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Assessment of botanical composition, biomass yield, nutritional quality and methane production of forages in selected grasslands, southern highlands of Ethiopia

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ABSTRACT

A study was conducted to assess botanical composition, biomass yield, nutritive value and methane production of forages in the grasslands of Kofele district in West Arsi Zone of Oromia National Regional State, southern Ethiopia. Three patches of the grassland including protected grassland, private grazing land used by smallholder farmers and ranch were selected for the study to represent three different grazing land management practices. Quadrats of 0.5 m × 0.5 m were used to determine biomass yield and collect samples of herbaceous forages from each site (12 quadrats from each site). For woody species four 10 m × 10 m plots were established along transect of 200 m with 20 m distance between plots to identify available species (in the ranch only). A total of 20 herbaceous species were identified, out of which 45% were grasses, 15% legumes, 10% sedges and 30% forbs. Out of 17 browse species identified in the ranch, 47.1% were trees while 52.9% were shrubs. The total biomass production from protected grassland (4.34 t/ha) was higher ($P<0.05$) than that of private grazing land (3.66 t/ha) and ranch (3.76 t/ha). Biomass production of sedge and forbs were the highest ($P<0.05$) in ranch. The ranges of chemical constituents for grasses were 8.44–10.74%, 52.8–72%, 27.7–37.4%, 3.1–5.6%, 58.2–76% for crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and in vitro dry matter digestibility (IVDMD), respectively. The CP and IVDMD for legumes varied from 15.64–20.33% and 80.1–85–1%, respectively. For browses the ranges of CP and IVDMD were 15.41–27.19% and 57.4–81.9%, respectively.. Among grass species, *Eragrostis botryodes* generated less methane. In general, legumes (5.5–6.5 mL/200 mg) and sedge (6 mL/200 mg) produced less amount of methane compared with grasses (7–10.5 mL/200 mg). Browses (9.5–13.5 mL/200 mg) produced more methane compared with herbaceous species (5.5–10.5 mL/200 mg). In conclusion protecting grassland and using cut

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and carry feeding system promoted more herbage production. The CP content of grass is generally good but supplementation with legumes and browses are required in practical feeding. The use of legumes with grasses and other browse species is recommended as a feeding strategy to reduce methane production However; further investigations on animal response trials are suggested to see the potential of these feed resources.

Introduction

In tropical production systems grasslands constitute the main sources of nutrition for domestic and wild herbivores. Grasslands are characterized as lands dominated by grasses rather than large shrubs or trees**.** However, grasslands do also contain a diversity of other herbs. Grasslands account for about 25 of land area worldwide [1] and 30% of the land cover and constitute 55% of feed resources for livestock in Ethiopia [2].

The ability of grassland to provide forage as an important source of nutrients to support livestock productivity depends on both their above-ground net primary productivity and the nutritional value of the available vegetation. Ruminants fed on these types of forages produce more methane (CH_4) than ruminants fed on high quality forage diets and there is a relationship between chemical composition and methane (CH_4) production [3]. Furthermore, CH_4 emissions represent a loss (up to 15%) of digestible energy to the animal as well as a threat to the environment [4]. Thus, it is important to identify forage species with low CH_4 production. Knowledge of the nutritional variation of grassland forage species is important to sustain satisfactory growth and reproduction of livestock without deterioration of grassland [5]. The performance of animals grazing tropical pastures is mainly influenced by availability and nutritional quality of the biomass on offer [6]. Evaluation of herbage yield and quality of natural pasture helps to arrive at the correct carrying capacity and stocking rate of ruminants [7].

Even though livestock play a crucial role in Ethiopian agriculture, productivity per animal is very low, and the contribution of the sector to the overall economy is much lower than expected due to many factors including poor nutrition [8]. In order to improve productivity of livestock, it is necessary to study the forage yield and quality, and thereby the carrying capacity of grasslands which constitute large amounts of the total available feed supply in the country. Studies in terms of species composition, biomass yield and nutritional qualities and methane production of grassland forages are important in order to establish sustainable management practices. Thus, the objective of the present study was to assess botanical composition, biomass yield, nutritional qualities and methane production potential of forages in some selected grasslands of Kofele area, southern Ethiopia.

Materials and methods

Description and selection of the study area

This study was conducted in Kofele district, West Arsi zone of Oromia National Regional State, Ethiopia, which is located at 316 km south of Addis Ababa, situated at 7°07′ N and 38°48′ E (Fig. 1). The elevation of the study area ranges from 2400 to 2700 m above sea level. It receives an average annual rainfall of 1800 mm with minimum and maximum of 230 mm and 2700 mm per annum, respectively. The temperature ranges from 17 °C to 22 °C [9].

Three sampling sites: protected grassland, private grassland and ranch, were purposively selected for the study representing different grass and grazing management. The protected area had 16 ha of grassland. The grassland was protected from livestock grazing until it is ready for harvesting. Then the grass is being sold to the surrounding community during the month of August once a year where the farmers use cut and carry system to feed animals. Private grassland has been used for crop cultivation for the last two years before initiating this study. The owners have been using the grazing land by shifting from time to time, cultivation and grazing. Farmers divided the grassland not to allow free access by livestock until the grass is ready for grazing and they use tethering system of grazing whereby animals are restrained to graze within a given radius of land before passing to the next. The ranch was established on 1600 ha of land in 1938 in a collaborative development project between government of Ethiopia and Sweden as breeding and multiplication center by crossing the local Arsi cattle with Holstein Friesian in order to distribute F1 heifers to smallholder farmers in the nearby districts. Now the ranch is owned by private farmer with an area of 550 ha which is used for grazing purposes. Animals of the ranch are allowed to freely graze in the ranch throughout the year without any restriction as long as grass is available.

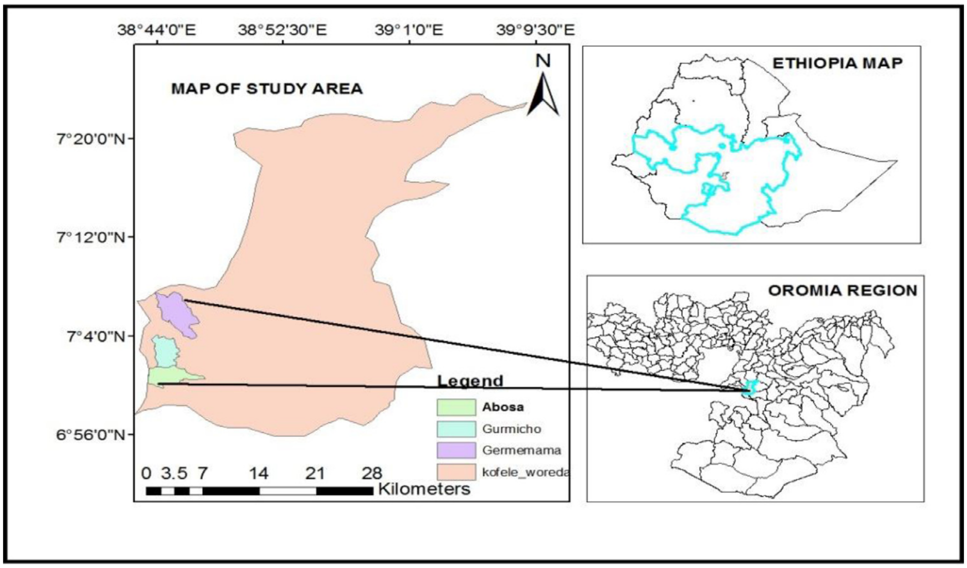

Fig. 1. ig 1. Map showing the study area.

Species identification and sampling procedures

Samples of herbaceous forages were taken from three sites (protected grassland, private grassland and ranch) purposively in August 2017 which is around the end of main rainy season. This time was selected with the expectation that most plant species could be easier to be identified and suitable time to take samples. Sampling areas of all the sites were protected from animals until the time of sampling from the beginning of the main rainy season (June) to the time of sampling (August).

For herbaceous species, three (5 m × 5 m) plots were established along a transect line of 100 m long at the interval of 20 m distance between each plots at representative location in the grassland of the study area [10]. Four (0.5 m × 0.5 m) quadrats were randomly placed in each plot (a total of 12 quadrats at each site) and all forage species in the quadrats were clipped to ground level using sickle. Harvested samples from all quadrats were identified by species and sorted into four botanical categories: grasses, legumes, forbs and sedges. Then weight of samples (based on botanical group) was taken and sub-sampled for yield determinations. In addition, samples of the most common nine herbaceous species, of which five grass species, a sedge species, three legume species were taken from grassland of the study area to determine chemical composition, in vitro dry matter digestibility (IVDMD), in vitro gas production and methane production. Selection of these species were based on their availability and information on their preference by grazing animals. Species identification was done in the field by an experienced botanist using botanical keys for Flora of Ethiopia [11], while local names were determined by consulting local community members.

For browses (large shrubs and trees above 2 m height), four (10 m × 10 m) plots were established based on vegetation heterogeneity along a transect line of 200 m with 20 m distance between each plots in the ranch. Browse species were not available in the studied grassland sites, except ranch which may be attributed to variation in the management practice of the sites. Species occurring in each plot were identified, counted and recorded. Five browse species were selected based on availability and preference by animals. Samples (only leaves) for each species were collected using scissor for analysis of nutritional qualities. Information about the preferences of these browse species was obtained from community working in the ranch.

Species composition (%) of herbaceous species (based on frequency of occurrence) and browse species (based on density) was expressed as: not present, present, common and dominant using values 0, <5, 5–20 and >20, respectively [12].

Biomass production and chemical composition of the grassland forages

Harvested samples from the 4 quadrats (0.25 m^2 each) of each study sites were separated into sub-samples of grasses, legumes, forbs and sedges in the field and the fresh weight of each group were taken using a digital balance. For chemical analysis and in vitro dry matter digestibility and gas production determination sub-samples for each species from the 4 plots were taken, mixed thoroughly and 600 gram of fresh weight were weighed and dried at 65 °C for 48 h. Where the same species occurred in the three grassland sites composite samples were taken and the analysis was done per pooled samples in duplicates and single values were presented for a composite sample. Since there were no common species for the grassland sites, analysis was done on individual species.

Chemical composition

The dried samples were ground in a Willey mill to pass through 1 mm sieve for the determination of chemical composition, IVDMD and in vitro gas production. Feed samples were analyzed for DM, crude fat (EE), N and ash using standard method [13]. The Kjeldahl method was used to determine nitrogen, and CP was calculated as $N \times 6.25$. Neutral detergent fiber (NDF) was analyzed sequentially [14] using an ANKOM^{220} fiber Analyzer (ANKOM Technology Corporation, NY, USA) without adding heat stable amylase. The acid detergent fiber (ADF) and acid detergent lignin (ADL) contents were determined according to method developed earlier [15]. Both NDF and ADF were expressed inclusive of residual ash.

In vitro dry matter digestibility

In vitro dry matter digestibility was determined according to earlier method [16] as modified later [15] in which the second stage (pepsin digestion) was substituted with neutral detergent solution. Rumen fluid was obtained by means of esophageal tube from the rumen of three Arsi-Bale sheep breed kept at maintenance diet (200 g wheat bran and ad libitum grass hay) daily. Rumen fluid was collected before morning feeding and immediately taken to laboratory using thermos flask. It was filtered through two layers of cheese cloth and flushed with CO_2. Sample of 0.25 g weighed in to ANKOM Filter bag (Ankom® Technology, # F57) were added in the ANKOM jars containing rumen fluid and medium mixture (solution A: KH_2PO_4, $MgSO_4{\bullet}7H_2O$, NaCl, $CaCl_2{\bullet}2H_2O$, urea, reagent grade and B: Na_2CO_3 and $Na_2S{\bullet}9H_2O$) of 1:4 ratio and incubated in an incubator at 39 °C for 48 h. After incubation for 48 h, the filter bags were washed with tap water until it was clear; soaked with acetone and then further extracted with neutral detergent solution in the ANKOM^{200} fiber analyzer.

In vitro gas production and methane estimation

For gas production study, three replicate samples of each forage species (each weighing about 200 mg) was added into 100 ml calibrated syringes together with a rumen fluid plus buffer solution (about 30 ml) under continuous flushing with CO_2 and incubated in a water bath which was maintained at 39 °C [17]. Rumen fluid was obtained from the same sheep used for IVDMD and the fluid was collected before the morning feeding by using esophageal tube. The fluid was strained through two layers of cheese-cloth. The initial volume of the material in each syringe was recorded before the commencement of the incubation of the samples. The gas volume was recorded after 3, 6, 12, 24, 48, 72 and 96 h of incubation.

The measured gas volume was adjusted and gas production characteristics were determined by exponential equation [18]: $p = a + b\,(1\text{-}e^{-ct})$, where: p = volume of gas produced at time't',

a = intercept (gas produced from the soluble fraction).
b = gas production from the insoluble fraction.
$a + b$ = potential gas production.
c = gas production rate constant for the insoluble fraction (b).
t = incubation time.

Post-incubation parameters, such as metabolisable energy (ME, MJ/kg DM), organic matter digestibility (OMD%) and short chain fatty acids (SCFA) were estimated [19]:

$$\mathrm{ME(MJ/kg\,DM)} = 2.2 + 0.136\ (\mathrm{GP24h}) + 0.0057\ (\mathrm{CP}),$$

$$\mathrm{OMD}\ (\%) = 18.53 + 0.9239(\mathrm{GP\ 48h}) + 0.0540\ \mathrm{CP\ and}$$

SCFA = (0.0239*GP24h) - 0.0601, Where: ME= metabolizable energy; GP = Net gas production over 24/48 h (ml/200 mg) of incubation; CP = Crude protein content of the samples; OMD= Organic matter digestibility at 48 h and SCFA= Short chain fatty acids.

At the end of 24 h incubation, 4.0 ml of NaOH (10 M) was added to the substrate in each syringe to determine methane production. Sodium hydroxide was added to absorb carbon-dioxide produced during the process of fermentation and the remaining volume of gas was recorded as methane [20].

Data analysis

Data of biomass yield, chemical composition and IVDMD of composite herbaceous forages were subjected to the general linear model (GLM) procedure [21]. Means were separated by Tukey pair-wise comparison and were considered significant at $P<0.05$. The following statistical model was used for analysis of biomass yield.

$$\mathrm{Yij} = \mu + \mathrm{si} + \mathrm{bj} + \mathrm{eij},$$

Where,

Yij = the dependent variable

Table 1
Identified forage species and species composition (based on% frequency of occurrence) in the selected grasslands.

Herbaceous species	Local name	Family	Life form	Species occurrence *PGr*	PG	R
Grasses:						
Andropogon amethystinus	*NI*	*Poaceae*	Perennial	C	D	D
Digitaria spp.	*Maqqaallaa*	*Poaceae*	Perennial	D	C	C
Eleusine floccifolia	*Daggoo*	*Poaceae*	Perennial	P	–	–
Eragrostis butroides	*Marga xaafii*	*Poaceae*	Perennial	D	P	P
Festuca simensis	*NI*	*Poaceae*	Annual	C	–	P
Pennisetum glabrum	*Migira*	*Poaceae*	Perennial	D	D	P
Pseudechinolaena polystachya	*NI*	*Poaceae*	Perennial	D	D	C
Snowdenia polystachya	*Muujjaa*	*Poaceae*	Annual	–	–	C
Sporobolus spp.	*Muriyyee*	*Poaceae*	Perennial	–	C	–
Legumes:						
Trifolium burchellianum	*Siddissa*	*Fabaceae*	Perennial	D	C	D
Trifolium cryptopodium	*Siddissa xiqqaa*	*Fabaceae*	Perennial	C	D	C
Trifolium decorum	*Siddissa*	*Fabaceae*	Annual	P	C	–
Sedges:						
Cyperus conglomeratus	*Qunnii*	*Cyperaceae*	Annual	C	P	D
Cyperus rigidifolius	*Quxxisa*	*Cyperaceae*	Annual	D	C	D
Forbs:						
Alchemela volkensi	*Baduubeera*	*Rosaceae*	Annual	C	P	D
Solanum anguivicam	*Baalbaxxee*	*Solanaceae*	Annual	D	D	P
Conyza spp.		*Adala*	*Asteraceae*	Perennial	P	C
Senecio bojeri	*Baallee*	*Asteraceae*	Annual	C	P	D
Sonichus spp.	*NI*	*Asteraceae*	Perennial	D	D	D
Alchemilla spp.	*NI*	*Rosaceae*	Annual	C	D	D

PGr= Protected grassland, PG = Private grassland, *R*= ranch, NI= Not identified, *D*=Dominant (>20%), *C*= Common (5–20%), *P*= Present (<5%), - = Not present.

μ = overall mean
si= the effect of sites (protected grassland, private grassland and ranch)
bj = the effect of replication (plots 1, 2, 3)
eij = random error

Data on chemical composition and in vitro gas production of individual herbaceous and woody species were presented using descriptive statistics (percentages). Results of chemical and in vitro gas production were from duplicate analyses of pooled samples.

Results and discussion

Herbaceous species composition

A total of 20 herbaceous species that belong to 6 families were identified from the selected grasslands (Table 1). There were 9 grasses, 3 legumes, 2 sedges and 6 forbs. It has been indicated that sustainable production in grassland areas requires that the nutritional status of animals is effectively monitored, thus providing an objective basis for various management decisions such as optimum allocation of forage to different types of animals, selection of animals compatible with the forage resources, selection of species for reseeding deteriorated ranges, as well as designing appropriate supplementation strategies [22]. The number herbaceous species observed in the current study were lower than the values (28 herbaceous species including 13 grasses, 7 legumes and 8 forbs) identified from grassland of north-western highland of Ethiopia [23]. Species composition varied from site to site, which may be related with management and utilization aspects of grasslands. It has been reported that large number of grass and forb species suggest that the grasslands are historically co-evolved with disturbance where most herbaceous species have developed grazing tolerance traits [24]. Moreover, species variation affect the nutritive value of forage plants [25] and translates into exacerbated low nutritive value of the available forage further hindering growth and sustainable livestock production [26].

From all identified herbaceous species 11 were perennials and 9 were annuals in terms of their life form. It has been suggested that annual plant species seem to thrive in highly disturbed habitats or in the early stages of post-disturbance succession, while perennials and woody species seem to dominate in less disturbed habitats and in latter stages of post-disturbance succession [27]. The species compositions varied among grassland sites. Of the total forage species identified from protected grassland, 8 species were dominant while 7 species were common to the grassland site. Among dominant species, 4 were grasses; 1 was legume; 1 sedge and 2 forbs. From common species, 2 were grasses; 1 legume; 1sedge and 3 forbs.

Table 2
Biomass yield (DM t/ha) of four groups (based on botanical group) herbaceous forages of the three selected grasslands sites.

Grassland sites	Forage composition				Total
	Grasses	Legume	Sedges	Forbs	
PGr	2.18[a]	0.72	0.57[b]	0.67[b]	4.34[a]
PG	1.67[b]	0.65	0.65[b]	0.69[b]	3.66[b]
R	1.41[c]	0.60	0.88[a]	0.87[a]	3.76[b]
SEM	0.12	0.06	0.15	0.01	0.04

Means with different superscript in a column are significantly different at $P<0.05$, PGr= Protected grassland, PG = Private grassland, *R*= ranch, SEM= Standard error of mean.

From the total forage species identified from the private grassland, 7 and 6 herbaceous species were recorded as dominant and common, respectively. The species from private grassland site were 3 grasses; 1 legume and 3 forbs. However, 2 grasses, 2 legumes; 1 sedge and 1 forb were classified as common forage species in the private grassland site of the study area.

Among the identified species of herbaceous forages from grassland site of ranch, 8 were classified as dominant while 6 of them were common species. The dominant forage species were 1 grass, 1 legume, 2 sedges and 4 forbs species. Of the common forage species of this grassland site, 3 were grasses, 1 legume and 1 forb. Dominant species of forbs and sedges from ranch could be related with management practice of the grassland. Livestock are able to selectively graze a small proportion of the palatable herbage available and ignore the undesirable ones, which favor the unpalatable ones at the expense of the palatable and less grazing tolerant species [28]. Moreover, grazing in palatable and less grazing tolerance species results in an increase in species with low forage value [29].

Species composition varied from site to sites. *Eleusine floccifolia* was found only in the protected grassland, while *Sporobolus* spp. (grass species) was found only in the private grassland. *Snowdenia polystachya* was available only in the grassland of ranch but *Trifolium decorum* was not found in this same site. The identified legume species from the grasslands of Kofele area were *Trifolium species* which was consistent with previous report [30] which indicated that *Trifolium* species frequently occur in areas between 2000 and 3000 m above sea level.

Browse species composition

The identified browses species with their scientific name and local names (Afan Oromo) are given in Table SM1. Farmers uses protected grassland through cut and carry feeding system, and private grassland by shifting the land for cultivation and as grazing land which may also influence browse species availability.We observed browse species only in the ranch where animals are allowed to graze without any restriction. The process of shifts in grassland species composition from herbaceous towards woody plant encroachment is also occurring in Southern Ethiopia [31].

A total of 17 browse species were identified from grassland of ranch. These were 8 tree and 9 shrub species contributing to 47.05% and 52.95% of the identified species. In terms of their abundance in the sward composition, 6 species (35.3%) were rated as dominant while 7 (41.2%) were common in the grassland. Most of browse species identified from the study area were reported in highlands of South Ethiopia [32]. *Buddleja polystachya* and *Vernonia amygadalina* were also identified from grassland of mixed farming system in South Ethiopia [33]. Some browse species like *Albizia schimperiana, Urera hypselodendron, Carissa spinarum* and *Croton macrostachyus* identified from the study area were also observed in North western Ethiopia [34].

Biomass yield and chemical composition of herbaceous forages in the three grassland sites of the study area

The results of biomass yield of four major groups (based on botanical group) of herbages is presented in Table 2. The highest ($P < 0.05$) grass herbage yield was recorded from protected grassland followed by private grassland and ranch. Sedges and forbs from ranch had higher ($p<0.05$) biomass yield compared with the remaining sites. Similarly, higher biomass production was reported in enclosure compared with communal grazing land for grass, legumes and forbs [35]. The variation in biomass yield among the sites may be due to variation in species composition, soil fertility, grassland management and utilization [33]. The highest yield of grass from protected grassland may be related with the dominance of perennial grasses from the grassland sites, as grasslands with dominant perennial species had better biomass yield. It has been indicated that grassland with dominant perennial species had better biomass yield [29].

High biomass yields of sedge and forbs from ranch may be due to grazing practices. Selective grazing favours less desirable species such as sedges and forbs [28]. Biomass yield of grass from this study was greater than that reported for North Shoa, Oromia region, Ethiopia [36]. Biomass yield of legumes in this study was higher than the value (0.37 ton/ha) reported for legumes from natural grazing land of highland of southern Ethiopia [37]. Variation in biomass yield between the study sites might be due to effect of edaphic conditions, management practice and livestock grazing pressure [36]. Moreover, the

Table 3
The chemical composition (%) and in vitro dry matter digestibility (%) of the major herbaceous species in the selected grasslands.

Species	CP	Ash	NDF	ADF	ADL	EE	IVDMD
Grasses:							
Andropogon amethystinus	8.44	7.8	72.0	37.3	3.5	1.5	58.2
Digitaria scalarum	10.74	12.4	69.9	34.9	4.3	1.0	72.3
Eragrostis botryodes	8.58	9.3	70.8	36.1	3.1	1.1	67.5
Pennisetum glabrum	9.18	9.9	64.7	37.4	5.6	0.3	73.3
Pseudechinolaena polystachya	10.48	10.9	52.8	27.7	4.5	1.0	76.0
Legumes:							
Trifolium burchellianum	20.33	15.5	39.0	23.1	7.1	2.1	85.1
Trifolium cryptopodium	15.64	10.3	43.7	28.8	8.6	2.0	80.8
Trifolium decorum	17.04	10.7	42.3	25.0	6.0	2.0	81.6
Sedge:							
Cyperus rigidifolius	7.19	7.8	74.2	44.9	6.8	0.4	54.8

CP, Crude protein; NDF, Neutral detergent fiber; ADF, Acid detergent fiber; ADL, Acid detergent lignin; EE, Ether extract; IVDMD, In vitro dry matter digestibility.

variation in herbage yield could be attributed to rainfall, evapotranspiration, edaphic factors and a rather low density of woody species among sites due to its effect on soil nutrient status which may favor growing conditions for grass [38]. Overgrazing is known to reduce biomass of the palatable herbaceous species [39] which is the case in private grazing land and ranch in the current study where the total biomass yield was lower than that of protected grassland. Moreover, it was found that herbaceous biomass were greater in enclosures than in grazed areas [40]. As indicated before, in protected and private grasslands animals were not allowed to graze for a certain time period which resulted in more biomass yield in protected grassland.

Chemical composition of herbaceous forages in the three grassland sites of the study area

Chemical composition of major herbaceous species sampled from the grasslands of the study area is shown in Table 3. The CP values varied from 7.19% for *Cyperus rigidifolius* to 20.33% for *Trifolium burchellianium*. Most grass species and sedge had a marginal CP content which is required for the normal functioning of the rumen microorganisms. It has been suggested that a minimum of 70% CP is required for optimum microbial growth and maintenance [41]. The variation in CP content of herbaceous forages among the study sites might be due to variation in species composition, soil fertility, and management practice of the grasslands [42]. *Cyperus rigidifolius* had the highest NDF and ADF content while the lowest value was recorded for *Trifolium burchellianum. Trifolium cryptopodium* had the highest ADL while the lowest was recorded for *Eragrostis botryodes*. The NDF, ADF and ADL values of studied herbaceous species in the present study was lower than the values reported (75.3%, 48.53% and 10.2%) for NDF, ADF and ADL, respectively, for grass species from Gambella rangeland previously [43]. This variation between studies may be attributed to climate condition, soil fertility and type of species evaluated. It is well known that different forage types exhibit differences in nutritive value [44]. Among grass species *Andropogon amethystinus* had the lowest value of IVDMD, while the highest value was recorded for *Pseudechinolaena polystachya*, while *Trifolium burchellianum,* had the highest IVDMD from legume species (Table 3). The factors that have been reported to affect the nutritive value of herbaceous plants are species variation [25], soil nutrient status of production location [45]), grazing pressure [46] and management aspects [47].

The high IVDMD for *Trifolium burchellianum* among all herbaceous species could be due to low fiber (NDF and ADF) content of the species. The IVDMD of all the studied forages in the current study are within the ranges (50%–80%) reported for tropical [48] and the IVDMD of legumes were above this range.

Chemical composition and in vitro dry matter digestibility of leaves of browse species

The chemical compositions of selected browse species are presented in Table 4. The highest CP value was recorded for *Albizia schimperiana* while the lowest was recorded for *Hagenia abyssinica*. The CP content of browse species in the current study was above the range of values (5.24–22.0%) reported for browse species of Ethiopian rift valley [49]. The CP content for *Buddleja polystachya* and *Vernonia amygdalina* were comparable with earlier report [33] which was 18.62% and 24.44% for both species, respectively. High CP contents of these indigenous browse species showed that they have potential to support animal growth and production. Forage with low protein content (7% or less), high acid detergent fiber (ADF) and neutral detergent fiber (NDF) cannot meet the nutritional needs of livestock without supplementation [44]. The CP content of most of the browses is higher than this threshold.

The ash content ranged from 6.5% for *Hagenia abyssinica* to 23.2% for *Urera hypselodendron.* Ash contents in the current study were greater than the ranges (5.4–11.49%) reported for tropical browse species [50]. The NDF content ranged from 33.1% for *Hagenia abyssinica* to 57.0% for *Buddleja polystachya.* The ADF value of entire selected browse species from the grassland of the study area was within the ranges (12.8–43.3%) of ADF values reported for tropical browse species [50]. The

Table 4
The chemical composition and in vitro dry matter digestibility of leaves of selected browse species from ranch.

	Composition (%)						
Species	CP	Ash	NDF	ADF	ADL	EE	IVDMD
Albizia schimperiana	27.19	12.4	45.7	31.7	20.8	2.2	74.8
Buddleja polystachya	17.49	7.5	57.0	38.1	19.1	2.0	57.4
Hagenia abyssinica	15.41	6.5	33.1	18.4	5.4	1.7	81.9
Urera hypselodendron	20.31	23.2	54.7	34.4	21.2	1.5	64.8
Vernonia amygadalina	25.78	12.1	45.9	33.1	24.2	2.1	79.6

CP, Crude protein; NDF, Neutral detergent fiber; ADF, Acid detergent fiber; ADL, Acid detergent lignin; EE, Ether extract; IVDMD, In vitro dry matter digestibility.

Table 5
Gas production characteristics and estimated parameters of major herbaceous species from the selected grasslands.

Species	Gas production characteristics (%)				OMD (%) at 48h	ME (MJ/kg DM)	SCFA (mmol/L)	Total gas (48 h)	CH4 (mL/200 mg) at 24h
	a	b	$a + b$	c (h^{-1})					
Grass:									
Andropogon amethystinus	1.3	47.9	49.2	0.060	59.89	7.51	1.06	44.26	8.5
Digitaria scalarum	1.2	44.4	45.6	0.063	56.97	7.44	1.13	40.98	9.5
Eragrostis botryodes	1.0	54.0	55.0	0.048	62.23	7.21	0.94	46.80	7
Pennisetum glabrum	1.5	52.2	53.7	0.047	60.16	7.16	0.98	44.53	10.5
Pseudechinolaena polystachya	1.6	56.4	58.0	0.062	71.02	8.03	0.91	56.19	9.0
Legumes:									
Trifolium burchellianum	1.1	42.9	44.0	0.064	57.78	7.19	1.05	41.29	6.5
Trifolium cryptopodium	0.8	39.0	39.8	0.068	54.87	7.13	1.14	38.42	6
Trifolium decorium	1.3	42.6	43.9	0.055	57.83	6.81	0.97	41.54	5.5
Sedge:									
Cyperus rigidifolius	1.4	45.9	47.3	0.069	60.72	7.65	1.07	45.24	6

a= rapidly degradable fraction, b = slowly degradable fraction, ($a + b$) = potential gas production, c = gas production rate constant for the insoluble fraction (b), OMD = Organic matter digestibility; ME= Metabolisable energy: SCFA = Short chain fatty acid; CH4= Methane.

ADL is the indigestible fraction of the plant cell wall. The ADL value of studied browse species was higher than the result (5.7–13.4%) reported [51] for browse species of Afar rangelands of Ethiopia. Ether extract values observed in this study was within the ranges (1.5–3.1%) reported for tropical fodder trees [52].

The IVDMD ranged from 54.7% for *Buddleja polystachya* to 81.9% for *Hagenia abyssinica. Hagenia abyssinica* had highest IVDMD which may be related to low NDF, ADF and ADL contents. There was inverse correlation between IVDMD and fiber contents of browse species [53].

Fermentation characteristics and estimated parameters of herbaceous forage species from the selected grasslands

Gas production characteristics of herbaceous forage species from the grasslands of the study area are presented in Table 5. Gas production characteristics of herbaceous forage species showed variability in values of the constants. The immediately fermented values (%) of species ranged from 1.0 for *Eragrostis botryodes* to 1.6 for *Pseudechinolacha polystachya.* The lowest slowly degradable fraction (“b”) was obtained from *Trifolium cryptopodium* (38.5%) and highest in *Pseudechinolacha polystachya* (56.4%). Except, *Andropogon amethystinus* and *Digitaria scalarum*, slowly degradable fraction (“b” values) observed for grasses and legumes in this study is within the range of values (49.2–59.2;39–45.2) reported for tropical grass and legume species, respectively [54].

Potential gas production ($a + b$) ranged from 39.8% for *Trifolium cryptopodium* to 58% for *Pseudechinolaena polystachya.* The rate of gas production (“c”) ranged from 0.047%/h for *Pennisetum glabrum* to 0.069%/h for *Cyperus rigidifolius*. Gas production characteristics of herbaceous forage species showed variability in values of the constants. The difference in values of “a”, “b” and “c” between forages species may be attributed to concentration of carbohydrates in each forage species [55].

The OMD (%) ranged from 54.87% for *Trifolium cryptopodium* to 71.02% for *Pseudechinolacha polystachya.* The result revealed that OMD in the current study was in agreement with the range of values (42–73%) reported for mid rift valley grassland forages [56]. The metabolisable energy (ME) content was highest for *Pseudechinolaena polystachya* (8.03 MJ/kg

Table 6
In vitro gas production characteristics and estimated parameters of selected browse species from ranch.

Woody species	Gas production characteristics (%) and estimated parameters								
	a	b	$a+b$	c (h^{-1})	OMD (%)	ME (MJ/kg DM)	SCFA (mmol/L)	Total gas (48 h)	CH4 (mL/200 mg) at 24h
Albizia schimperiana	3.0	57.1	60.1	0.053	72.44	8.53	0.97	56.66	10.5
Buddleja polystachya	1.1	42.8	43.9	0.047	56.72	6.40	0.90	40.31	9.5
Hagenia abyssinica	2.8	47.0	49.8	0.041	61.11	6.53	0.81	45.19	13
Urera hypselodendron	1.4	50.0	51.4	0.046	63.13	6.72	0.85	48.19	14
Vernonia amygadalina	2.0	51.0	53.0	0.044	65.04	6.92	0.82	48.87	13.5

a= rapidly degradable fraction, b = slowly degradable e fraction, ($a+b$) = potential gas production, c = gas production rate constant for the insoluble fraction (b), OMD = Organic matter digestibility; ME= Metabolisable energy: SCFA = Short chain fatty acid; CH_4= Methane.

DM) while the lowest was recorded in *Trifolium decorium* (6.81 MJ/kg DM). Metabolisable energy content in the current study was within the ranges of values (7.4–10.6 MJ/kg DM; 5.8–10.2 MJ/kg DM) for common tropical forages and for mid rift valley forages of Ethiopia as reported earlier [545] and [56], respectively. The nutrient contents like metabolisable energy (ME), short chain volatile fatty acid (SCFA) and organic matter digestibility (OMD) of forages can also influence the production of animals [57]. The SCFA (mmol/L) values were between 0.91 (*Pseudechinolaena polystachya)* and 1.14 (*Trifolium cryptopodium*). The SCFA (mmol/L) values are within the range (0.90–1.35 mmol/L) reported for grassland herbaceous forages [57].

Methane produced from the herbaceous forages of the study area was greater than the ranges of 3.18–7.01 ml/200 g DM reported earlier [54]. The variations in methane production among the studied forages could be related to variations in species and their chemical composition. Legume species produced less methane volume compared to others, which may be related to their high CP contents since protein fermentation produce low CH_4 than carbohydrate fermentation [54].

Gas production characteristics and estimated parameters of browse species from ranch

In vitro gas production characteristics and estimated parameters of five selected browse species are presented in Table 6. Rapidly soluble fraction ("a" value) varied from 1.1% for *Buddleja polystachya* to 3% for *Albizia schimperiana*. Slowly degradable fraction ("b" value) ranged from 42.8% for *Buddleja polystachya* to 57.1% for *Albizia schimperiana.*

Slowly degradable fraction ("b" value) of browse species observed in this study was within the range of values (49.15–94.19%) reported earlier [52]. Variation in potential gas production of browse species can be attributed to compositional difference of browse species, especially CP and fiber components [57]. The rate of gas production ("c" value) ranged from 0.041%/h in *Hgenia abyssinica* to 0.053%/h for *Albizia schimperiana*.

The OMD at 48 h ranged from 56.72% in *Buddleja polystachya* to 72.44% in *Albezia schimperiana*. Low OMD of *Buddleja polystachya* in this study may be due to high NDF content of the species. The NDF value has negative effect on OMD [51]. The OMD values of browse species in the grassland of the study area is greater than the ranges (47–57%) reported [51] for leaves of browse species in Afar rangeland. The OMD of *Vernonia amygadalina* from this study was higher than the value (58.54%) reported [56] from mid rift valley of Ethiopia.

The SCFA values (mmol/L) ranged from 0.81 mmol/L for *Hagenia abyssinica* to 0.97 mmol/L for *Albizia schimperiana*. The values of SCFA observed in this study were in line with the values of 0.53 to 1.32 mmol/L reported for browse species in Afar rangelands of Ethiopia [52].

The metabolisable energy (ME) value of leaves of browse species from the study area is within the ranges (5.58 to 8.75 MJ/kg DM) reported earlier [52]. Methane production at 24hr ranged from 10.5 ml/200 mg DM for *Albizia schimperiana* to 14 ml/200 mg DM for *Urera hypselodendron.* The low methane production for *Buddleja polystachya* may be due to low gas production of the plant. Previous study showed that methane production decreased with decreasing gas production [55].

Conclusion

Generally, there were variations among the grassland sites in terms of species composition, biomass yield and nutritional qualities of forages. Different forage species with varied occurrence belonging to different families were identified from the three grassland management practices. Seventeen browse species were identified from the ranch composed of trees and shrubs. Exclusion of animals from grassland throughout the grazing season (protected grassland) and feeding animals in the form of cut and carry system were good in promoting better yield compared with ranch where animals were allowed to graze without any restriction and private grazing land where tethering is practiced. Even thouhgh there are variations in CP and IVDMD among grass species these could be offset by better CP and IVDMD. Generally the CP content of browses is high although more methane was generated from the browses. Due to the high CP content these browses could be used as supplement to poor quality grass observed in this experiment. Animal experiment is required to assess the performance of animals fed on forages in such varying qualities.

Authors contribution

AM: study conception and design, data collection and analysis, manuscript preparation. AN and MB: study conception and design, manuscript preparation, securing fund and critical revision. AT and AH and SY: study conception and design, securing fund and revision on the manuscript. SM: Involved in identification of species and manuscript revision. All authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that there is no competing interest.

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