BIODIVERSITAS
Volume 26, Number 5, May 2025
Pages: 2410-2415

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d260538

Vegetation diversity and composition, and forage production of natural pasture in East Luwu District, South Sulawesi, Indonesia

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Manuscript received: 28 January 2025. Revision accepted: 13 May 2025.

Abstract. *Sema, Syamsu JA, Ako A, Rinduwati. 2025. Vegetation diversity and composition, and forage production of natural pasture in East Luwu District, South Sulawesi, Indonesia. Biodiversitas 26: 2410-2415.* Increasing the productivity of ruminants should be supported by the availability of forage. In the context of pasture, forage availability is determined by type of vegetation and the amount of production in the area so that it can meet the needs of livestock. Research related to forage plant vegetation in South Sulawesi, Indonesia, have been carried out, but more nuanced study is needed to account specific context of biophysical conditions. This study aims to determine the types of vegetation and forage production in a natural pasture in Malili Sub-district, East Luwu District, South Sulawesi. Data was collected by establishing 20 sampling plots with a size 1x1 m, totalling a sampled area of one hectare. Types of vegetation and forage production were measured using the Summed Dominance Ratio method based on frequency, density, and cover area. The result showed that the botanical composition of the sampled pasture based on Dry Weight Rank consisted of 30.00% grass, 15.00% legumes and 55.00% weeds. The pasture comprised of 21 species of grass, 7 species of legumes and 21 species of weeds with three dominant grass species were *Cynodon dactylon* (5.12%), *Epidendrum culculatum* (3.59%) and *Mecardonia procumbens* (3.44%). The carrying capacity of the pasture was 0.16 AU/hectare/month or equivalent to 1,75 AU/hectare/year. The results of this study indicate that the productivity of the existing pasture is relatively low and special efforts are needed to improve its quality.

Keywords: Forage production, grass, legumes, pastures, weeds

INTRODUCTION

Grazing areas are a crucial component of livestock farming, providing high-quality and productive feed sources for livestock (Kaiser 2024). However, in recent decades, the availability of forage in grazing areas across various tropical countries has continued to decline due to land conversion and weed invasion (Ibrahim and Usaman 2021). The loss of grazing areas affects the extent of grassland and the sustainability of natural grazing, which is closely related to livestock management systems. Weed invasion can alter vegetation composition and reduce feed quality. Additionally, factors such as climate change, soil conditions, livestock density, and grazing intensity also influence grassland vegetation composition (Wróbel et al. 2023).

Grasslands play a vital role in supporting livestock systems and providing ecosystem services (Bey et al. 2016). However, financial profitability considerations often determine the type of vegetation cultivated, posing challenges in balancing economic productivity and ecological functions (Vlasenko and Shagaipov 2021). Therefore, a connection between plant vegetation conservation and grassland management is needed. Grassland rehabilitation is a common model in temperate regions such as New Zealand, where *Lolium perenne* is a key component of grasslands, although its contribution to total annual yield is less than 20% (Watuwaya et al. 2022). In contrast, in tropical regions, natural grass vegetation can contribute up to 84.42% of grassland yield (Sema et al. 2023). Forage production in South Sulawesi, Indonesia, fluctuates from 1.39 tons per hectare during the dry season to 5.35 tons per hectare in the rainy season. This seasonal variation also alters the proportion of forage types, with grass accounting for 50% of the dry-season forage, increasing to 69% in the rainy season (Rinduwati et al. 2016).

South Sulawesi has significant potential for beef cattle farming. The beef cattle population increased from 1,310,194 in 2018 to 1,483,709 in 2022. However, the number of cattle slaughtered tends to fluctuate, indicating relatively low reproductive efficiency. Additionally, land conversion from grasslands to agricultural land reduces grazing areas, making the improvement of the remaining grassland quality a key solution for providing livestock feed. Despite the high potential for beef cattle farming in South Sulawesi, research on grassland vegetation in this region remains limited. Differences in biophysical factors and research methods pose challenges in obtaining consistent data. Therefore, more comprehensive research is needed to identify plant vegetation types and forage production in the grasslands in East Luwu District, South Sulawesi Province, Indonesia. The results of this study are expected to provide valuable information for livestock businesses, academics, and stakeholders in the management and development of grasslands in the region.

MATERIALS AND METHODS

Study area and period

This research was conducted in Malili Sub-district, East Luwu District, South Sulawesi Province, Indonesia, over a period of one year, from July 2023 to December 2024. Geographically, the study area is located between 2°03'00"-3°03'25" S and 119°28'56"-121°47'27" E. The topographical characteristics of the region are predominantly hilly, with an average elevation of 96.36 meters above sea level. The land slope varies across three categories: 15-25%, 25-45%, and above 45%. The soil type in this area is classified as latosol.

The annual average temperature in the region ranges from 23°C to 32°C, with humidity levels between 80% and 100%. Monthly rainfall is projected to vary between 160 mm and 361 mm, with the highest precipitation occurring in December. The peak number of rainy days is recorded in April, with 23 days of rainfall. Meanwhile, the dry season typically occurs from August to September. The research sample collection sites are presented in Figure 1.

Data collection

This research focused on all types of grass and legumes that grow on natural grazing areas at the study site. Several tools were used including sickle, scissors, plastic bags, scales, calculators, cameras, and Global Position System (GPS). This study used primary data obtained from direct survey in the field and secondary data from literature and related institutions.

Vegetation sampling was conducted by establishing 1x1 meter plots using quadrant frame located randomly at the study site. First, quadrant frame was located randomly with the aim of determining the starting point. From this starting point, the subsequent sampling plots were placed for the four cardinal directions: east, west, north and south with 20 plots for each direction. In total, there were 20 sampling plots established. Within each plot, all plant species were recorded and counted its abundance and coverage to determine the frequency, density and dominance of each species.

Data on forage production was measured using destruction method to calculate the Actual Weight Estimate/Dry Weight Rank as prescribed by Sema et al. (2021). Within each plot, all vegetation was cut and put into plastic bags to be weighed immediately.

Proximate and Van Soest analysis are common methods used in feed composition analysis. Proximate analysis includes the measurement of moisture content, ash, crude protein, crude fat, crude fiber, and nitrogen-free extract through standard laboratory procedures. Van Soest analysis is used to determine fiber content in feed, including Neutral Detergent Fiber (NDF) and Acid Detergent Fiber (ADF), which are analyzed using detergent reagents to separate fiber fractions.

Laboratory procedures

Sample preparation

Feed samples are dried at 60°C for 48 hours in a drying oven. The samples are then ground to pass through a 1 mm sieve before analysis.

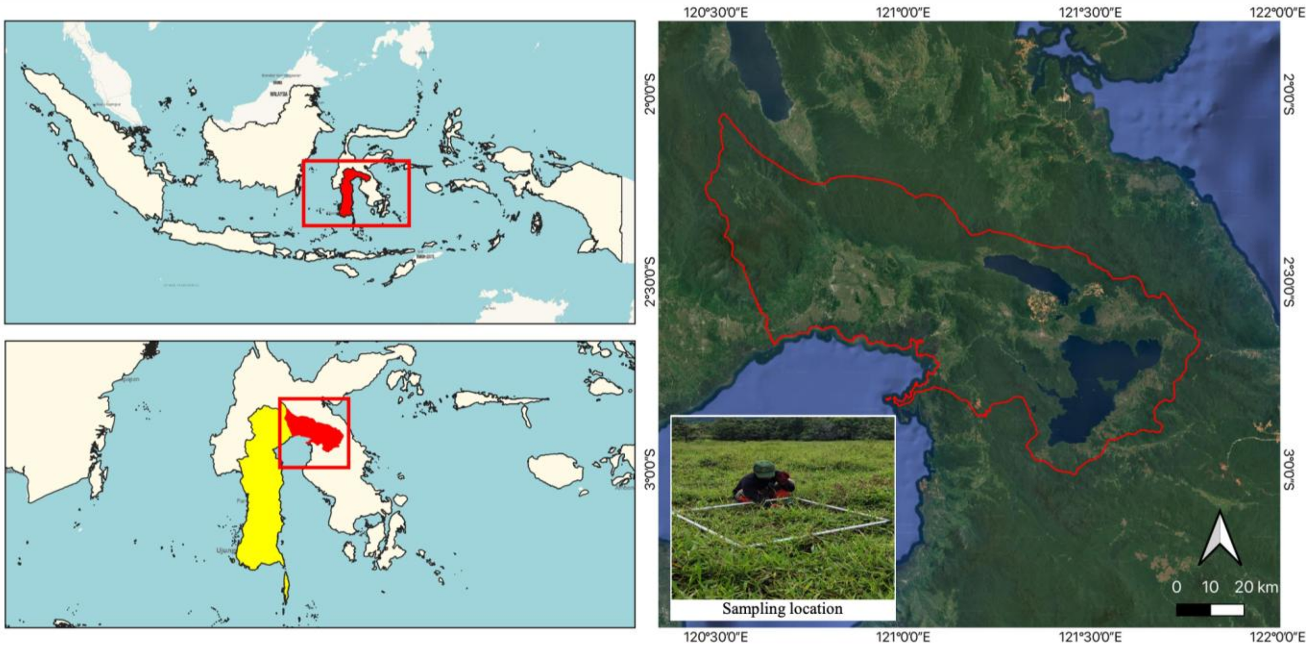

Figure 1. Map of study area in Malili Sub-district, East Luwu District, South Sulawesi Province, Indonesia

Proximate analysis (Based on AOAC methods)

Moisture Content: Determined using a drying oven at 105°C until a constant weight is achieved. Ash Content: The sample is converted into ash using a furnace at 550°C for 4-6 hours. Crude Protein: Measured using the Kjeldahl method to determine total nitrogen content, then multiplied by a conversion factor (6.25). Crude Fat: Determined through extraction using an organic solvent (e.g. Soxhlet method). Crude Fiber: Determined through sequential acid and alkali treatments, after which the residue is dried and weighed.

Van Soest analysis (Based on Van Soest methods)

Neutral Detergent Fiber (NDF): The sample is refluxed with a neutral detergent solution to remove soluble cell components (proteins, fats, starch), leaving crude fiber, hemicellulose, cellulose, and lignin. Acid Detergent Fiber (ADF): The NDF sample is then refluxed with an acid detergent to remove hemicellulose, leaving cellulose and lignin. Lignin (ADL): The ADF sample is treated with 72% sulfuric acid to remove cellulose, leaving the lignin fraction.

Data analysis

The variables measured in this study were the diversity and composition of vegetation and forage production in the grazing area following the methods by Vlasenko and Shagaipov (2021) and Salugin and Vlasenko (2022). All primary data were tabulated and calculated to produce vegetation composition and forage production in the form of fresh and dry materials method Association of Official Analytical Chemists (AOAC 2005).

RESULTS AND DISCUSSION

Botanical composition

Vegetation composition determines the quality of pasture that can affect livestock activity (Franca et al. 2016). Botanical composition of undergrowth vegetation at grazing area in East Luwu, South Sulawesi Province, Indonesia, is presented in Table 1. This table shows that weeds dominated the vegetation composition in the grazing area with 55%, while grass and ground cover only comprised 30% and legumes 15%. This means that the quality of pastures in Malili Sub-district is low. The proportion of legumes in grazing pastures in East Luwu is lower than weeds and grasses due to increased competition. This is in line with (Salugin and Vlasenko 2022) that the presence of other plants can trigger competition in obtaining nutrients in the soil and also suppress growth, especially if the proportion of legumes below 20%.

Natural grazing area which is dominated by weeds and few legumes causes low quality forage, because in addition to the presence of allelopathic substances, weed also inhibit the growth of grass and legumes beneficial for livestock feed source. Legumes contain higher nutrients than grass and also contribute to the provision of nitrogen through N fixation. The presence of legumes is important in managing pastures to maintain sustainable pasture quality (Rusdy et al. 2019). According Rusdy (2020), Watuwaya et al. (2021) and Sema et al. (2023), the ideal vegetation composition of grazing area is 60% grass and ground cover, and 40% legumes. Vlasenko et al. (2022) stated that one of the reasons for the low percentage of legumes is due to the slightly alkaline soil, making it difficult for plants to absorb soil nutrient ions.

Table 1. Botanical composition of undergrowth vegetation at grazing area in Malili Sub-district, East Luwu District, South Sulawesi, Indonesia as Dry Weight Rank (DWR)

Species name	Indonesian name	Percentage (%)
Grasses and ground cover		
Axonopus compressus	*Karpet*	0.53
Crysopogon aciculatus	*Jarum*	0.25
Cynodon dactylon	*Bermuda*	5.12
Cyperus rotundus	*Teki*	2.85
Dactyloctenium aegyptiun	*Tapak jalak*	0.50
Dichanthelium clandestinum	*Lidah rusa*	0.69
Digitaria sanguinalis	*Jari*	0.89
Echinocola colona	*Bebek*	1.82
Eleusina indica	*Belulang*	0.83
Epidendrum cucullatum	*Anggrek*	3.59
Hypoxis hemerocallidea	*Afrika*	0.30
Imperata cylindrical	*Alang-alang*	1.00
Mecardonia procumbens	*Bintang kuning*	3.44
Panicum maximum	*Benggala*	0.30
Paspalum conjugatum	*Pahit*	2.69
Pennisetum purpureum	*Gajah*	0.15
Scoparia dulcis	*Sapu manis*	1.21
Setaria neglecta	*Setaria*	0.19
Schoenoplectus lacustris	*Teki*	0.28
Spermacoce remota	*Setawar*	0.37
Sub Total		30.00
Legumes		
Alysicarpus vaginalis	*Vaginalis*	1.28
Amaranthus viridis	*Bayam raja*	1.01
Calopogonium mucunoides	*Kalopo*	2.05
Cyanthillium cinereum	*Sawi langit*	2.04
Desmodium triflorum	*Desmodium*	5.49
Ludwigia palustris	*Cacabean*	1.40
Phyllantus urinaria	*Meniran*	1.38
Sub Total		15.00
Weeds		
Ageratum conyzoides	*Bandotan*	1.04
Ambrosia artemisiifolia	*Ambrosia*	0.83
Callisia repens	*Merayap kura-kura*	1.31
Chromolaena odorata	*Kerinyuh*	11.07
Crassocephalum crepidioides	*Sintrong*	1.28
Crepis bursifolia	*Bunga liar*	1.80
Crepis pulchra	*Sawi liar*	1.50
Eclipta prostrata	*Urang aring*	8.41
Elephantopus mollis	*Tapak gabus*	1.19
Erigeron bonariensis	*Jelantir*	2.14
Galinsoga quadriradiata	*Galinsoga berbulu*	6.78
Ipomoea lacunosa	*Kangkung liar*	1.04
Lantana camara	*Tahi ayam*	2.20
Melastoma malabathricum	*Herending*	2.92
Mentha logifolia	*Bejanggut kuda*	1.78
Nepenthes gracilis	*Kantong semar*	2.26
Rubus fruticosus	*Beri hitam*	0.92
Senna alata	*Ketepeng cina*	0.86
Stachytarpheta jamaica	*Jarong*	3.44
Veronica arvensis	*Mata ayam*	0.98
Sub Total		55
Total		100

Water availability, soil topography, and climatic variables, such as temperature, humidity, rainfall, light intensity and altitude, are the main factors affecting the nutritional value and forage production. Rainfall generally increases the nitrogen, phosphorus and crude fat content of forage plants. East Luwu District is classified as a tropical climate of type B with temperatures of 29-31°C or an average temperature of 29°C during the day. This change occurs in an average of three months, namely April to July and August to October, with an average rainfall of 8,000 mm with 120 rainy days. The altitude factor has a lot of influence on the distribution of forage species, while livestock grazing is the main factor in the degradation of grasslands (Gang et al. 2014; Kust et al. 2020).

Production of fresh matter and dry matter

Plant species, soil and climate are internal and external factors that can affect the production of fresh and dry matter, including those used as feed sources for ruminants. About 80% of feed for ruminants comes from forage sourced in pastures (Sema et al. 2023) so that the availability of feed in terms of quantity, quality and continuity throughout the year needs to be considered. The grazing fields in East Luwu have the production of fresh and dry forage material during the dry season as presented in Table 2.

Dry matter content (Table 2) is slightly higher in legumes at 3.03 tons/hectare compared to grass and other plants. The dry season in East Luwu with its reduced moisture levels, results in higher dry matter content, making the forage more concentrated. However, forages have higher moisture content during the rainy season, leading to lower dry matter percentages. Organic matter is highest in grass at 4.20 tons/hectare.

Several studies highlight the significant impact of environmental factors such as rainfall, drought, and salinity on the growth phases of grasses and legumes (Eisenhauer and Türke 2018; Mykhalkiv et al. 2023; Khaerani et al. 2024; Pirnajmedin et al. 2024). Adequate rainfall ensures sufficient water for physiological processes, while temperature regulates transpiration and photosynthesis rates. Excessive temperatures reduce photosynthetic efficiency, ultimately impacting forage production and quality.

Besides the plant itself, factors affecting the growth and production of forage are external factors, namely rainfall and temperature, which directly relate to growth and production. Adequate rainfall will ensure the availability of water that can be utilized by plants in physiological processes (Bamutaze et al. 2019). In addition, temperature also has a direct effect and is closely related to the rate of transpiration. If the temperature exceeds the optimum range, the rate of photosynthesis will decrease which will affect the production and quality of forage (Schuppli et al. 2014). Alternating wet and dry seasons exacerbate this issue by adversely affecting the quality and quantity of available forage in natural grasslands. During the rainy season, forage production is abundant but of lower quality compared to the dry season (Salugin et al. 2019; Kust et al. 2020).

Quality of forage

The quality of forage in the grazing fields in East Luwu District is shown in Table 3. The quality of forage in pastures decreases due to the intensive use of continuous grazing activities. The fodder is consumed immediately without delay, so that the feeding pressure on the grass and legumes is strong. Legumes have strong roots and are not resistant to being trampled by animals (Pierre et al. 2021).

The NDF and ADF content are important components in livestock feed which are often used as feed test standards for fiber analysis. NDF content indicates the sum of cell wall components of hemicellulose, while ADF content represents cellulose and lignin. NDF is used to predict potential intake, and ADF is used to calculate digestibility (Eisenhauer and Türke 2018). The lower the NDF and ADF fraction values, the more digestible the feed. The lower NDF is due to the increase in lignin content, and the decrease in hemicellulose content. Hemicellulose and cellulose are cell wall components that can be digested by microbes. The high lignin makes it impossible to break down hemicellulose and cellulose. In this study, the grass contained NDF 45.26%, ADF 43.70% and dry matter 22.18 % which are in the normal range. The range of NDF and ADF in the grass varies according the grazing time where in the first stage of cutting NDF 60-65% and ADF 36-44%, after cutting NDF > 65% and the ADF > 45%.

Carrying capacity

Carrying capacity is a measure of pasture productivity that support particular units of livestock. The carrying capacity of grazing field in East Luwu is presented in Table 4.

Table 2. Average production of fresh matter and dry matter of forage in grazing fields in East Luwu District, South Sulawesi, Indonesia

Vegetation type	Fresh matter production (tons/hectare)	Dry matter production (tons/hectare)
Grass	30.15	7.53
Legumes	12.10	3.03
Total	42.25	10.56

Table 3. Average quality of forage based on Proximate and Van Soest analyses in East Luwu District, South Sulawesi, Indonesia

Vegetation type	Nutritive value (%)						
	DM	OM	CP	C Fiber	CF	NDF	ADF
Grass	22.18	82.45	6.40	33.36	2.47	45.26	43.70
Legumes	25.55	77.32	8.32	31.17	4.50	48.46	45.30
Other plants	23.86	81.67	8.10	27.35	4.78	54.15	48.62

Table 4. Carrying capacity of grazing field in East Luwu District, South Sulawesi, Indonesia

Variable			
DM production (tons/hectare/year)	**Proper Use Factor (PUF) 70% (tons/hectare/year)**	**Carrying capacity (Animal Unit (AU)/month)**	**Carrying capacity (Animal Unit (AU)/Year)**
10.56	7.40	0.16	1.75

The average dry matter production in East Luwu District was 10.56 tons/hectare/year with a PUF of 70% was 8.40 tons/hectare/year. The carrying capacity of a pasture will decrease along with the increasing possibility of erosion, overgrazing or other factors that can inhibit the growth of forage in a pasture. For pastures with light grazing, the carrying capacity of the pasture land ranges from 25-30%, moderate grazing ranges from 40-45%, and heavy grazing ranges from 60-70%. The management of the pasture needs to consider topography, climate and soil conditions, so the measurement of the carrying capacity of the pasture uses the carrying capacity of the pasture land of 70%. The results of this study indicate that the productivity of the pasture was 0.16 AU/hectare/month or equivalent to 1.75 AU/hectare/year, which is categorized low to support the development of beef cattle. This calculation used the standard of 1 AU which is equivalent to an adult cow weighing 300 kg. It was assumed that 0.16 AU/hectare/month is equivalent to 2 calves or 1.75 AU/hectare/year is equivalent to 1 adult bull and 2 calves aged 1 year.

The quality of forage was determined by the composition of forage in the pasture. The quality of forage can change in composition due to the influence of climate, soil conditions, and grazing intensity by livestock. Specific efforts to improve the quality of pasture include allowing pastures to be rested from grazing to give legumes the opportunity to grow better, increasing the abundance and types of legumes in pastures, and regulating the time and number of livestock individuals grazed in pastures (Utamy et al. 2018; Sollenberger et al. 2019). Legumes introduced to pastures in Malili Sub-district, East Luwu District should be shrubs or trees. This type of plant is resistant to livestock trampling and most importantly has deep roots. The introduction of legumes to pastures will increase the sustainability of pasture-based livestock production because it can increase forage production and is able to improve soil quality, especially in fertilizing the soil through biological nitrogen fixation mechanisms. The most important thing for livestock farmers is to increase the nutritional value of forage to increase the efficiency of converting forage into animal protein, which leads to increased livestock farmers' welfare (Syamsu et al. 2019). Other strategy is to build a green fodder garden, for example by cultivating *Pennisetum purpureum* grass with a planting distance of 100×60 cm at an area of one hectare.

In conclusion, the pasture in East Luwu consisted of 30% grass, 15% legumes and 55% weeds based on Dry Weight Rank. The pasture vegetation was composed by 21 species of grass, 7 species of legumes and 21 of weeds with three dominant grass species were *Cynodon dactylon* (5.12%), *Epidendrum culculatum* (3.59%) and *Mecardonia procumbens* (3.44%). The carrying capacity of the pasture was 0.16 AU/hectare/month or equivalent to 1.75 AU/hectare/year. The results of this study indicate that the productivity of the existing pasture is still relatively low and special efforts are needed to improve its quality. To increase in beef cattle production and efforts to achieve the beef self-sufficiency program, it is necessary to improve the management of cattle maintenance at the farmer level appropriately.

ACKNOWLEDGEMENTS

This research was funded by The Center for Higher Education Funding and Asessment (PPAPT) through the Indonesia Endowment Fund (LPDP) with the Indonesian Educational Scholarship (BPI) No. 202101122658. Thank you to the Rector of Universitas Hasanuddin, South Sulawesi, Indonesia, for giving researchers the opportunity to continue their studies at Universitas Hasanuddin. We also sincerely thank the East Luwu District Government, South Sulawesi, for facilitating the research process and providing the necessary resources. Their collective support has successfully completed this research and its subsequent publication.

REFERENCES

Association of Officiating Analytical Chemists (AOAC). 2005. Official Method of Analysis. 18th Edition, Association of Officiating Analytical Chemists, Washington DC, Method 935.14 and 992.24.

Bamutaze Y, Kyamanywa S, Singh BR, Nabanoga G, Lal R. 2019. Agriculture and Ecosystem Resilience in Sub Saharan Africa: Livelihood Pathways Under Changing Climate. Springer Nature, Switzerland. DOI: 10.1007/978-3-030-12974-3.

Bey A, Díaz AS, Maniatis D, Marchi G, Mollicone D, Ricci S, Bastin J, Moore R, Federici S, Rezende M, Patriarca C, Turia R, Gamoga G, Abe H, Kaidong E, Miceli G. 2016. Collect earth: Land use and land cover assessment through augmented visual interpretation. Remote Sens 8 (10): 807. DOI: 10.3390/rs8100807.

Eisenhauer N, Türke M. 2018. From climate chambers to biodiversity chambers. Front Ecol Environ 16: 136-137. DOI: 10.1002/fee.1784.

Franca A, Caredda S, Sanna F, Fava F, Seddaiu G. 2016. Early plant community dynamics following overseeding for the rehabilitation of a Mediterranean silvopastoral system. Grassl Sci 62 (2): 81-91. DOI: 10.1111/grs.12114.

Gang C, Zhou W, Chen Y, Wang Z, Sun Z, Li J, Qi J, Odeh I. 2014. Quantitative assessment of the contributions of climate change and human activities on global grassland degradation. Environ Earth Sci 72 (11): 4273-4282. DOI 10.1007/s12665-014-3322-6.

Ibrahim KH, Usaman LA. 2021. Management practices of pasture, range and grazing reserves for livestock production in the tropics: A review. Am J Entomol 5 (2): 18. DOI: 10.11648/j.aje.20210502.11.

Kaiser M. 2024. Pasture management for improved livestock productivity. J Fish Livest Prod 12 (6): 545. DOI: 10.4172/2332-2608.1000545.

Khaerani PI, Musa Y, Utamy RF, Ishii Y. 2024. Botanical composition and yields of forages in natural pastures using principal component.

analysis and cluster dendrogram in South Sulawesi, Indonesia. Online J Biol Sci 24 (4): 613-623. DOI: 10.3844/ojbsci.2024.613.623.

Kust GS, Andreeva OV, Lobkovskiy VA. 2020. Land degradation neutrality: The modern approach to research on arid regions at the national level. Arid Ecosyst 10 (2): 87-92. DOI: 10.1134/S2079096120020092.

Mykhalkiv L, Kots S, Obeziuk I. 2023. Influence of salinity on legume plants and their use for restoration of soil fertility. Biol Stud 17 (3): 211-224. DOI: 10.30970/sbi.1703.733.

Pierre JF, Latournerie-moreno L, Jacobsen KL, Laboski CAM, Salazar-barrientos LDL. 2021. Farmer perceptions of adopting novel legumes in traditional maize-based farming systems in the Yucatan Peninsula. Sustainability 13 (20): 11503. DOI: 10.3390/su132011503.

Pirnajmedin F, Majidi MM, Jaškūnė K. 2024. Adaptive strategies to drought stress in grasses of the Poaceae family under climate change: Physiological, genetic and molecular perspectives: A review. Plant Physiol Biochem 213: 108814. DOI: 10.1016/j.plaphy.2024.108814.

Rinduwati, Hasan S, Jasmal A Syamsu DU. 2016. Carrying capacity and botanical diversity of pastoral range in Gowa Regency. Intl J Sci Basic Appl Res 29 (3): 105-111.

Rusdy M, Baba S, Garantjan S, Syarif I. 2019. Effects of supplementation with *Gliricidia sepium* leaves on performance of Bali cattle fed elephant grass. Livest Res Rural Dev 31 (6): 1-7.

Rusdy M. 2020. Silvopastoral system using *Leucaena leucocephala* for sustainable animal production in the tropics. Livest Res Rural Dev 32 (4): 57-63.

Salugin AN, Vlasenko MV, Kulik AK, Pleskachev YN. 2019. Modeling of ecosystem dynamics: Nonlinearity and synergetics. IOP Conf Ser Earth Environ Sci 341 (1): 012003. DOI: 10.1088/1755-1315/341/1/012003.

Salugin AN, Vlasenko MV. 2022. Mathematical models of the dynamic stability of arid pasture ecosystems in the South of Russia. Agronomy 12 (6): 1448. DOI: 10.3390/agronomy12061448.

Schuppli CA, von Keyserlingk MAG, Weary DM. 2014. Access to pasture for dairy cows: Responses from an online engagement. J Anim Sci 92 (11): 5185-5192 DOI: 10.2527/jas2014-7725.

Sema, Nurjaya N, Nurcaya N. 2021. Produksi hijauan, komposisi botani dan kapasitas tampung di Padang Penggembalaan Alam pada Musim Hujan. Jurnal Ilmu Industri Peternakan 7 (2): 124. DOI: 10.24252/jiip.v7i2.25071. [Indonesian]

Sema, Nurjaya, Syahrullah, Septiani T, Rinduwati, Hasan S, You A, Be M, In I. 2023. Botanical composition and forage production in the dry season in natural pasture. AIP Conf Proc 2628: 110001. DOI: 10.1063/5.0143992.

Sollenberger LE, Kohmann MM, Dubeux JCB, Silveira ML. 2019. Grassland management affects delivery of regulating and supporting ecosystem services. Crop Sci 59 (2): 441-459 DOI: 10.2135/cropsci2018.09.0594.

Syamsu JA, Yusuf M, Zulkharnaim. 2019. Sustainability status of pasture for cattle development area in Pinrang District, South Sulawesi. IOP Conf Ser: Earth Environ Sci 247 (1): 012058 DOI: 10.1088/1755-1315/247/1/012058.

Utamy RF, Ishii Y, Idota S, Khairani L. 2018. Effect of repeated application of manure on herbage yield, quality and wintering ability during cropping of dwarf napiergrass with Italian ryegrass in hilly Southern Kyushu, Japan. Agronomy 8 (3): 30. DOI: 10.3390/agronomy8030030.

Vlasenko MV, Rybashlykova LP, Turko SY. 2022. Restoration of degraded lands in the arid zone of the European part of Russia by the method of phytomelioration. Agriculture 12 (3): 1-23. DOI: 10.3390/agriculture12030437.

Vlasenko MV, Shagaipov MM. 2021. Elimination of the consequences of pasture digression in the desert-steppe zone with the help of phytomelioration. IOP Conf Ser Earth Environ Sci 867 (1): 012081. DOI: 10.1088/1755-1315/867/1/012081.

Watuwaya BK, Syamsu JA, Budiman, Useng D. 2021. The DWR approach review: Measuring the botanical composition of native grassland in East Sumba Regency, East Nusa Tenggara Province. IOP Conf Ser Earth Environ Sci 788 (1): 012174. DOI: 10.1088/1755-1315/788/1/012174.

Watuwaya BK, Syamsu JA, Budiman, Useng D. 2022. Forage productivity in native grasslands of Haharu Sub-district, East Sumba District, Indonesia. Biodiversitas 23 (3): 1361-1367. DOI: 10.13057/biodiv/d230321.

Wróbel B, Zielewicz W, Staniak M. 2023. Challenges of pasture feeding systems: Opportunities and constraints. Agriculture 13 (5): 1-31. DOI: 10.3390/agriculture13050974.