage production, dry matter requirement and carrying capacity in Gilireng and Majauleng Subdistricts, Wajo Regency, South Sulawesi are presented in Table 3. Forage DM production in Gilireng subdistrict was higher at 9.01 t/ha than that in Majauleng subdistrict at 5.20 t/ha, which was linearly higher available forage dry matter production in Gilireng than in Majauleng. Thus, carrying capacities of natural pastures under the feed DM requirement at 3.0% of cattle body weight at 300 kg

(9.00 kg/day) in Gilireng and Majauleng subdistricts were 2.56 and 1.44 Animal unit (AU)/ha/year, respectively (Table 3).

Variance in PCA Biplot among Subdistricts

The blue and yellow circles (Fig. 2) are used to visually distinguish between the two subdistricts on the biplot. Presumably, the blue circle represents the Gilireng subdistrict, while the yellow circle represents the Majauleng subdistrict. This coloring convention helps viewers easily identify which data points correspond to each subdistrict. The PCA biplot of the data among subdistricts is presented in Fig. 2. The blue and yellow circles represent the Gilireng and Majauleng subdistricts, respectively.

Figure 2, dimension 1 had a high kurtosis. The further the circle in the X-axis, the higher the data variance. As dimension 1 becomes wider, the variance becomes more extensive compared to dimension 2. Figure 2 demonstrated that dimension 1 had a variance percentage of 66.2%, while dimension 2 had a variance percentage of 26.5%. The principal component (dimension 1) interprets the largest variances from data in natural pastures.

Variance in PCA Biplot Among Villages

The biplot (Fig. 3) illustrates the principal components derived from the MANOVA, where each point represents a village and the direction and length of vectors indicate the relationship between variables and dimensions.

Villages in the Gilireng subdistrict are depicted in blue, with Lamata designated as LMV, Poliwalie as PV and Poliondro as PLV. Villages in Majauleng Subdistrict are represented in orange, with Macanang designated as MV and Liu as LV.

Figure 3 demonstrates the association of the village's variance over the dimension. The biplot showed that the points of the two villages in Majauleng subdistrict were strongly positively correlated to those in Gilireng's villages where dimension 1 accounts for 66.2% of the total variance, while dimension 2 accounts for 26.5%.

Dendrogram Analysis on Forage Classification

Dendrogram analysis plays a crucial role in forage species classification by providing a systematic framework for understanding species relationships. Dendrogram analysis on forage species classification in the two Gilireng and Majauleng subdistricts of Wajo Regency is presented in Fig. 4.

For the abbreviations of Subdistricts and Villages, refer to the footnotes in Fig. 3.

In grass species, Signal grass is designated as SG, Elephant grass as EG, Para grass as PG, Corabao grass as CG, Setaria as S, Dwarf napier grass as DNG, Speargrass as SPG, Coco-grass as COG, Lesser spear grass as LSG, Indian goosegrass as IG and Mexicana grass as MG.

In legume species, Desmodium is designated as D, Sun hemp as SH, Hyacinth bean as HB and Quickstick as QS.

In weedy species, Lesser roundweed is designated as LR, West Indian Lantana as WIL, Redflower ragleaf as RR and shameplant as SP.

Dendrogram analysis on forage species classification in the two Gilireng and Majauleng subdistricts of Wajo Regency indicates a combination of plant-environment with the agglomerative coefficient of 0.84 and dissimilarity of approximately 30%.

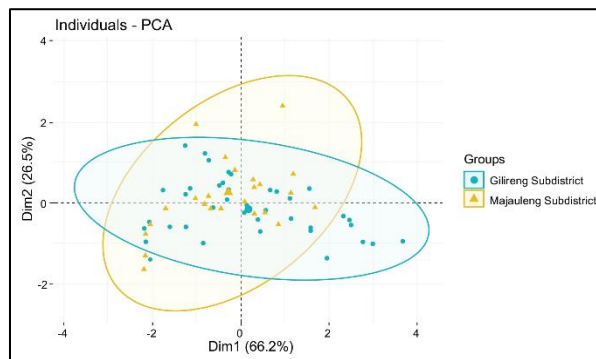


Fig. 2: PCA biplot of the data among subdistricts. The blue and yellow circles represent Gilireng and Majauleng subdistricts, respectively

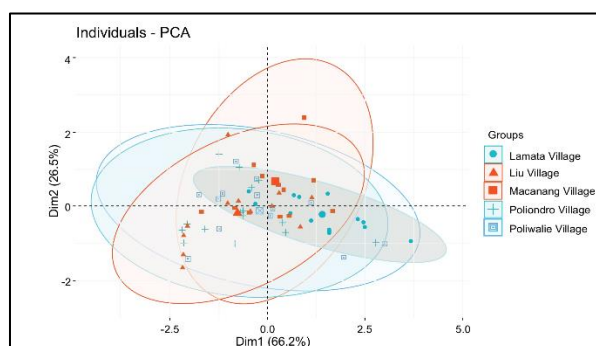


Fig. 3: PCA biplot of the data among villages. Villages in Gilireng Subdistrict are depicted in blue, with Lamata designated as LMV, Poliwalie as PV and Poliondro as PLV. Villages in Majauleng subdistrict are represented in orange, with Macanang designated as MV and Liu as LV

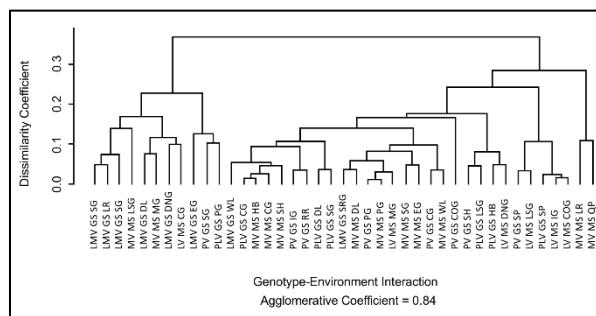


Fig. 4: Dendrogram to the classification of forage species found in 2 subdistricts in Wajo Regency, South Sulawesi

Discussion

Botanical Composition

Typically, natural pastures comprise a diverse array of plant species. A study of the botanical composition facilitates understanding the diversity present within these

pastures. Botanical composition of forage species in Gilireng subdistrict, Table 2, identified a proportion of grasses (81.2 %), legumes (10.2 %) and weedy plants (8.6 %), suggesting a lower percentage of grass composition, compared to the study performed by Tana *et al.* (2015) in Kupang Regency, Indonesia, where the natural pastures were consisted of grasses, legumes and weeds at approximately 89.8, 4.8 and 5.4 %, respectively. The majority of available forages in natural pastures of Gilireng subdistrict was composed of grasses and a small proportion of legumes, causing low forage quality since forages play an important role in sustaining the soil fertility and nutritional improvement of forages in natural pastures. Khatiwada *et al.* (2020) stated that legumes significantly impact pasture utilization as the primary forage sources for livestock since the abundance of legumes could boost the nutritional capacity of a pasture. Its production per land area unit and fertility through microbial nitrogen fixation and application of organic manure (Hasan *et al.*, 2019; Utamy *et al.*, 2018). It has become the key issue for environmentally friendly and healthy soil conditions (Navarro-Pedreño *et al.*, 2021).

The fast regrowth of grasses after defoliation also inhibits legume growth (Capstaff and Miller, 2018). It confirms that tropical legumes grow slower than grasses, while both grasses and legumes play a major part in the pasture (Jolaosho *et al.*, 2009). In addition, legumes have a high nutritional content for ruminants and several types of legumes are required to improve the quality of a pasture. This is in accordance with a study performed by Junaidi and Sawen (2010), stating that the availability of legumes in the pasture is necessary since legumes have a higher nutritional content than grasses, particularly protein content.

The forage composition of natural pastures in the Majauleng Subdistrict was shown in lower grass composition at 63.9 %, which is lower than a previous study of the botanical composition consisting of 90.4, 4.3 and 5.3 % in grass, legumes and weeds, respectively (Manu, 2013). This is due to the low soil fertility and climatic conditions in the Majauleng Subdistrict are depressing the growth of forages. This is in line with the study by Núñez *et al.* (2010) that the botanical composition of unstable pasture is strongly affected by adverse conditions in climate, soil condition and grazing system. Several studies revealed that cattle grazing plays a promising option for maintaining and promoting grassland biodiversity (Wrage *et al.*, 2011; Tälle *et al.*, 2016; Huang *et al.*, 2018; Schmitz and Isselstein, 2020). López-Bucio *et al.* (2005) suggested that the stability of vegetative communities is affected by the biotic environment (cattle) and abiotic variables like water, soil, climate and temperature, as well as rainfall (Matthew *et al.*, 1994). Therefore, the plants unable to grow in certain conditions will be replaced by other species. Forage productivity in pastures could be improved concerning nutrient and water

requirements (Amsalu and Addisu, 2014; Al-Kelaby *et al.*, 2022), or forage cultivation through plant breeding techniques (Khaerani *et al.*, 2021; 2024; Musa *et al.*, 2021). In natural pastures, the botanical composition of forage can influence the quantity and quality of forage selected and consumed by ruminants. The techniques used to determine the botanical composition, intake and digestibility of forage by ruminants are critical to understanding the nutritional value of forage and its impact on animal performance (Pepeta *et al.*, 2022; Xu *et al.*, 2024).

Forage Production and Carrying Capacity

The carrying capacity of natural pastures in the Gilireng subdistrict (Table 3) was around 2.56 AU/ha/year, lower than that in the previous study by Pangestu *et al.* (2019), where the carrying capacity stood at 3.25 AU/ha/year. According to Muhakka *et al.* (2019), the higher the level of forage production per hectare, the higher the carrying capacity of a pasture. The carrying capacity of natural pastures in the Majauleng subdistrict (Table 3) was about 1.44 AU/ha/year. It was relatively low compared to the study performed by Yoku *et al.* (2014), reporting that the carrying capacity in Bitawi Pasture, Inam village, West Papua was 1.77 AU/ha/year. The carrying capacity of tropical pasture was generally around 2-7 AU/ha/year, as supported by Reksohadiprodjo (1981), stating that a pasture may be considered productive if the carrying capacity is achieved to 2.5 AU/ha/year. Low carrying capacity will be impacted by the forage productivity within the pastures, which will negatively affect the grazing livestock performance (Bell *et al.*, 2014). When using a well-managed grazing system, harvest efficiency can be improved over time of grazing, by calculating carrying capacity using the relative production estimation method (De Figueiredo *et al.*, 2017; Roche *et al.*, 2017)

Forage production and carrying capacity are essential factors in pasture management. The carrying capacity refers to the maximum number of grazing livestock that a piece of land can sustain for the long term while maintaining or improving pasture resources. Carrying capacity is expressed in Animal Unit Months (AUMs) or AU per unit area and is a measure of a pasture's ability to produce enough forage to meet the requirements of grazing livestock. This AU concept is useful for determining grazing animals when livestock consume 2.5% of their body weight each day (Launchbaugh, 2017). The carrying capacity of pastures is closely correlated with the type of grazing livestock, production rates of grasses, season and the acreage of pastures. Disregarding the carrying capacity of livestock density eliminates the growth of preferable forages by the livestock. Consequently, the livestock population will experience declining productivity since these forages have little chance to regrow (Norton *et al.*, 2013).

Principal Component Analysis and Dendrogram Analysis

PCA is a variable reduction feature widely used in multivariate statistics. The purpose of PCA is to reduce high data dimensions into a lower data dimension with a lower risk of information loss (Smith, 2002; Izzuddin, 2015). In the context of forage analysis, PCA can be applied to investigate the botanical composition of pastures, which is essential for understanding forage's nutritional value and quality. Furthermore, PCA can be employed to examine the correlation between botanical content, yield and forage quality. It is crucial to comprehend how various plant species impact the pasture's overall production and nutritional quality. As can be seen from Figs. 2-3, PCA maximized the proportion of the total variance of the data set represented by principal components. Figure 2, forages from the Gilireng subdistrict had extensive variance compared to the variance in the Majauleng subdistrict. Figure 3 also indicates the presence of overlapping between the variances of the Gilireng Subdistrict and the Majauleng Subdistrict. Dimension 1 accounts for 66.2% of the total variance, while dimension 2 accounts for 26.5%. This suggests that dimension 1 captures a larger proportion of the variability present in the dataset compared to dimension 2. This finding is often the main result in PCA, where the principal components are sorted by the amount of variance. In addition, there were plants considered to be outliers. The excluded forages indicate data from the overlapping between yellow and blue circles. Based on Fig. 3, the PCA biplot among dimension 1 villages is more extensive compared to dimension 2, which seems to overlap. This implied that the data centralization in Fig. 3 is relatively similar. The major variance observed in Fig. 3 can be seen from the variance with the largest circle. In large circles from both dimensions 1 and 2, their variances will be more balanced.

Dendrogram analysis in Fig. 4 further indicated a combination of plant and environment with an agglomerative coefficient of approximately 0.84. This coefficient indicates the degree of similarity between different clusters of forage species. A coefficient of 0.84 suggests a relatively high level of similarity among the species within the clusters. In other words, there are distinct groupings of forage species that share common characteristics or environmental preferences. When the agglomerative coefficient value gets closer to 1, it indicates that the clustering structure is strong. Figure 4, in general, indicates 2 major groups where the primary group with a greater number of sub-clusters demonstrates greater variances. Figure 4 shows the values dissimilarities in both groups by about 30%. This indicates the level of difference or dissimilarity between the clusters identified in the dendrogram. A dissimilarity of 30% suggests that while there are significant

similarities within clusters, there are also notable differences between them.

Before applying PCA and dendrogram clustering, the data set requires normalization and therefore, each attribute with a greater domain will not dominate the attributes with a smaller domain. Consequently, it reduces the data set acquired from the implementation of PCA and is applied to the clustering algorithm (Dash *et al.*, 2010). PCA and combining dendrogram clustering analysis may reduce dimension or data without reducing the data characteristics significantly and it is effective in the classification and screening of forages in pastures. PCA and dendrogram clustering can be used to analyze the relationship between different plant species and their nutritional value, as well as to identify groups of similar species with similar nutritional properties. This can help optimize grazing management in natural pastures ensuring animal productivity while preserving the composition and biodiversity (Gorlier *et al.*, 2012; Palumbo *et al.*, 2021).

According to De Carvalho *et al.* (2022), the variables that contributed most significantly to discriminating between forage cultivars related to PCA analysis consisted of the Number of Tillers Per Plant (NTPP), Number of Leaves Per Plant (NLPP), Mean Leaf Width (MLW), Stem Dry Matter Yield (SDMY), Leaf to Stem Ratio (L:S), DM, Crude Protein (CP) and Neutral Detergent Fiber (NDF)% of leaves, as well as CP, Ether Extract (EE) and Acid Detergent Fiber (ADF)% of stems. Principal Component Analysis (PCA) has proven to be a valuable tool in optimizing the evaluation of forage cultivars, leading to a reduction in the number of yield and nutritional characteristics. This reduction in the number of measured variables translates to significant savings in time and resources in the evaluation of forage cultivars without sacrificing the integrity of the information obtained. Although PCA is a frequently used and adaptive descriptive data analysis technique in the standard form, it also has various adaptations that make it applicable to a wide range of circumstances and data types in a variety of disciplines (Jolliffe and Cadima, 2016).

Conclusion

The productivity and the carrying capacity of natural pastures in the Gilireng and Majauleng subdistricts are still considered low. Through the approach of PCA, the classification and screening of forage in pastures will be more informative. It was revealed that the PCA biplot between the subdistricts and villages indicated the extensiveness. Dendrogram analysis further indicated a combination of plant and environment with a significant degree of similarity in agglomerative coefficient and indicating the strong clustering structure of classification

of legumes and sampling sites found in the Wajo Regency of South Sulawesi. The PCA and dendrogram clustering offer a method of time and resource efficiency in the classification of forages. The findings of this study provide valuable insights for future investigations aimed at identifying the most suitable optimized pasture and contributing to forage diversity of natural pasture.

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Author's Contributions

Purama Isti Khaerani: Conceived and designed the experiments, performed the field experiments, performed analyzed data and wrote the study.

Yunus Musa, Renny Fatmyah Utamy and Yasuyuki Ishii: Conceived and designed the experiments, performed the field experiments, performed analyzed data and wrote the study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all other authors have read and approved the manuscript and no ethical issues have been involved.

Declaration of Interest Statement

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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