EFFECT OF MANAGEMENT PRACTICES AND HARVESTING STAGE ON BOTANICAL COMPOSITION, BIOMASS YIELD, AND NUTRITIONAL VALUE OF NATURAL PASTURE UNDER TRADITIONAL LIVESTOCK PRODUCTION SYSTEM IN THE CENTRAL HIGHLANDS OF ETHIOPIA†

[EFECTO DE LAS PRÁCTICAS DE MANEJO Y ETAPA DE COSECHA SOBRE LA COMPOSICIÓN BOTÁNICA, RENDIMIENTO DE BIOMASA Y VALOR NUTRICIONAL DE LOS PASTOS NATURALES BAJO EL SISTEMA DE PRODUCCIÓN GANADERA TRADICIONAL EN LAS TIERRAS ALTAS CENTRALES DE ETIOPÍA]

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SUMMARY

Background: Natural pasture is an essential source of livestock feed worldwide, particularly in Ethiopia. Though pastureland coverage and management practices are changing over time, studies are limited in addressing the status under the dynamics of smallholder management conditions. **Objective:** To evaluate natural pasture botanical composition, biomass yield, and nutritional value under different management and stages of harvesting in the central highlands of Ethiopia. **Methodology:** The pasture was harvested at three stages (pre-flowering, mid-flowering, and after full flowering) under different management (extensive, semi-intensive where urea was used as a fertilizer, and seasonal grazing). Quadrats of 0.25 m^2 were used for herbaceous species identification, biomass yield estimation and nutritive value analysis. Chemical composition of the samples were analyzed using Near-Infrared Reflectance Spectroscopy. **Results:** Thirty-one herbaceous species were identified (38.71% grasses, 19.35% legumes, 9.67% sedges, and 32.26% forbs), which belong to 11 families. The total biomass yield under semi-intensive management practice at full maturity stage was greater than seasonally grazed and extensively managed pasture. The species richness, species evenness Shannon-Wiener diversity (H' max) and maximum possible diversity (H'max) were similar (P>0.05) under all management practices. Natural pasture condition score was fair under seasonal grazing, while the score was excellent under extensive and semi-intensive management. Metabolizable energy (ME), and *in vitro* organic matter digestibility (IVOMD) were higher (P<0.5) under extensive management compared to the semi-intensive management. The pasture harvested at the pre-flowering stage had higher (P<0.05) CP content, IVOMD, and ME, but low neutral detergent fiber, acid detergent fiber and acid detergent lignin values. **Implications:** The findings provide new insights into improving the biomass yield and quality of the pasture in semi-intensive pastureland management, and harvesting after the full flowering stage. **Conclusion:** This study recommended semi-intensive management and harvesting after the full flowering stage for higher pasture biomass yield, pasture condition, and nutritional value in the highlands of Ethiopia. Further study is required to investigate the combined effects of fertilizer (organic, inorganic) application and other management on biomass yield and quality of natural pasture in similar and other areas in the highlands of Ethiopia.

Key words: Extensive; grazing; herbaceous; semi-intensive; species richness.

RESUMEN

Antecedentes: Los pastos naturales son una fuente esencial de alimento para el ganado en todo el mundo, particularmente en Etiopía. Aunque la cobertura de los pastizales y las prácticas de gestión están cambiando con el

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tiempo, los estudios son limitados a la hora de abordar su condición bajo la dinámica de gestión de los pequeños agricultores. **Objetivo:** Evaluar la composición botánica, el rendimiento de biomasa y el valor nutricional de los pastos naturales bajo diferentes manejos y etapas de cosecha en las tierras altas centrales de Etiopía. **Metodología:** El pasto se cosechó en tres etapas (prefloración, media floración y después de plena floración) bajo diferentes manejos (extensivo, semiintensivo donde se utilizó urea como fertilizante y pastoreo estacional). Se utilizaron cuadrantes de 0.25 m^2 para la identificación de especies herbáceas, estimación del rendimiento de biomasa y análisis del valor nutritivo. La composición química de las muestras se analizó mediante espectroscopía de reflectancia del infrarrojo cercano. **Resultados:** Se identificaron 31 especies herbáceas (38.71% gramíneas, 19.35% leguminosas, 9.67% juncos y 32.26% herbáceas), las cuales pertenecen a 11 familias. El rendimiento total de biomasa bajo la práctica de manejo semi-intensivo en la etapa de plena madurez fue mayor que el pastoreo estacional y el pastoreo extensivo. La riqueza de especies, la uniformidad de especies, la diversidad de Shannon-Wiener (H'max) y la diversidad máxima posible (H'max) fueron similares (P>0.05) bajo todas las prácticas de manejo. El puntaje de la condición del pasto natural fue regular bajo pastoreo estacional, mientras que el puntaje fue excelente bajo manejo extensivo y semi-intensivo. La energía metabolizable (EM) y la digestibilidad de la materia orgánica in vitro (IVOMD) fueron mayores (P<0.5) bajo manejo extensivo en comparación con el manejo semi-intensivo. El pasto cosechado en la etapa de prefloración tuvo mayor (P<0.05) contenido de PB, IVOMD y EM, pero bajos valores de fibra detergente neutro, fibra detergente ácida y lignina detergente ácida. **Implicaciones:** Los hallazgos proporcionan nuevos conocimientos sobre cómo mejorar el rendimiento de la biomasa y la calidad de los pastizales en el manejo semiintensivo de los pastizales y la cosecha después de la etapa de plena floración. **Conclusión:** Este estudio recomendó el manejo semiintensivo y la cosecha después de la etapa de plena floración para lograr un mayor rendimiento de biomasa de los pastos, condiciones de los pastos y valor nutricional en las tierras altas de Etiopía. Se requieren más estudios para investigar los efectos combinados de la aplicación de fertilizantes (orgánicos, inorgánicos) y otros tipos de manejo sobre el rendimiento de biomasa y los pastos naturales de calidad en áreas similares y otras en las tierras altas de Etiopía.

Palabras clave: Extensivo; pasto; herbáceo; semi-intensivo; riqueza de especies.

INTRODUCTION

Grassland is part of Earth's major biomes and the home of native vegetation which covers 30 to 40 % of the globe's surface (Blair *et al.,* 2014). It has a great role in maintaining the biodiversity of numerous plants, animals and microbes (Scholtz and Twidwell, 2022). Grassland is composed of rangeland and pastureland (Allen *et al.,* 2011). Natural pastureland consists of grasses, forbs, legumes, and shrubs. Natural pastureland is an essential source of livestock feed worldwide. Pastureland is the land and the vegetation growing on it, mainly introduced or native, grown specifically for animal feed, harvested by grazing or cutting while rangeland is a vast landscape with native vegetation, primarily grasses and shrubs, supporting grazing animals and wildlife as a natural ecosystem (Allen *et al.,* 2011).

Livestock production in the central highland of Ethiopia is integrated into society's livelihood. Particularly, dairy farming is widely practiced in the current study area (Salale) and it is dependent on free grazing of natural pasture as the major feed resource. Salale area is endowed with conducive environment and vast natural pastureland, which is owned by private, communal and state. It has a great potential for livestock production particularly for milk production. Salale farmers have a long established culture of hay-making from natural pasture (Feyissa *et al.,* 2013). In addition, the hay produced in the area serves as a potential feed source for commercial livestock production system and drought emergency interventions in the lowland areas of Ethiopia.

The pastureland production potential is determined by coverage of the land, species composition, soil nutrient contents, grazing management systems and condition of the pastureland (Wegi *et al.,* 2021). Furthermore, land use change, population pressure, change in soil fertility, rainfall, climate change and overgrazing may have an impact on natural pasture species composition, productivity and biomass yield (Debeko *et al.,* 2018; Wang *et al.,* 2019). The coverage of natural pastureland is declining in the central highlands of Ethiopian due to massive expansion of cropland at the cost of pastureland (Minta *et al.,* 2018). Settlements, and climate change issues also might have contributed to the reduction in pastureland area coverage and production (Mengistu *et al.,* 2017).

Hence, assessment of pastureland is necessary for proper pastureland management intervention in time and space. Knowing the existing pastureland species composition, nutritional quality and biomass related to stages of harvesting is important in order to manage, conserve, optimize and utilize pastureland in a sustainable way (Bezabih *et al.,* 2014).

With respect to this, there are some research reports which were conducted to assess the impacts of harvesting frequency and inorganic fertilizer application on pastureland in the central highland of Ethiopia (Feyissa *et al.,* 2013; Kitabe and Tamir, 2005). Though pastureland coverage and management practices are changing through time, studies are limited in addressing the status under the dynamics of smallholder management conditions. It is hypothesized that the pastureland of the current study site (Degem area, Ethiopia) has a significant variation in biomass yield, nutritional status, and species composition due to the variation in management practice and stage of harvesting. Therefore, this study was aimed to evaluate the potential of natural pasture in terms of biomass production, botanical composition, and nutritional value under different pastureland management practices and harvesting stages.

MATERIALS AND METHODS

Description of the study area

The study was conducted in Degem district of North Shoa Zone in the Oromia Regional State, Ethiopia. It is located at 125 km northwest of Addis Ababa, positioned at 9°34’ N and 38°39’ E (Figure 1). The district has an elevation ranging from 1500-3541 meters above sea level. Agro-ecologically, the district has three climatic zones: highland (30%), midland (32%), and lowland (38%). The district receives 900-1400 mm rainfall annually with a bimodal rainfall pattern. The main rainy season is from June to September, and the short rainy season is from March to April. Its temperature range from 15 to 22 ºC. The district has a total area of 64,919 hectares of which 65.8%, 18.2%, 14%, 2% and 6.9% was used as cropland, pastureland, swampy area, forest, and for settlement purposes, respectively (NSDAD, 2019). Furthermore, the district is characterized by a crop-livestock mixed farming system, and cattle and sheep are the dominant livestock species in the district. Normally farmers allow these livestock to graze together in such type of system. The soil type of the district is classified as loam, clay, black and red soil (NSDAD, 2019).

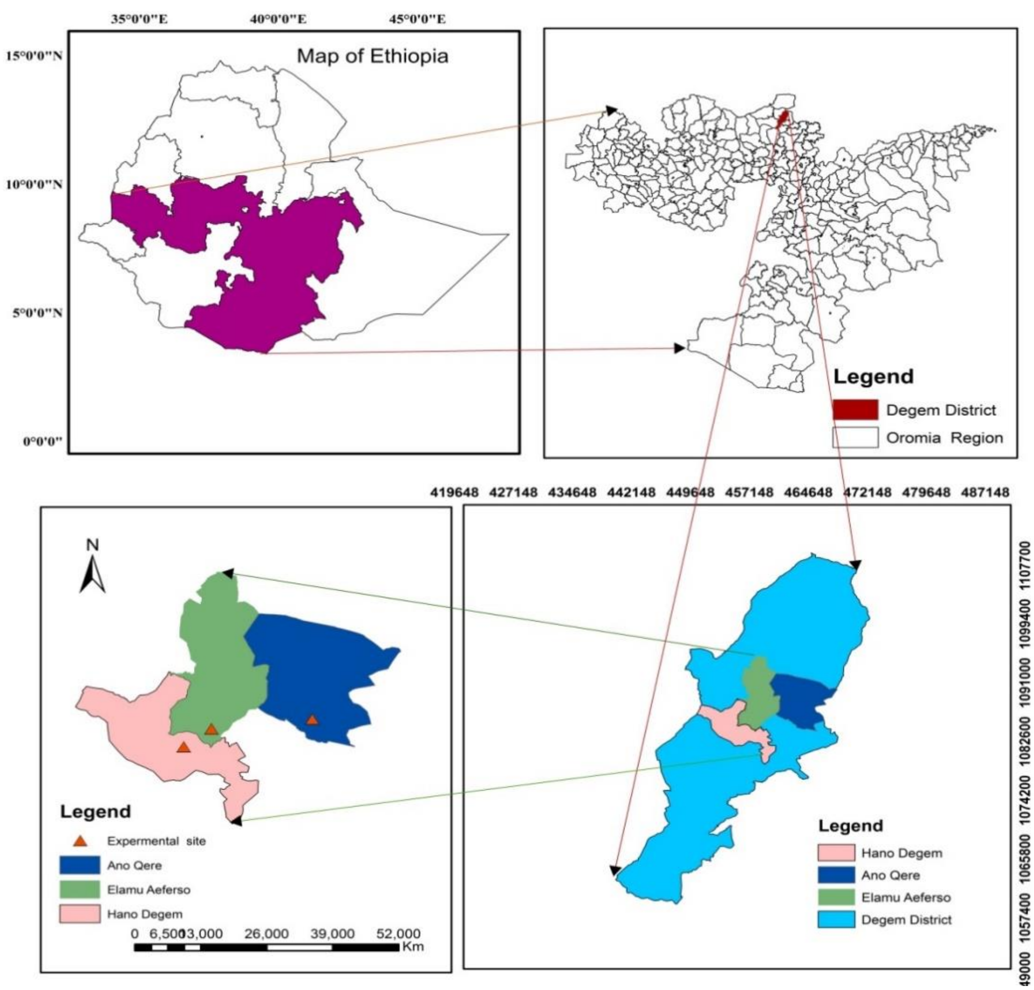

Figure 1. Map of the study area (Source: Developed from Ethio-GIS).

Experimental site selection

The district was selected based on the potential of pastureland, livestock production potential, and pasture management experiences of the smallholder farmers. The smallholder farmers in the study area are using the natural pastureland for livestock grazing and natural pasture hay production. Farmers have used different natural pastureland management practices which depend on their pastureland size and knowledge. Hence, three natural pastureland sites: seasonal grazing pastureland, extensively managed pastureland for hay production, and semi-intensively managed pastureland for hay production were purposefully selected for the study, representing different pastureland management practices. The seasonal grazing land was protected for livestock grazing in the rainy season without the application of any kind of fertilizer, and it was used for the last 30 years during dry season free livestock grazing (standing hay), locally called “Kallo”. The extensive pastureland was protected from animal grazing until it was harvested for haymaking. The farmers managed the natural pastureland without the application of any organic and inorganic fertilizer for the last 30 years. The semi-intensive pastureland management system was protected from animal grazing until it reached harvesting for hay production. In the semi-intensive management system the farmers applied 50 kg urea per hectare over sown at the beginning of the rainy season. The three management system is what is normally practiced in the study district and urea application was the recent phenomenon used by some farmers.

All three pasturelands sites were within the highland altitude gradients ranging from 2500 to 3100 meters above sea level. The selected pastureland sites were protected from animals during the long rainy season from mid-June to mid-October 2020 to get better biomass (Feyissa *et al.*, 2013). These months are the time during which grass grows best since it is rainfed. After this time it has to but cut for hay production or grazed by livestock. Twelve plots were selected and enclosed with the size of 10 × 10 m^2 (four plots per each pastureland management) and border edge effects were considered during plot establishment (Mueller-dombois, 1974). The plots were established at the selected site with a 20 m distance between plots.

Herbaceous compositions evaluation and biomass estimation

The protected pastureland under seasonal grazing, extensive and semi-intensive management were sampled for herbaceous composition and biomass evaluation. Sampling was made using 0.5 m × 0.5 m metal quadrats (Figure 2) for the identification of the pasture species composition. The quadrat was thrown randomly at five locations inside the established plots under each management practice making 20 quadrats and a total of 60 quadrats (3 managements × 4 replication plots × 5 quadrats per plots) for the determination of botanical composition. The species identification was carried out in mid-September 2020 with the help of experienced technical experts from Holetta Agricultural Research Center. The identification of herbaceous species was carried out with the aid of Edwards *et al.* (1995) guideline. Forages inside the quadrat were harvested at 5 cm above ground using a sickle and sorted into grass, legumes, sedges, and forbs. Then, fresh weight was taken with sensitive balance (Nimbus NBL 2602e, from Adam equipment with a capacity 2600 g and readability of 0.01 g) and recorded.

The biomass and nutritive value of grasses were assessed at different stages of harvesting and management practices. Four plots were established from selected sites for each management practice. The size of each plot was 10 m × 10 m (Mueller-dombois, 1974). Then 0.5 m × 0.5 m quadrat was thrown in four random locations in the plot for the three harvesting stages (early maturity stage, mid-maturity stage, and full maturity stage). The early stage of maturity means plant species at a vegetative state or before starting flowering; mid-maturity stage refers to the flowering state, and full maturity refers to the stage when farmers harvest for conservation as hay. The forage inside the quadrats was cut at 5 cm above the ground using sickle to estimate biomass yield. The samples were weighed using a sensitive balance (Nimbus NBL 2602e, from Adam equipment with a capacity 2600 g and readability of 0.01 g), simultaneously sorted into the herbaceous components and the average weight was taken; and air-dried under shed.The samples were then oven dried at 105 °C for overnight for biomass yield estimation.

Pastureland condition assessment

The pastureland condition assessment was conducted during the long rainy season (June to September, 2020) in the study area. Twenty quadrates were used per pasture management practice. A quadrat size of (0.5 m × 0.5 m) was thrown randomly in the experimental plots (Mueller-dombois, 1974). During the assessment of the pasture condition, a guide to pasture condition scoring approach was used (Cosgrove *et al.*, 2001). Ten pastureland condition indicators and their score rates were used during visual assessment (Table 1). However, to assess livestock grazing, concentration, and soil parameters outlined in a guideline for pasture conditions assessment, the guideline setup is for active grazing land instead of protected pastureland for this parameter. As a result, the designated experimental area remained protected from animals. Open grazing land next to the seasonal grazing land was used to assess those parameters.

In the condition score sheet, each parameter had five designated scores, from the lowest (1) to the maximum (5). The percentage of desirable plants was visualized by dry weight estimation from the total biomass. A designation of desirable, intermediate, and undesirable species was taken based on previously published articles that contained Ethiopian rangeland and pastureland studies (Abate *et al.*. 2009; Nemera *et al.*, 2017). The presence of legumes was assessed in a quadrat as a proportion to the total dry weight of herbage yield. The percentage of the soil surface covered by live plants was observed, and a score of 1 was provided for less than 40% coverage and a score of 5 for above 95% coverage (Cosgrove *et al.*, 2001). The plant diversity score described the number of well-represented different herbaceous species (grass, legume, and forbs) and the presence of multiple desirable forage species, each of which had a dominance level exceeding 15%, was assigned a score ranging from 2 to 5 points. Plant residue on soil cover proportion of less than 20% was scored the lowest 1-point and 80% and above was scored 5 points. Grazing utilization and severity were observed in relation to the degree of grazing by livestock. The one highly overgrazed was scored 1 point and the ungrazed one was scored 5 points.

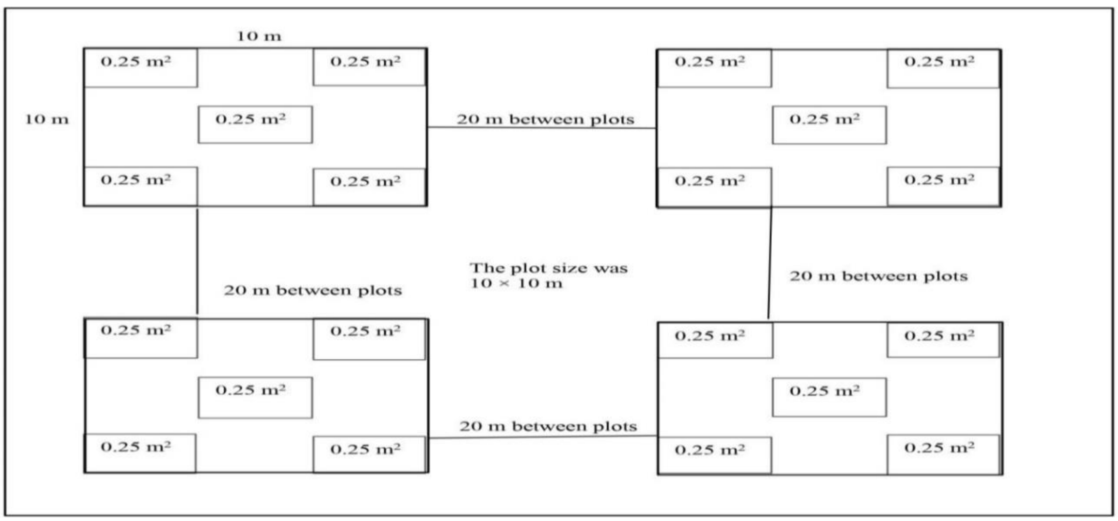

Figure 2. Layout of the experimental plot.

Table 1. Pastureland condition assessment guide.

Indicator	1 point	2 points	3 points	4 points	5 points
Percent of desirable plants	<20%	20-40%	41-60%	61-80%	>80%
Percent of legumes	<5%	5-10%	11-20%	21-30%	31-40%
Live plant cover	<40%	40-65%	66-80%	81-95%	>95%
Plant diversity (dominance of desirable species & different herbaceous species)	1.1	2.1	3.1	4.2	4.3
Plant residues & litter as soil cover	<20%	21-40%	41-60%	61-80%	>80%
Grazing utilization & severity	Overgrazed	Overgrazing & poor species	Uneven grazing	Minimal overgrazing	No overgrazing
Livestock concentration areas	Very high	High	Medium	Low	None
Soil compaction & regenerative capacity	Compaction densely	Compaction Moderate	Compaction Thin	Compaction	Compaction no
Plant Vigor	No plant recover	Some recovery	Adequate recovery	Good recovery	Rapid recovery
Erosion	Very high	High	Medium	Low	None

Source: Cosgrove *et al.* (2001).

A different technique was employed to evaluate the concentration of livestock in this experimental condition, which was accurate in the active grazing land. According to Gebrehiwot and Tadesse (1985), natural pastureland in the central highlands of Ethiopia can accommodate 2 to 3 livestock units (LSU) per hectare from July to December or 10 to 15 sheep per hectare per year. However, the communal grazing areas adjacent to the well-managed land support fewer animals than stated before. This report was used as a reference to determine higher or lower livestock concentration parameter during pasture condition assessment. A higher concentration of animals in the study plot was scored one, and the free plot from animals were scored 5 points, a detailed description are in Table 1. Soil compaction was also assessed by looking at the existence of animal hoof print and the degree of soil compaction; non-compacted was scored 5 points and highly compacted pastureland was scored one. Plant vigor was assessed based on recovery time and healthiness of the pastureland herbaceous species after being harvested or grazed. Five point score was given for rapid regrowth, and the lowest score (1) was given for longer recovery. Soil erosion in the pastureland was investigated and a score of one was provided for highly affected land and a score of five for no visible erosion. Based on these parameters, the pastureland condition scores were determined. The maximum possible score was 50 points. Pasture condition score was interpreted as excellent (41-50), good (31-40), fair (21-30), poor (11-20), and very poor (3-10) (Cosgrove *et al.*, 2001).

Chemical analyses and in vitro dry matter digestibility

Representative forage samples were taken from each plot and pooled together. Then subsamples were taken from each pastureland management practice at each harvesting stage. The fresh weight of harvested sample was taken and air-dried under shade. The air-dried subsampled forages were transported into the laboratory and were dried in an oven for 48 h at 65°C. The dried sample was ground to pass through a 1-mm sieve size using a Wiley laboratory mill. The dry matter, ash, crude protein, neutral detergent fiber, acid detergent fiber, acid detergent lignin, and in vitro organic matter digestibility were analyzed using Near-Infrared Reflectance Spectroscopy (NIRS) at International Livestock Research Institute (ILRI), Ethiopia. The metabolizable energy content was estimated from the value of in vitro organic matter digestibility using eqution: ME (MJ/kg DM) = 0.015*IVOMD (g/kg DM) (MAFF, 1984). The ground samples were put in an oven overnight at 65°C, then packed into NIRS cups and scanned using a NIR spectrometer (FOSS NIRS, model 5000). The NIRS scanning wavelength range was between 1100 nm and 2500 nm.

Data analysis

Analysis of variance (ANOVA) was carried out using SAS version 9 (SAS, 2002) with generalized linear model procedures. One way ANOVA was used for single factors and factorial ANOVA was used for interaction effects. Significant level was declared at P>0.05. Mean separation was done using Duncan's Multiple Range Test.

The model used for biomass estimations and chemical composition was:

$$Y_{ijk} = \mu + M_i + H_j + M{*}H_k + e_{ijkl}$$

Whereas: μ = overall mean,
M_i = Management practices (extensive, semi-intensive and seasonal grazing)
H_j =Harvesting stage (j= pre, mid and after full flowering)
$M{*}H_k$ =Interaction effect of management and harvesting stage
e_{ijkl} = random error

The following model was used for pasture condition assessment:

$$Y_{ij} = \mu + M_i + eij$$

Whereas: μ = overall mean;
M_i = Management practice (extensive, semi–intensive and seasonal grazing)
e_{ij}= random error

Diversity (H‘) and Evenness (J) of the plots for grasses, legume and forbs compositions were determined following Shannon and Wiener (1949) diversity indices procedures.

$$H' = -\sum_{i=1}^{s} (\text{pi} * \ln\text{pi}) \text{ and,}$$

$$J = H'/H'\max = \frac{-\sum_{i=1}^{s} \text{pi}*\ln\text{pi}}{\ln s}$$

Where: H‘ = Shannon‘s diversity index,
Pi = the proportion of individuals of the i^{th} species,
S = total number of species in the quadrate,
J = Species evenness
ln = log base 10

RESULTS

Herbaceous species compositions

Thirty-one herbaceous species were identified (38.71% grasses, 19.35% legumes, 9.67% sedges, and 32.26% forbs), which belong to 11 families (Table 2). The grass and sedge species were perennials and annuals. Legume and forb species were annuals in their life cycle except *Erucastrum arabicum* which is a perennial forb. *Andropogon abysinicus* and *Pennisetum glabrum* from the grass species showed high dominancy under semi-intensive management condition. *Trifolium tembense* and *Trifolium decorum* were dominant in extensive and seasonal grazing land, respectively.

Table 2. Forage species and species compositions under different pastureland management conditions.

Scientific name	Local name	Family name	Lifespan	Desirability	Species occurrence & dominance		
					EM	SG	SM
Grasses							
Andropogon abyssinicus	Baallamii	Poaceae	A	HD	C	C	D
Cynodon dactylon	Saardoo	Poaceae	P	HD	-	P	-
Digitaria abyssinica	Waratii	Poaceae	A	ID	-	P	-
Eragrostis tenuifolia	Marga xaafii	Poaceae	A	HD	P	P	P
Euleusine spp	Coqorsa	Poaceae	P	LD	-	P	-
Hyparrhenia rufa	Gonfaa	Poaceae	P	LD	-	C	P
Lolium spp	NI	Poaceae	A	HD	P	P	P
Pennisetum clandistinum	NI	Poaceae	P	LD	C	P	C
Pennisetum salifix	Qamuxxee	Poaceae	P	LD	-	-	P
Pennisetum glabrum	Migira saree	Poaceae	P	LD	P	P	D
Snowdenia polystachya	Muujjaa	Poaceae	A	HD	-	P	P
Sporobolus spp	Murunyii	Poaceae	P	LD	P	P	P
Legumes							
Trifolium decorum	Amaagixoo	Fabaceae	A	HD	C	D	P
Trifolium multinerves	Amaagixoo	Fabaceae	A	HD	P	P	P
Trifoium pretense	Amaagixoo	Fabaceae	A	HD	-	P	P
Trifolium quartinianum	Siddisa	Fabaceae	A	HD	P	-	-
Trifolium rueppellianum	Amaagixoo	Fabaceae	A	HD	P	-	-
Trifolium tembense	Amaagixoo	Fabaceae	A	HD	D	P	C
Sedges							
Cyperus rigidifolius	Qunnii	Cyperaceae	P	LD	P	P	P
Cyprus rotundus	Qunnii	Cyperaceae	P	LD	P	C	P
Cypurs spp	Qunnii	Cyperaceae	P	LD	P	-	P
Forbs							
Amaranthus sp.	Raafuu	Amaranthaceae	A	LD	P	-	-
Bidens pachyloma	Abaabichoo	Asteraceae	A	LD	P	P	-
Commelina Africana	Gura fardaa	Commelinaceae	A	LD	P	-	-
Commolina banghalensis	Gura fardaa	Commelinaceae	A	LD	-	C	P
Erucastrum arabicum	NI	Brassicaceae	P	LD	-	P	-
Foeninculum vulgare	NI	Apiaceae	A	LD	-	P	-
Galium spurium	Kuffee	Rubiaceae	A	LD	P	-	P
Occimum spp.	NI	Lamiaceae	A	LD	-	-	P
Rumex abyssinicus	NI	Polygonaceae	A	LD	P	P	-
Rumex bequaertii	Shultii	Polygonaceae	A	LD	P	P	-

EM, Extensive management; SG, Seasonal grazing land; SM, Semi intensive management;A, Annual; P, Perennial; HD, Highly desirable; LD, Less desirable; ID, Intermediate desirable; NI, No information; D, Dominant (> 20%); C, Common (5-20%); P, Present (< 5%); -,Not present.

The effects of pastureland management and harvesting stage on pasture biomass yield

Figure 3 shows the biomass yield of herbaceous species as affected by pastureland management and harvesting stages.The herbaceous proportional biomass yield in the semi-intensive management was larger than seasonally grazed pasture. The grass yield was higher among herbaceous components under all management practices and harvesting stages. Legume yield under seasonal grazing and semi-intensively managed pasture were lower than 1 t/ha. Sedge yield from seasonal grazing and extensive management higher than semi-intensive management practices. The yield of forbs was < 1 t/ha under all management practices and stages of harvesting. The total biomass yield under semi-intensive management practice was higher than seasonally grazed pasture. Also, the gross biomass yield at full maturity stage of harvesting was higher than pre-flowering and mid-flowering stage of harvesting.

The effects of pastureland management on species richness, evenness and diversity

The effect of pastureland management on species richness, evenness, and diversity is presented in Table 3. The species richness, species evenness Shannon-Wiener diversity (H' max) and maximum possible diversity (H'max) were similar (P>0.05) under all management practices. However, all parameters were recorded under seasonal grazing management show better numbers.

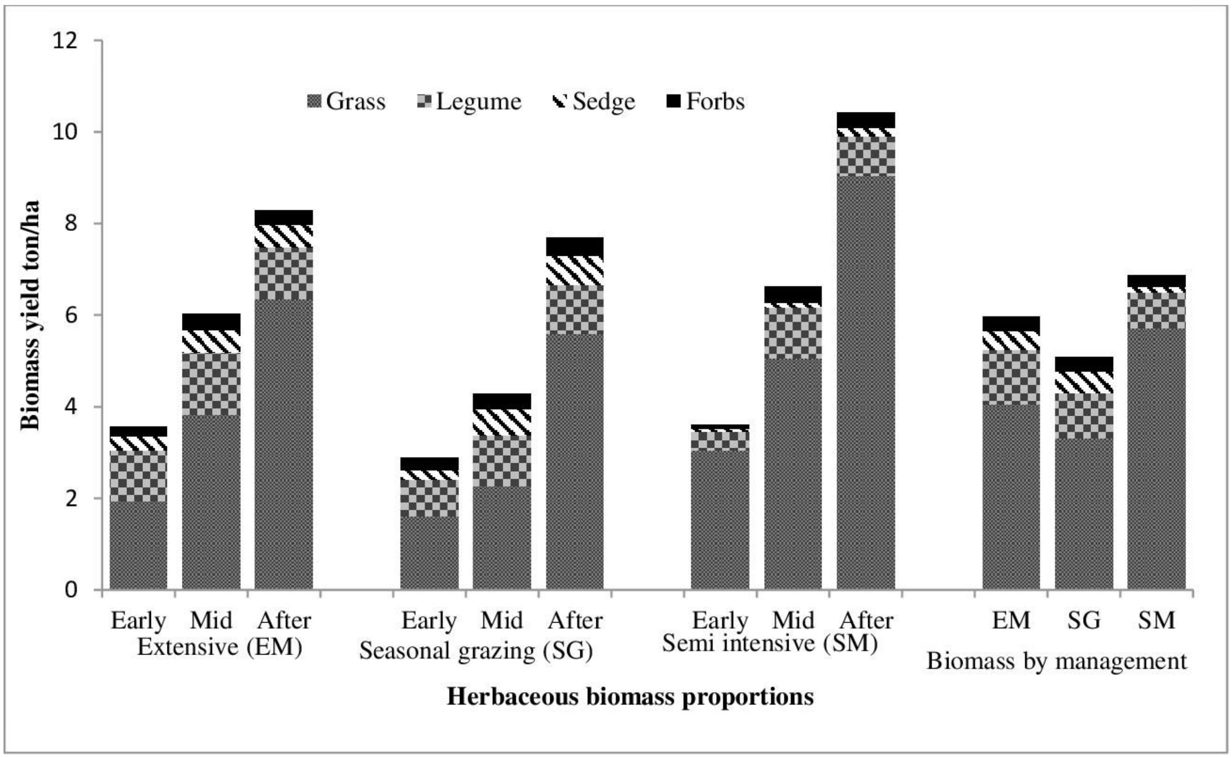

Figure 3. The effect of management practices and harvesting stages on biomass.

Table 3. The effect of pastureland management on species richness, evenness, and diversity.

Parameters	EM	SG	SM	SEM	*P-value*
Species richness (Total)	10.60	14.60	12.60	1.14	0.083
Species evenness	0.95	0.96	0.94	0.004	0.098
Shannon-Wiener diversity index (H')	2.23	2.58	2.39	0.09	0.061
Maximum possible diversity (H'max)	2.34	2.67	2.52	0.09	0.090

EM, Extensive management; SG, Seasonal grazing land; SM, Semi intensive management; SEM, Standard error of mean.

Pastureland condition

The pastureland condition assessment score is summarized in Table 4. The grazing severity, livestock concentration, soil compaction and soil erosion under seasonal grazing was greater (P<0.05) than the pasture under extensive and semi-intensive management. The highest (P<0.05) desirable plant species, plant cover, plant residues cover and plant vigor were recorded under semi-intensive pasture management. The overall pastureland condition assessment score was fair under seasonal grazing management, while the score was excellent under extensive and semi-intensive pastureland management.

Effects of management practice and harvesting stage on pasture nutritional value

The result on chemical composition and IVOMD of natural pasture under different management practices and harvesting stages is presented in Table 5. The ME contents, and IVOMD were higher (P<0.5) in the extensive management compared with semi-intensive management, while seasonally grazed pasture had an intermediate value. Lower (P<0.05) ADL value was recorded under extensive and semi-intensive pasture management. The pre-flowering stage of harvesting resulted in the highest (P<0.05) CP content, IVOMD, and ME, while ADF values were the lowest as compared to the pasture at the mid flowering and full maturity stages. The NDF content was lower (P<0.05) in the pre-flowering stage than mid flowering and full maturity stages.

At the pre-flowering stage, the ash, and IVOMD were higher (P<0.5) under extensive management compared with the semi-intensive management. Nevertheless, the NDF was lower in extensive than semi-intensive pasture management. However, no difference (P>0.05) was observed in pasture quality under the different management practices at the mid-flowering stage.

At the full maturity stage, the CP content was higher under extensive management than under the semi-intensive management. At the full maturity stage, the NDF content was higher (P<0.05) in semi-intensive than extensive management and seasonal grazing land management. But, the ADF content was higher (P<0.05) in seasonal grazing land management compared with the extensive management.

DISCUSSION

Herbaceous species composition

The herbaceous species identified in this study are similar to those previously reported in the central highlands of Ethiopia (Zewdu, 2005). Also our findings are consistent with Wegi *et al.* (2021), who reported 22 herbaceous species from enclosed and 27 herbaceous species from open grazing land management practices in the central highlands of Ethiopia.Moreover, Mosisa *et al.* (2021) found 20 herbaceous species under traditional grassland management in the southern Ethiopian highlands, which is consistent with the identified herbaceous species in the present study under extensive pastureland management.On the other hand, Abate *et al.* (2009) identified 48 herbaceous species in the Rayitu district of the Bale Zone, Ethiopia, under traditional grassland management. The coverage of study areas, greater time gaps, changes in land use, site-specific agro-ecological factors, grassland management

Table 4. Pasture condition scoring under different management practices.

Parameters	EM (n=20)	SG (n=20)	SM (n=20)	SEM	*P-value*
Percent of desirable plant	3[b]	2[c]	4[a]	0.24	0.001
Percent of legume	4[a]	2[c]	3[b]	0.19	0.001
Plant cover	5[a]	3[b]	5[a]	0.84	0.001
Plant diversity	5	5	5	0.00	1.000
Plant residue cover	3[b]	2[c]	4[a]	0.15	0.001
Grazing severity	5[a]	4[b]	5[a]	0.09	0.001
Livestock concentration	4[a]	2[b]	4[a]	0.17	0.001
Soil compaction	5[a]	1[b]	5[a]	0.00	0.001
Plant vigor	4[b]	2[c]	5[a]	0.11	0.001
Soil erosion	5[a]	3[b]	5[a]	0.12	0.001
Total Pasture score	43	27	44		
Pasture condition rate	Excellent	Fair	Excellent		

n = number of samples; means with different superscript in a row are significantly different (P<0.05); SEM, Standard error of mean; EM, Extensive management; SG, Seasonal grazing; SM, Semi-intensive; excellent (41–50); good (31-40); fair (21-30); poor (11-20) and very poor (3-10) >20 poor.

Table 5. Effects of pastureland management and harvesting stages on chemical composition (% DM, except DM) and in-vitro organic matter digestibility of natural pasture in the study areas.

Management & harvesting		DM %	Ash	CP	NDF	ADF	ADL	ME (MJ/kg-DM)	IVOMD (% DM)
Pasture Management	EM	93.8	10.9	12.1	61.6	41.9	6.1^{b}	7.8^{a}	55.4^{a}
	SG	93.7	9.7	10.3	64.9	44.4	6.9^{a}	7.6^{ab}	53.4^{ab}
	SM	93.7	10.0	9.0	67.8	43.9	6.2^{b}	7.4^{b}	52.0^{b}
	SEM	0.062	0.531	0.977	1.995	0.878	0.215	0.090	0.923
	P-value	0.398	0.296	0.098	0.106	0.110	0.023	0.034	0.041
Harvesting stage	Pre-flowering	93.9	11.9^{a}	13.8^{a}	59.2^{b}	40.6^{c}	6.17	7.8^{a}	56.4^{a}
	Mid flowering	93.8	10.2^{b}	9.1^{b}	66.0^{a}	45.8^{a}	6.6	7.5^{b}	52.6^{b}
	Full maturity	93.6	8.5^{c}	8.5^{b}	69.1^{a}	43.9^{b}	6.5	7.5^{b}	51.8^{b}
	SEM	0.05	0.36	0.76	1.74	0.67	0.24	0.08	0.81
	P-value	0.06	0.001	0.001	0.001	0.001	0.404	0.022	0.0007
Pre-flowering	EM	93.9	13.2^{a}	17.0	52.7^{b}	38.2	5.95	8.1	59.7^{a}
	SG	93.8	11.9^{ab}	13.6	58.0^{ab}	41.0	6.49	7.8	56.4^{ab}
	SM	93.8	10.5^{b}	10.9	67.0^{a}	42.6	6.05	7.5	53.2^{b}
	SEM	0.08	0.53	1.60	3.38	1.42	0.36	0.16	1.58
	P-value	0.577	0.020	0.066	0.042	0.146	0.561	0.084	0.051
Mid-flowering	EM	93.9	10.6	9.2	65.9	44.9	5.9	7.6	53.5
	SG	93.8	9.2	8.9	67.8	47.2	7.3	7.4	51.9
	SM	93.7	10.6	9.3	64.2	45.5	6.7	7.5	52.9
	SEM	0.11	0.64	0.93	2.60	0.97	0.38	0.11	0.92
	P-value	0.773	0.260	0.954	0.634	0.271	0.080	0.417	0.342
Full maturity	EM	93.6	8.8	10.1^{a}	66.2^{b}	42.7^{b}	6.6	7.6	53.1
	SG	93.4	8.0	8.4^{ab}	68.8^{b}	45.1^{a}	7.1	7.6	52.3
	SM	93.6	8.7	7.0^{b}	72.1^{a}	43.8^{ab}	5.8	7.2	49.8
	SEM	0.06	0.39	0.58	0.89	0.56	0.34	0.11	0.86
	P-value	0.077	0.378	0.015	0.003	0.039	0.081	0.136	0.060
Grand	Mean	93.7	10.2	10.5	64.8	43.4	6.4	7.6	53.6
Grand	SEM	0.05	0.33	0.68	1.62	0.607	0.21	0.080	0.72
Effect M *H	*P-value*	0.003	0.001	0.001	0.001	0.001	0.049	0.0034	0.0001

Means within a column a management & stage of harvesting with different letters are significantly different, $P<0.05$: SEM, Standard error of mean; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; ADL, acid detergent lignin; ME, metabolizable energy; DM, dry matter; H, Harvesting; M, Management. EM, Extensive management; SG, Seasonal grazing; SM, Semi-intensive

practices, soil type, and rainfall might account for the variation in herbaceous species composition (Qasim *et al.,* 2017). The application of inorganic fertilizer may be the reason for fewer herbaceous species in semi-intensive pastureland management which is consistent with the findings by Tessema *et al.* (2010), who observed lower herbaceous species when urea was applied on the natural pastureland.

In semi-intensive pastureland management, *Andropogon abyssinicus* was the dominant grass species followed by *Pennisetum glabrum.* In the central highlands of Ethiopia, *A. abyssinicus* grass species were reported in protected area which is similar to the current findings (Woldu,1986). *A. abyssinicus* species may have low tolerance in open grazing land due to its palatability and classification as a highly desirable grass species. In the present study, *Trifolium decorum* dominated seasonal grazing land among the legumes, which could be because of its ability to tolerate grazing, fix nitrogen, quickly reproduce, and withstand drought (Kahurananga and Asres, 1984). *T. tembense* was dominant under extensive pasture management,which might be due to its adaptability to a wide range of soil types and seasonal waterlogging (Heuzé *et al.,* 2017). The highlands of Ethiopia, which include the current study site, are home to *T. tembense* and *T. decorum. Trifolium* species are the most promising legume forages in the Ethiopian highlands, which is used for hay production in waterlogged areas because of its high yielding ability (Kahurananga and Asres, 1984).

In the current study, the life forms of grasses and sedges were perennial which could be due to their ability to tolerate grazing and grow in waterlogged areas, particularly *Cyperus spp*. Most forbs and all leguminous species were annuals, which might be related to their early reproduction nature to survive and quickly colonize the pastureland than late maturing plants. In the present study, all identified *Trifolium* species was annual life forms. Two-thirds of *Trifolium* species in Ethiopia are annuals (Akundabweni, 1984).

Effects of management and harvesting stage on pasture biomass yield and herbaceous species composition

The proportions of herbaceous components in pasturelands influence above ground biomass production, the nutritional value of hay, and the potential for grazing (Schaub *et al.*, 2020). In turn, pasture herbaceous composition is determined by the pasture management practices. Our finding shows that the proportion of grasses was highest under semi-intesive pastureland management. According to Kitabe and Tamir (2005), traditionally managed pastureland was comprised of 87.2%, 10.5%, and 4.9% grasses, legumes, and other herbages, respectively.

As suggested by Qasim *et al.* (2017) pastureland protection leads to an increase in biomass yield. Total biomass yield under extensive and semi-intensive management in the current study was higher than the value (5.40 tons/ha) reported by Isaias *et al.* (2015) from northwestern Ethiopian lowlands but comparable (6 tons/ha) to Yihalem (2004) under well-managed pasturelands in the central highlands. Our finding shows that semi-intensive management practices resulted in higher biomass yield of the grass species compared to seasonal grazing and extensive management. Urea application resulted in a large proportion of grass and legumes (Tessema *et al.*, 2010). The application of urea can increase total biomass yield, which can favor grass species over other herbaceous species due to the better response of grasses to nitrogen fertilizer (You *et al.*, 2017; Yalew *et al.*, 2020). The low biomass yield recorded under seasonal grazing management could be due to higher proportions of legume, sedge, and forb species than in semi-intensive pastureland management (Figure 3). Legume, sedge, and forb species have a lower biomass yield than grasses species (Nemera *et al.*, 2017).

In the current study, the maximum biomass yield obtained at full maturity stage under semi-intensive management is consistent with a previous study by Feyissa *et al.* (2013), who reported that biomass yield was highly affected by harvesting stage. In the current study, pastureland management and harvesting stages had a substantial effect on the biomass production of natural pasture. Our result is in line with the report by Kitaba (2007), who found that harvesting frequency and management practices change the above-ground biomass yield of natural pasture in the central highland of Ethiopia.

Our study showed that different pastureland management practices and harvesting stages promotes the growth of different herbaceous species categories. To optimize the biomass yield of natural pasture in the central highlands of Ethiopia, late harvesting, nitrogen application, and well-planned grassland management measures are encouraged.

Effect of pastureland management on species richness, evenness and diversity

The species richness and diversity of herbaceous plants in pastureland may affect the harvesting time/stage and the potential biomass of the grassland (Schaub *et al.*, 2020). Compared to protected and well-managed grassland, moderate grazing practices improve the richness of herbaceous species (Pulungan *et al.*, 2019; Wegi *et al.*, 2021). It has been shown that the presence of grazing animals can have both positive and negative effects on species richness in pasture ecosystems. A study by Milchunas and Lauenroth (1993) found that moderate grazing by herbivores can enhance plant species richness by reducing competition from dominant species and creating a more diverse plant community. However, high animal loads or overgrazing can lead to a decrease in species richness by damaging vegetation and altering habitat conditions. Adler *et al.* (2001) suggested that the impact of animal load on species richness in pastureland is dependent on factors such as grazing intensity, grazing management practices, and plant community composition. Therefore, one need to be cautious whether the difference in species richness is because of natural structure of the pastureland or animal load. Our result under the semi intensive management with use of urea in the current study in contrary with the findings by Soons *et al.* (2017), who reported that application of urea can reduce species diversity in herbaceous communities. Across grassland systems, urea application reduces the diversity of herbaceous species in a universal pattern (Humbert *et al*., 2016). The variation between the current study report might be due to the amount of urea used, methods of urea application, soil type and location. The maximum species diversity (H'max, 2.67) in ecological index observed under seasonal grazing management in the current study might be attributed to the formation of heterogeneous landscape, reduction of dominant grasses, and promotion of short-lived forbs (Gao and Carmel, 2020). The diversity of pastureland species has an advantage for resistance to stress (Sanderson *et al.*, 2007). In all, management practices under the current condition have led to maximum species evenness (0.94 to 0.96) in the current study. However, seasonal grazing management provides equal opportunities for all herbaceous species types to grow and maintain an even distribution of herbaceous species by reducing dominant grasses during grazing (Gao and Carmel, 2020). Mixture of grasses and legumes (particularly clover) in grassland is important for improving biomass yield, protein content, and also has ecological importance (Mengistu, 2002).

Effect of pastureland management on pasture condition

The pasture condition under semi-intensive and extensive pastureland management was excellent in the current study. Pastureland managed improve pastureland productivity and pasture conditions (Berauer *et al.,* 2020). The lower percentage of desirable plants, plant cover, plant vigor, and excessive soil compaction under seasonal grazing management in the present study may indicate poor management practices (Bezabih *et al.,* 2014). Managing natural pastureland can enhance soil fertility, which results in greater above-ground biomass yield, an abundance of desirable species, and improved pasture conditions (Wang *et al.*, 2019). Therefore, the semi-intensive pastureland management in the study areas may be suitable to maximize productivity of the pasture and its condition.

Effects of management practice and harvesting stage on pasture nutritional value

In the present study, lower crude protein content and digestibility were recorded when the pasture was harvested after the full-flowering stage, which is consistent with previous work by Elgersma and Søegaard (2018) who reported that late harvesting reduces the CP content of natural pasture. In this study, the mean CP content varied from 13.8 to 8.5% at the pre-flowering and after full-flowering stages. Legumes species after the full-flowering stage may disappear because of the moisture shortage, which leads to lower protein value. The CP content was higher in number in extensive management than in semi-intensive and seasonal grazing management, but it was similar statistically among the pasture management practices in the present study. Similarly, the application of urea on natural pasture in the highlands of Ethiopia did not show any significant difference in CP content compared to the control group (Tessema *et al.,* 2010). On the other hand, Berauer *et al.* (2020) observed that the intensity of grassland management and application of N fertilizer increased the CP content of forage. Therefore, the soil fertility, the rainfall amount, and the response of the land to urea and the amount used could contribute to the variation in CP contents (Sanderson, 2010). However, the CP content under all pasture management was adequate to satisfy the minimum requirement for rumen microbes (Van Soest, 1994). The CP content recorded under extensive pastureland management lies within the range of high-quality roughage (Berauer *et al.,* 2020).

In the current study, the NDF content increased from the pre-flowering to full-flowering harvesting stages, which is similar to the findings by Tessema *et al.* (2010), who reported that increment of NDF content is related to the advanced harvesting stage. The difference in the value of pasture NDF% could be attributed to the defoliation of leaves and the increment of plant cellulose component is related to maturity (Waramit *et al.,* 2011). The higher NDF value recorded in semi-intensive management might be due to the application of nitrogen fertilization on natural pastureland that encouraged early maturity (Abdi *et al.,* 2015). However, in the present study, the recorded NDF content was in the normal range, which could not limit consumption of pasture by livestock (Van Soest, 1994).

In the present study, the IVOMD of forage showed decreasing trends when the forage is harvested at advanced growth stages, which is consistent with the report by Feyissa *et al*. (2014), who stated that the higher contents of neutral detergent fiber and acid detergent fiber found in late harvesting stage. Higher fiber content leads to lower digestibility in the feed.

Pastureland management practices and harvesting stage affected metabolizable energy value in the current experiment. This report is similar to the previous study of natural pastures in the central highland of Ethiopia harvested early to after-flowering show a decreasing value of ME (Fekede *et al.,* 2014). The ADF content is directly related to the stage of harvesting. This is because some grasses have a unique cell wall structure related to maturity, changes in plant species composition, and changes in soil conditions. The mid-flowering stage is associated with the elongation of the stem and the production of reproductive parts,which may decrease the leaf/stem ratio and root/shot ratio (Pearson and Ison, 1997).

In the present study, pastureland management interaction with harvesting stages affected chemical composition of the pasture.This result agrees with the previous finding by Bezabih *et al.* (2014), who reported that chemical composition of natural pasture changes with various grazing types.

CONCLUSION

We conclude that different pastureland management practices and harvesting stages are the main factors that determine the aboveground biomass yield, proportions of herbaceous species, and the nutritional value of natural pasture. We observed a higher biomass yield in semi-intensive management than in seasonal grazing pasture management practices. Application of urea and harvesting after the full-flowering stage has resulted in better pasture biomass yield, pasture condition and nutritional quality. The area has the potential as a source of quality hay, which can be further promoted for commercial purposes. Further study is required to investigate the combined effects of fertilizer (organic, inorganic) application and other management practices on biomass yield and quality natural pasture in the current study areas and other similar areas in the highlands of Ethiopia.

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