Identification and evaluation of agro-ecological variation in dry matter yield and nutritional values of local grasses used as livestock feed in Adola Reedde, Guji Zone, Ethiopia

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ABSTRACT
A study was conducted in Adola Reedde to identify major grass species and evaluate their chemical composition, in vitro digestibility, and dry matter yield. Sixty key informants taken from the sampled kebele of three agro-climates were interviewed to identify common grasses in their vernacular name. Relative feed value and dry matter digestibility were computed using neutral detergent fibre and acid detergent fibre contents. Spearman’s rank correlation was used to examine relationships between laboratory results and farmers’ perception of grass quality. Fifteen grass species were identified and ranked by farmers according to the species’ preferences for cattle. Crude protein values ranged from 56.5 g/kg DM for lowland to 113 g/kg DM for highland agro-climate, overall mean of neutral detergent fibre was 662 g/kg DM, and in vitro dry matter digestibility and relative feed value were 446.5 g/kg DM and 60.97%, respectively. Total dry matter yield and dry matter of individual grass species were significantly (P<0.001) higher in highland than in low land agro-climate. Dry matter yield across agro-climate ranged from 92.47±0.04 g m⁻² to 119.41±0.07 g m⁻² for highland and lowland agro-climate, respectively. Generally, study highlights the potential of herbaceous species to support livestock production if the grassland is properly rehabilitated and managed.

Introduction
In Sub-Saharan Africa, ruminant livestock commonly relies on feed resources viz: natural grasses, forbs with some browse shrubs and trees (Abususawar and Ahmed 2010). In Ethiopia, the livestock population is 60.39 million cattle, 31.30 million sheep, 32.74 million goats, 56.06 million poultry, 2.01 million horses, 8.85 million donkeys, 0.46 million mules, 1.42 million camels and 5.92 million hive-bee colonies (CSA 2017/18). The total production capacity for the country is about 3.32 billion litres of cow milk, 327.64 million litres of camel milk, 66.22 million kilograms of honey and 136.76 million eggs (CSA 2017/18).

Even though Ethiopia has an enormous and substantial number of farm animals, their productivity and contribution to its economy are pretty low (Adugna 2008). This disparity arises from limited feed resources and the low quality of the existing range of land resources which hinders anticipated livestock productivity (Solomon and Teferi 2010). The significant reason for low milk production in Ethiopia is linked to the insufficiency of livestock feeds, especially during the dry season (Zewdie 2010). The low nutritive value leads to high livestock death, longer calving interval and substantial weight losses, particularly during the dry season (December to May) in most central Ethiopia (Adugna 2007; Shenkute et al. 2012). Furthermore, the degradation of rangelands due to the disproportionate use of communal grazing lands of undulated topography in the highlands and erratic rainfall in semi-arid areas have further declined the availability of rangeland resources (Abule 2003; Solomon and Teferi 2010).

The shortage of animal feed in quantity and quality is worse in arid, semi-arid and tropical regions because of scarce and erratic rainfall that hinder the growth of natural pasture species, resulting in low biomass yield. Thus, livestock in such regions has the challenge of low-quality feed resources for most parts of the year (Robles et al. 2008; Boufennara et al. 2012).

The productivity of range animals is directly related to the quantity and nutritive quality of the available forage (Hussain and Durrani 2009). Sheep is the most appropriate species of livestock for utilization of open sparse vegetation and can convert the course roughages into valuable products meant for human use.

Adugna et al. (2012) classified feed resources into the natural pasture, crop residues, improved pasture and forage and agro-industrial by-products, of which pasture and crop residues contribute the most significant part. Natural pastures encompass naturally occurring grasses, legumes, herbs, shrubs and tree foliage (Adugna 2008). The productivity of natural pastures is gradually decreasing because of the rapid increase in human population pressure, expansion of arable land farming for food crops and shrinkage of grazing land areas, resulting in a shortage of livestock feed (Adugna 2007).
Continuous overstocking also declines the potential of valuable species and favours replacement by less nutritious and unpalatable species (Hassen 2006). Even though indigenous plant species are dominant and still contribute as an indispensable source of feed for ruminant livestock across the agro-climatic regions in Ethiopia, the anticipated production potential and quality of natural grazing lands have been decreasing over time and could not support optimal livestock production. This arises from overgrazing of the natural grazing lands due to poor grazing land management (Alemayehu 2003; Getnet 2003; Wondatir and Yoseph 2014). Several studies have evaluated the chemical composition of native grasslands and reported that the potential and nutritional contents of indigenous plant species differ in all seasons agro-climates (Angassa and Oba 2010; Geleti et al. 2012; Keba et al. 2013). Natural grazing lands are heterogeneous (Eaton et al. 2011). Its chemical constituents differ with environmental factors such as altitude, rainfall, soil type, cropping intensity, grazing land management and variation in the genetic characteristics inherent to specific individual plant species (Alemayehu 2003; Robles et al. 2008; Teka et al. 2012). These factors also affect forage yield, intake and digestibility and animal grazing behaviour (Solomon and Teferi 2010).

The feeding value of animal feed determines the optimal herbivore body size and the relative success of livestock. Hence, evaluating the nutritional value of animal feed is imperative in livestock feeding because effective livestock production is linked to the quantity of nutrients in the feed (Schut et al. 2010). The study area, particularly the Adola Reedde district, has huge potential and great diversity of local grass species. However, detailed studies have not yet been done concerning the assessment, identification and determination of the nutritional composition of local grass species. Therefore, the current study was designed with the objectives of identifying major grass species evaluating their chemical composition, in vitro digestibility, and dry matter yield under varying agro-climate of the Adola Reedde district.

**Materials and methods**

**Description of the study area**

The study was conducted in the Adola Reedde district, Guji zone of Oromia National Regional State, located about 475 km south of Addis Ababa. The area is located between 5° 44’10” N–6°12’ 38” N latitude and 38° 45’10” E longitude – 39°12’ 37” E. The district shares boundaries with the Girja district in the Northeast direction, Anna Sorra in the Northwest direction, Oddo Skakiso in the Southern direction and Wadara in the Southeast direction. It has a total area of about 1401 km². The district has 28 rural and two urban kebele, and it is characterized by dega (highland), woina dega (midland) and kola (lowland). The percentage of the coverage of each agro-climate zone of the district is highland at 33%, midland at 47% and lowland at 20%. The major soil of the Adola Reedde district is nitisols (red basaltic soil), and the soil is dominantly brown (Guji Zone 2014). Moreover, it has a land surface with an elevation ranging from 1,500 m in the Southern part to over 2,000 m in the Northwestern part. The farming system in the Adola Reedde is traditional, with oxen and yoke, and labour as major means of production during land preparation, planting and harvesting, as well as post-harvest processes. However, semi-pastoral economic activity is also practised as a means of livelihood by some residents (Aschalew 2014). Rainfall and temperature of the district are estimated to be 900–1700 mm on average and 12°C–28°C. The geographical location of the study area is presented in Figure 1.

**Selection of the study site and sampling methods**

The study district was selected from the Guji zone because of its huge potential and great diversity of local grass species, large total area with different agro-ecologies and massive livestock (Guji Zone 2014). A multi-stage sampling technique was used to select the agro-climate. The rural kebele (the smallest administrative structure in Ethiopia) was stratified into agro-climates, namely highland (dega), midland (woina dega) and lowland (kola) and the kebele within strata were selected purposively based on the availability, potential and accessibility of indigenous grass species. Accordingly, highland (Meleka and Sekaro), mid-altitude (Gunacho and Bilu), and lowland (Bechera and Chemibe) kebele were selected as representatives of the agro-climates.

Twenty key informants were selected from each agro-climate, giving 60 key informants across the three agro-climates. Common grasses were identified in their vernacular name, and ranking was then done based on information obtained from key informants regarding their relative abundance in the area and their consumption preference by livestock. For fresh herbage biomass yield estimation, three 50-m-long transects were established at three slopes of each kebele, and the average of its yield was used to represent each agro-climate. Then a metal frame quadrant of 0.5 m x 0.5 m with short legs welded to its corners was placed at every 10 m starting from one end, making five samples per transect; thus, fifteen 0.25 m² quadrant samples per each kebele and thirty 0.25 m² quadrant samples per each agro-climate. The transect positions within each kebele were then selected to represent the upper, medium and lower positions to determine the dry matter yield of different slopes across three agro-climates in the Adola Reedde district. Herbaceous vegetation within the quadrants was manually clipped at the height of 5 cm above the ground (Allen et al. 2011), sorted into different species, and their fresh weight was recorded using a sensitive balance. Then, each fresh grass species was chopped into 2–5 cm and dried in an oven at 65°C for 48 h. Finally, the dry matter (DM) yield of each grass species at each agro-climate was calculated by multiplying the percentage dry weight of each grass species by the fresh weight of the respective grass species in each quadrant per 0.25 m² area. Herbaceous species were sampled in the mid-September for three consecutive days.

**A sampling of local grass species for identification**

For grasses whose scientific names were not correctly identified in the field, specimens were collected in duplicate, pressed between white plain papers, labelled, dried and transported...
to the National Herbarium of Addis Ababa University for identification and naming. These grass species were identified following the guideline provided in the Flora of Ethiopia (Hedberg and Edwards 1989, 1995).

Preparation of grasses for chemical analysis

The samples of common grass species were bulked together and thoroughly mixed, and then one composite sample was maintained per agro-climate. The air-dried samples were dried at 65 °C for 72 h in a forced-draft oven to obtain partial dry matter (Sanson and Kercher 1996). The partially dried samples were ground, and then about 2 g of grass sample was weighed in a clean and dried porcelain crucible and dried in an oven at 105 °C for 24 h. Dry matter (DM %) was calculated using the following formula: Dry matter (DM %) = \( \frac{\text{oven dried sample}}{\text{sample weight}} \) x 100. Ash was determined according to the procedure of AOAC (1990). Briefly, two grams of ground grass sample was added to a clean, dry crucible in an oven at 100 °C for 2 h and ignited in a muffle furnace at 550 °C for 3 h and weighed after cooling in a desiccator.

Figure 1. Geographical location of the study area.

Source: Developed from Ethio-GIS (2013)
Nitrogen content was analyzed according to the procedures described by AOAC (1990). Nitrogen was analyzed by the Kjeldahl technique, and crude protein (CP) content was calculated as nitrogen (N) × 6.25. Neutral detergent fibre (NDF), acid detergent fibre (ADF), and acid detergent lignin (ADL) were determined following the method of Van Soest et al. (1991).

**In vitro dry matter digestibility**

In vitro dry matter digestibility (IVDMD) of each grass species was determined by the method of Tilley and Terry (1963), as modified by Van Soest and Robertson (1985). A sample analysis was done at the Holeta Agricultural Research Centre animal nutrition laboratory. The samples, dried at 65°C to constant weight, were ground to pass through a 1 mm sieve. About 0.5 g of the sample was incubated in 125 ml Erlenmeyer flasks containing rumen fluid-medium mixture. Then, it was incubated for 48 h at 39°C for microbial digestion. For enzyme digestion, duplicate samples were then incubated for 48 h with acid pepsin solution. Empty samples containing only buffered rumen fluid were also incubated in duplicates for adjustment. The sample residues were dried at 105°C for 24 h. The rumen fluid was obtained from three rumen fistulated (Boran × Friesian) cross-bred steers kept on a maintenance diet. Dry matter loss was calculated as the difference between the dry matter weight of the sample at the start of the incubation and the weight of residue dry matter remaining at the end of the incubation period, as stated by Tilley and Terry (1963). All measured concentrations were expressed on a dry matter basis. In vitro dry matter (IVDM) was calculated as dry sample weight—(residue- blank)/dry sample weight × 100.

| No | Grass species                      | Family name | Local name          | Common name |
|----|------------------------------------|-------------|---------------------|-------------|
| 1  | Cenchrus ciliaris                  | Poaceae     | Mita                | Buffel grass|
| 2  | Cynodon dactylon (L. Pers.)        | Poaceae     | Qoraa               | Bermuda grass|
| 3  | Sporobolus pyramidalis P. Beauv.   | Poaceae     | Micica              | Giant rat’s tail grass |
| 4  | Heteropogon contortus (L.) Roem. & Schult | Poaceae | Qophii              | Black spear grass |
| 5  | Chrysopterus ascheri               | Poaceae     | Alaloo              | Auchi’s grass (Kenya) |
| 6  | Setaria barbata (Lam.) Kunth       | Poaceae     | Sokorrri            | Bristly foxtail grass |
| 7  | Hyparrhenia hirta (L.) Stapf       | Poaceae     | Luuccole            | Common thatching grass |
| 8  | Panicum maximum Jacq              | Poaceae     | Laabbessa           | Guinea grass |
| 9  | Sorgium arundaceum (Desv.) Stapf   | Poaceae     | Obbaa               | Kamerun grass |
| 10 | Digitaria ternata (A. Rich.) Stapf | Poaceae     | Sutta               | Blackseed crabgrass |
| 11 | Sporobolus festivus               | Poaceae     | Micica lagga        | Red dropseed southern cutgrass |
| 12 | Leersia hexandraSw                | Poaceae     | Qabatay             | Red grass |
| 13 | Themeda triandra                  | Poaceae     | Saamphilee          | Creeping bluegrass |
| 14 | Bothriochloa insculpta             | Poaceae     | gammoogii           | Love grass or cane grass |
| 15 | Eragrostis papposa                | Poaceae     | Qaanwaa             |                        |

The sample was ashed to estimate in vitro organic matter digestibility (IVOMD). The ME content was estimated using the equation: ME (MJ kg⁻¹ DM) = 0.15*IVOMD (Beever and Mould 2000).

**Determination of relative feed value**

The relative feed value (RFV) was calculated according to Stalling (2005) using the following procedure:

\[
RFV = \frac{\text{Dry matter digestibility (DMD)x Dry matter intake (DMI)}}{\text{1.29}} \times 100
\]

where 1.29 = the expected digestible dry matter intake as % of body weight;

\[
\text{DMD} = 83.58 - 0.824 \times \text{ADF} \% + 2.626 \% \text{N}\% \quad (\text{Oddy et al. 1983})
\]

\[
\text{DMI} = \frac{120}{\% \text{NDF}} \quad (\text{Sanson and Kercher 1996}).
\]

**Perception analysis**

Perceptions of key informants were taken during the field sample collection. A community-level group discussion was held at each agro-climate, and the key informants were selected based on the individual’s experience in livestock keeping and vegetation. The selected respondents participated in the ranking of the same common grass species used for laboratory analysis. The cumulative match of key informant perception of ordering a particular grass species across the study location was divided by the total number of respondents (i.e. 60) and multiplied by 100 to obtain the percentage value for that particular species. All the species were ranked in a descending order based on their percentage value concerning other species under examination. The perception value of individual species was then correlated with the results of the chemical composition of that particular species using Spearman’s rank correlation (Fowler and Cohen 1996).

**Statistical analysis**

Agro-climate and species were considered independent variables. Grass species’ nutritive values and their dry matter yield were considered response variables. General Linear Model procedure of statistical analysis system (SAS) version 9.1 (SAS 2008) was used to compute statistical analysis. The experimental design was completely randomized and analyzed as a two-factor experiment (agro-ecology and species). LSD was used to determine mean differences at P≤0.05.

The model used was

\[
Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + e_{ijk}
\]

where \(Y\) is the response variable,

\(\mu\) is the overall mean,

\(A_i\) is the grass species effect,

\(B_j\) is the agro-climate effect,

\((AB)_{ij}\) is the interaction between species and agro-climate and

\(e_{ijk}\) is the random residual error assumed to be normally and independently distributed.
Results

Major grass species

The farmers identified the grass species according to their vernacular name. Fifteen major grass species were found in all agro-climates (lowland, midland and highland). The grass species and their local and botanical names are presented in Table 1.

Chemical composition and IVDMD of grass species

The mean crude protein (CP) values of 15 grass species for the highland and midland agro-climate of the study area were 78 g/kg DM and 73 g/kg DM, respectively, but reduced to a mean value of 66 g/kg DM at lowland agro-climate with an overall mean value of 72.3 g/kg DM. The highest crude protein (CP) was recorded for C. dactylon (L.) Pers (113.0 g/kg DM) at highland agro-climate and the lowest was recorded in H. contortus (L.) Roem. & Schult (56.5 g/kg DM) at lowland agro-climate. The highest dry matter (DM) was recorded for the H. contortus (L.) Roem. & Schult (95.7%) at lowland agro-climate and the lowest was recorded in C. dactylon (L.) Pers (88.7%) at highland agro-climate. All the species recorded higher values for DM, ADF, NDF, ADL, and ash at lowland than in highland and midland agro-climate (Table 2).

The mean value ash content was significantly higher in the lowland agro-climate than in highland and midland agro-climates and ranged from (132-91.5 g/kg DM), (113.5-87 g/kg DM), and (120.5–92 g/kg DM), respectively. The highest ash content was observed in the H. contortus (L.) Roem. & Schult (132 g/kg DM) followed by C. aucheri (131 g/kg DM) in the lowland, whereas the lowest ash content (87 g/kg DM) was observed in C. dactylon (L.) Pers followed by D. ternata (A. Rich.) Stapf (99 g/kg DM) in highland agro-ecology.

The highest neutral detergent fibre (NDF) (701.4 g/kg DM), acid detergent fibre (ADF) (492.5 g/kg DM) and acid detergent lignin (ADL) (142 g/kg DM) content were recorded for H. contortus (L.) Roem. & Schult (L.) Roem. & Schul t at lowland Agro-climate and the corresponding lowest NDF (586 g/kg DM), ADF (397.5 g/kg DM), and ADL (90.5 g/kg DM) content were recorded for C. dactylon (L.) Pers in highland agro-climate. The overall mean values of in vitro dry matter digestibility (IVDMD) and metabolizable energy (ME) were 446.5 g/kg DM and 66.9 (MJ), respectively. The highest in vitro dry matter digestibility (IVDMD) (556 g/kg DM) and ME (8.34MJ kg$^{-1}$ DM) values were observed in the highland agro-climate for C. dactylon (L.)Pers, whereas H. contortus (L.) Roem. & Schult exhibited the lowest in vitro dry matter digestibility (IVDMD) (403 g/kg DM) and metabolizable energy (ME) (6.05MJ kg$^{-1}$ DM) in lowland agro-climate. Of grass species, the highest relative feed value (RFV) was recorded in C. dactylon (L.)Pers (73.16%) in highland agro-climate, whereas H. contortus (L.) Roem. & Schult (53.88%), and C. aucheri (59.72%) exhibited the lowest relative feed value (RFV) in lowland agro-climate.

Frequency of grass species occurrence

Based on the relative frequencies of each grass species across all agro-climates, three grass species, E. papposa, C. ciliaris, and C. aucheri, with respective percentage values of 62.98, 58.85 and 54.64 were dominant and had high frequencies of >50%. Eleven other species were of intermediate frequency (20–25%), while the remaining two grass species, S. arundinaceaum (Desv.) Stapf and S. barbata (Lam.) Kunth, had frequencies below 20%.

Dry matter yield of grass species

Dry weights of individual species in the three agro-climates are presented in Table 3. In the highland agro-climate, C. ciliaris, H. contortus (L.) Roem. & Schult, H. hirta (L.) Stapf and C. aucheri were the dominant grass species recorded in higher proportions than others (Table 3). In all agro-climates, species such as B. insculpta, C. aucheri, C. dactylon (L.)Pers., E. papposa, T. triandra, C. ciliaris, H. contortus (L.) Roem. & Schult, and H. hirta (L)Stapf were commonly recorded. The highest dry matter (DM) yield (119.41 ± 0.07 g m$^{-2}$) was recorded for highland agro-climate and the lowest dry matter (DM) yield (92.47 ± 0.04 g m$^{-2}$) was recorded for lowland agro-climate. The effect of intra-location transect position was not significantly different ($P > 0.05$) for dry matter (DM) yield (Table 4).

The rank of grass species according to the perception of key informants

The ranking of the common grass species according to the perception of key informants is presented in Table 5. The key informants of the three agro-climates identified common grass species and ranked them according to relative abundance, preferences, and palatability of grass species by grazing animals. Of the 60 key informants, more than 85% mentioned C. ciliaris, C. dactylon (L.)Pers., S. pyramidalis P.Beauv, H. contortus (L.) Roem. & Schult and C. aucheri were the dominant grasses out of the 15 identified grass species. According to key informants, S. festivus, L. hexandra Sw, T. triandra, B. insculpta, and E. papposa were perceived as species of low preference and palatability, while the remaining grass species were perceived as moderately preferred and palatable species in the study area.

Correlation between ranks of key informants’ perceptions and the nutritional value of grass species across three agro-climates

The correlation coefficient between the key informant’s perception ranking and the nutritive value of the common grass species is presented in Table 6. There was inconsistency in key informants’ perception of agro-climates. The ranking value of individual grass species based on the perception of key informants was positively correlated with the laboratory results of dry matter (DM), crude protein (CP), relative feed value (RFV), metabolizable energy (ME), in vitro dry matter digestibility (IVDMD), and ash of grass species from highland and mid-altitude agro-climate, but negatively correlated with neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). The laboratory results of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid
detergent lignin (ADL) and ash were positively correlated with key informants’ ranking values at lowland agro-climate but negatively correlated with dry matter (DM), crude protein (CP), relative feed value (RFV), metabolizable energy (ME), and in vitro dry matter digestibility (IVDMD).

The correlation between the different parameters of the nutritional value of the grass species is given in Table 7. The results indicated that CP was positively correlated with RFV at \( r = 0.935, p < 0.001 \), ME at \( r = 0.961, p < 0.001 \), and IVDMD at \( r = 0.961, p < 0.001 \) respectively, while negatively correlated with NDF at \( r = -0.951, p < 0.001 \), ADF at \( r = -0.922, p < 0.001 \), ADL at \( r = -0.852, p < 0.001 \), DM at \( r = -0.196, p < 0.001 \), and Ash at \( r = -0.924; P < 0.05 \). There was also a positive correlation between structural constituents of herbaceous plants viz, NDF, ADF, and ADL.

### Discussion

**Chemical composition of grass species and their correlation with the perception ranking of key informants across three agro-climates**

All the grass species recorded higher values of crude protein (CP) at highland than midland and lowland agro-climates.

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**Table 2. Chemical composition of grass species across three agro-climate of the study area.**

| Grass species | Agro ecology | CP (% dry matter) | ADL (% dry matter) | NDF (% dry matter) | ADF (% dry matter) | RFV | IVDMD | ME (MJ) |
|---------------|--------------|-------------------|-------------------|-------------------|-------------------|------|-------|---------|
| Cenchrus ciliaris | Lowland | 93.25 | 94.00 | 114.00 | 116.00 | 668.60 | 2.12 | 113.50 | 95.30 |
| Cyanodon dactylon (L.) Pers. | Lowland | 90.75 | 94.00 | 116.00 | 120.00 | 660.00 | 2.12 | 113.50 | 95.30 |
| Sorghobobus pyramidalis P. Beauv. | Lowland | 94.90 | 96.00 | 120.00 | 120.00 | 688.50 | 2.12 | 125.00 | 56.50 |
| Heterogenous kontorus (L.) Roem. & Schult | Lowland | 95.70 | 96.50 | 130.00 | 130.00 | 701.40 | 2.12 | 140.00 | 53.88 |

**LSD = Least Significant Difference; CP = Crude Protein; NDF = Neutral Detergent Fibre; ADF = Acid Detergent Fibre; ADL = Acid Detergent Lignin; ME = Metabolizable Energy; IVDMD = In vitro DM digestibility; RFV = Relative Feed value; Means with different letters within column and grass species are significantly different at \( p < 0.05 \).**
while the reverse was true for neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL). The probable reason for the highest crude protein (CP) content in the highland agro-climate may be attributed to the relatively mid-stage maturity of grass species at harvest compared to the lowland agro-climate, which maintains the structural constituents of herbaceous plants. On the other hand, grass species of lowland agro-climate had an early stage of maturity, which is attributed to the high development of fibre constituents at the same harvesting time. The variation in chemical constituents may also be associated with differences in temperature, precipitation and soil characteristics (Alemu et al. 2007; Asmare et al. 2017) for other types of agro-climate is in line with the lowest mean value of dry matter (DM) exhibited in lowland agro-climate during the wet and dry seasons, respectively, in the rangeland of Gambella. The result of crude protein (CP) content of tropical grass species is in the range of 40–80 g/kg DM. The crude protein (CP) content of grass species for optimal rumen functioning and microbial activity is 70–80 g/kg DM. The crude protein (CP) content of grass species during the wet and dry seasons, respectively, in the rangeland of Gambella. The result of crude protein (CP) is also in line with the finding of Clay et al. (2006) that recommended the crude protein (CP) content of tropical grass species is in the range of 40–150.1 g/kg DM.

### Table 3. Dry matter yield of herbaceous species by their dry weight across three agro-climates of the Adola Reedde district.

| Species | Lowland | Highland | Midaltitude |
|---------|---------|----------|-------------|
| Cenchrus ciliaris | 0.32 | 0.40 | 0.34 |
| Cynodon dactylon (L.) Pers. | 0.41 | 0.37 | 0.32 |
| Sporobolus pyramidalis P. Beauv. | 0.31 | 0.35 | 0.36 |
| Heteropogon contortus (L.) Roem. & Schult | 0.33 | 0.46 | 0.35 |
| Chrysopogon aicheri | 0.38 | 0.44 | 0.40 |
| Setaria barbata (Lam.) Kunth | 0.16 | 0.18 | 0.22 |
| Hyparrhenia hirta (L.) Stapf | 0.30 | 0.40 | 0.34 |
| Panicum maximum Jacq | 0.32 | 0.39 | 0.35 |
| Sorghum arundinaceum (Desv) Stapf | 0.20 | 0.25 | 0.22 |
| Digitaria tenuata (A. Rich.) Stapf | 0.26 | 0.31 | 0.30 |
| Sorghum festivus | 0.29 | 0.33 | 0.31 |
| Leersia hexandra Sw | 0.31 | 0.39 | 0.35 |
| Themeda triandra | 0.30 | 0.36 | 0.30 |
| Bothriochloa insculpta | 0.33 | 0.38 | 0.34 |
| Eragrostis papposa | 0.42 | 0.39 | 0.35 |

### Table 4. Dry matter yield (g m⁻²) (Mean ± SE) as sampled from different slopes across three agro-climates in the Adola Reedde district.

| Slope | Lowland | Highland | Midland |
|-------|---------|----------|---------|
| Medium | 92.49±0.01 | 119.36±0.04 | 112.37±0.17 |
| Upper | 92.5±0.02 | 119.41±0.07 | 112.65±0.17 |
| Lower | 92.47±0.04 | 119.17±0.17 | 112.71±0.17 |

Means with different letters across a row are significantly different and means with the same letters within the column are not significantly different at p ≤ 0.05.

### Table 5. Rank of herbaceous species according to Adola Reedde pastoralists' perception.

| (close-strick)Species name | Rank by Respondents | Low land | High Land | midland | RFR (%) |
|---------------------------|---------------------|----------|-----------|---------|---------|
| Cenchrus ciliaris | 1 | 18 | 20 | 18 | 93.33 |
| Cynodon dactylon (L.) Pers. | 2 | 20 | 16 | 19 | 91.67 |
| Sporobolus pyramidalis P. Beauv. | 3 | 17 | 18 | 17 | 86.67 |
| Heteropogon contortus (L.) Roem. & Schult | 4 | 19 | 14 | 16 | 81.67 |
| Chrysopogon aicheri | 5 | 16 | 15 | 12 | 71.66 |
| Setaria barbata (Lam.) Kunth | 6 | 15 | 12 | 13 | 66.67 |
| Hyparrhenia hirta (L.) Stapf | 7 | 13 | 11 | 14 | 63.33 |
| Panicum maximum Jacq | 8 | 9 | 17 | 11 | 61.6 |
| Sorghum arundinaceum (Desv) Stapf | 9 | 10 | 8 | 10 | 56.67 |
| Digitaria tenuata (A. Rich.) Stapf | 10 | 12 | 10 | 10 | 53.33 |
| Sporobolus festivus | 11 | 8 | 13 | 9 | 50 |
| Leersia hexandra Sw | 12 | 14 | 8 | 7 | 48.33 |
| Themeda triandra | 13 | 11 | 6 | 6 | 38.33 |
| Bothriochloa insculpta | 14 | 17 | 7 | 5 | 31.67 |
| Eragrostis papposa | 15 | 6 | 3 | 2 | 18.33 |

Notes: Rank by respondents 1–5 = best, 6–10 = moderate, 11–15 = worst. RFR = Frequency of Respondent.
time, and decreases the efficiency of conversion of metabolizable energy to net energy. This result is in line with the results reported by Geleti et al. (2012), who noted a mean neutral detergent fibre (NDF) value of 760 g/kg DM for grass species that exceeds the threshold level and they exhibit the lowest voluntary feed intake. The higher mean value of neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) contents of grass species in the study area are attributed to the higher percentage of structural carbohydrates and a higher proportion of stems. The reported mean value of ash in this study is in line with Mlay et al. (2006), which ranges from 65 to 140 g/kg DM. The highest ash in the lowland agro-climate may be attributed to the soil type due to the accumulation of topsoil by flooding and erratic rainfall down the lower gradient.

The average in vitro dry matter digestibility (IVDMD) value (426.7–467.9 g/kg DM) recorded in this study was comparable with those reported by Geleti et al. (2012) and lower than the values reported by Gemiyo et al. (2013). This difference could result from wide variations in topography, elevation, rainfall distribution, soil fertility, management conditions and probable variations in the maturity stage of grass species. The highest metabolizable energy (ME) values at the highland agroclimate attribute to the highest in vitro dry matter digestibility (IVDMD) at the highland agro-climate than midland and lowland agro-climates. As cited by Geleti et al. (2012), Leng (1990) and Adugna and Said (1994) indicated that forage with respective crude protein (CP), and digestibility values lower than 80 and 550 g/kg DM are categorized under low-quality forages. As a result, they exhibit low intake, digestibility and poor utilization of dry feed matter (DM). Therefore, in terms of crude protein (CP) and digestibility values, grass species studied in the current study fall under low-quality forages.

The reported overall average value of relative feed value (RFV) (60.97) is in agreement with the report of Keba et al. (2013). However, this was apparently below the threshold level of 100 according to the report of Dunham (1998) and below 151 reported by other researchers (Redfearn and McNaughton 1993; Frank et al. 2002; Hellström et al. 2003; Sankaran and Augustine 2004; Patra 2005). The pressure of grazing at lowland agro-climate could also result in removing plant shoot tissue (defoliation) (Frank and McNaughton 1993). Defoliation affects plant growth and carbon allocation (Briske et al. 1996; Ferraro and Oesterheld 2002) and reduces the input of aboveground litter to the soil and the amount of coarse organic matter in the soil (Burke et al. 1999).

The low dry matter (DM) yield of grass species in the lowland compared to highland agro-ecology corresponds to the reports of Abate (2007) and Asrat et al. (2015), who suggested that rangelands in deprived conditions had low pasture production with unpalatable pastures than those rangelands under good conditions. The low dry matter yield of herbaceous plant species in lowland agro-climate can be generally attributed to poor management practices and soil fertility, inadequate and erratic rainfall, recurrent drought and high grazing pressure. The present findings are in line with previous

### Table 6. The correlation coefficient between farmers perception’s and the nutritional value of grass species.

| Agro-climate | DM | CP  | Ash | NDF | ADF | ADL | RFV | ME  | IVDMD |
|--------------|----|-----|-----|-----|-----|-----|-----|-----|-------|
| Lowland      | −0.163 | −0.125 | 0.179 | 0.200 | 0.191 | 0.200 | −0.204 | −0.187 | −0.187 |
| Highland     | 0.014 | 0.080 | 0.200 | −0.213 | −0.041 | −0.172 | 0.136 | 0.304 | 0.036 |
| Midland      | 0.147 | 0.372 | 0.168 | −0.167 | −0.154 | −0.154 | 0.139 | 0.139 | 0.139 |

CP = Crude Protein; NDF = Neutral Detergent Fibre; ADF = Acid Detergent Fibre; ADL = Acid Detergent Lignin; ME = Metabolizable Energy; IVDMD = In vitro DM digestibility; RFV = Relative Feed value.

### Dry matter yield of grass species

The high total dry matter (DM) yield and dry matter (DM) of individual grass in highland than lowland in the current study are linked to the impact of farming. In the highland agro-climate, there is a mixed farming (crop-livestock) system that minimizes the pressure of grazing compared to the lowland agro-climate, where farmers own several animals as a source of income and food that increases the pressure of grazing. Grazers owned in lowland agro-climate could also affect plant community structure, primary production, growth, and turnover of its roots, microbes, and animals that control the decomposition of dead organic matter in the soil (Frank and McNaughton 1993; Frank et al. 2002; Hellström et al. 2003; Sankaran and Augustine 2004; Patra 2005). The pressure of grazing at lowland agro-climate could also result in removing plant shoot tissue (defoliation) (Frank and McNaughton 1993). Defoliation affects plant growth and carbon allocation (Briske et al. 1996; Ferraro and Oesterheld 2002) and reduces the input of aboveground litter to the soil and the amount of coarse organic matter in the soil (Burke et al. 1999).

### Table 7. The correlation between different parameters of the nutritional value of the grass species across three agro-climates.

| CP     | Ash | NDF | ADF | ADL | DM  | RFV | ME  | IVDMD |
|--------|-----|-----|-----|-----|-----|-----|-----|-------|
| 1.000  |     |     |     |     |     |     |     |       |
| Ash    | −0.924** |     |     |     |     |     |     |       |
| NDF    | −0.951** | 0.988** |     |     |     |     |     |       |
| ADF    | −0.922** | 0.996 | 0.991** |     |     |     |     |       |
| ADL    | −0.852** | 0.983 | 0.956** | 0.981 | 1.000 |     |     |       |
| DM     | −0.196** | 0.989 | 0.984** | 0.991** | 0.975** | 0.975** | 1.000 |       |
| RFV    | 0.939** | −0.993 | −0.997** | −0.997** | −0.967** | −0.967** | −0.967** | 1.000 |
| ME     | 0.961** | −0.943** | −0.971** | −0.953** | −0.885** | −0.940** | 0.967** | 1.000 |
| IVDMD  | 0.961** | −0.943* | −0.971** | −0.953** | −0.885** | −0.940** | 0.967** | 1.000 |

*= significant difference at p < 0.05 and **= highly significant difference at p < 0.001.
Grass species quality as perceived by the farmers

In the present study, although interviewed key informants lack knowledge related to physiological functions and anatomical characteristics of livestock, they have developed the ability to identify common grass and rank them according to their preferences and palatability because of the long experiences acquired through the years. This result is in line with the finding of Bothma (2010), who suggested that feed selection by livestock is primarily influenced by two factors: palatability and preference for feeds.

The correlation of the ranking value of farmer’s perceptions with laboratory analysis results of grass species at highland and midland agro-climate indicated that farmers are familiar with grass species quality based on preferences and palatability of grass species by a particular class of livestock. However, there was some variation among farmers in lowland agro-climate. This inconsistence in farmer perception might result from heterogeneity in species composition, topographical difference, land-use patterns and soil characteristics of varying agro-climates of the study area. The correlation result was not in agreement with Keba et al. (2013), who suggested a strong correlation between species ranking value and nutritional value of grass species based on pastoral perception in semi-arid rangelands of Ethiopia. Indigenous knowledge refers to the traditional or local acquaintance existing within and accustomed to the specific conditions of indigenous people in particular geographic areas (Leonti et al. 2003). Disagreement and inconsistence in the present study might result from variation in the perception of different communities on particular species of their particular area.

Conclusion

Crude protein values were higher at highland than midland and lowland agro-ecology for all grass species. The crude protein content of herbaceous species was adequate for the maintenance requirements of most domestic herbivores at high land agro-climate but considerably declined towards lowland agro-climate. The structural carbohydrate (neutral detergent fibre, acid detergent fibre, acid detergent lignin) and dry matter (DM) in the sampled herbaceous species were higher in lowland agro-climate, with critical implications for forage quality and the sustainability of livestock production. Overall, the low accumulation of crude protein and increased structural fibres were a clue to the poor quality of forage. The nutritional quality of herbaceous forage is more affected by the stage of maturity, which results from agro-ecological differences, than any other factor that was pronounced in lowland agro-climate. Grass quality attributes generally indicate that the vegetation is poor in providing forage biomass capable of meeting livestock nutritional quality requirements.

The correlation of ranking value with laboratory analysis results was inconsistent across agro-climate except in highland and midland agro-climates. This might result from heterogeneity in species composition, spatial variation in topography, land-use patterns, soil characteristics and variation in the perception of different communities in particular species of their particular area. Dry matter yield of grass species implied that the status of grasslands in the lowland agro-climate was in poor condition compared to midland and highland agro-climate due to relatively low rainfall, high temperature, and grazing pressure. Generally, the results of this study highlight the potential of the herbaceous species to support ruminant livestock production, particularly in semi-arid areas where prevailing climate change/variability and global warming impact forage species availability if the rangeland/grassland is properly rehabilitated and managed.

Recommendation

Our findings indicated a need for protein and energy supplementation, rangeland improvement for in situ conservation of key forage species by use of holistic planned grazing and enclosure. Our study also indicated a need for documentation and integration of local knowledge of farmers into rangeland resources management to understand the prevailing land-use impacts, develop new insights into improving existing scientific research, designing proper research and development policies for improvement, sustainable utilization, and conservation of natural resources and in turn alleviating the problem of food and feed shortage/scarcity.

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