Range Management and Agroforestry, 2026
ISSN 0971-2070 (Print); 2249-5231 (Online)
https://doi.org/10.59515/rma.2026.v47.i2.1444

Research article

Existing livestock feed resource potential and nutrient balance in the intensive crop-livestock farming areas of Bale Highlands, Southeast Ethiopia

Girma Defar[1*], Ashenafi Mengistu[2] and Gebreyohannes Berhane[2]

[1]Department of Animal Sciences, Madda Walabu University, P.O. Box 243, Ethiopia
[2]Department of Animal Production, Addis Ababa University, P.O. Box 34, Ethiopia
[*]Corresponding author email: girmad16@yahoo.com

Received: 15th January, 2026 Accepted: 24th April, 2026

Abstract

The study was conducted in the intensive crop-livestock farming areas of the Bale highland to look into feed availability and nutrient content. Using multi-stage purposive sampling, 156 households of the three wealth groups were selected. Structured questionnaires, focus group discussions, field visits, and feed sample chemical analyses were the methods employed. The nutrient balance was estimated based on the livestock maintenance demand and supply. Descriptive statistics and one-way ANOVA tests were used to analyze the data. The mean land holding was significantly ($p < 0.001$) different between wealth groups, while more land is used for crop cultivation (83.9%). Cattle were the dominant (84.3%) of livestock herds owned by farmers. Major feeds mean DM contributions were 66.7, 13.0, and 12.4% from cereal straws, crop aftermath and private natural grazing, respectively. Roughage feeds have lower Metabolizable Energy (ME) and Digestible crude protein (DCP). The mean *in-vitro* digestible organic matter in the dry matter (IVDOMD) of the dominant feeds (cereal straw and native pasture) ranges from 49.9 to 62.6% across the wealth groups. Average deficit of ME (24.2%) was observed for the better group, while DCP satisfied only 33.3% of the requirement for the same group and the situation suggests searching for a solution for the thrilling feed shortage associated with quality. Therefore, quality feed supply and promotion of farm-level feed production and improvement technologies should be practiced wisely to increase livestock productivity.

Keywords: Bale highland, Crop-livestock, Feed balance, Fodder, Nutrient

Introduction

Mixed farming system dominated the highlands of Ethiopia, which approximated to cover less than 40% of the land mass of the country, and maintains 85% of the human population (Mekasha *et al*., 2014; Mekonnen *et al*., 2023). Mixed farming areas are known as 'livestock production systems' in which more than 10% of the dry matter (DM) fed to livestock comes from crop by-products and crop aftermath (Seré *et al*., 1996; Mamo *et al*., 2023). However, reports from elsewhere in the country indicated that crop residue contribution is very high compared to the FAO definition (Gurmessa *et al*., 2015; Tolemariam and Jaleta, 2015). In Ethiopia, the farming community significantly depends on a rain-fed subsistence crop-livestock system where livestock is integrally linked to cultivation. In the system, for a long time, livestock have been used for draught power, crop threshing, transportation, a source of food, manure (fuel and fertilizer), replacement, savings, and grants a significant degree of food security during crop failure (Mekonnen *et al*., 2023; Abate *et al*., 2012).

However, huge livestock numbers and diversified roles prevail; low production outputs were a key challenge associated with low quantity and quality of feeds due to land use change and cropping intensification (Shapiro *et al*., 2015; Desta, 2024). Much has been reported about livestock feed sources in mixed farming areas, and major basal feeds are straw, native pasture, and crop aftermath, with the contribution to the total feed resource varying from area to area, attributed to cultivation intensity (Defar *et al*., 2025; Tahir *et al*., 2018; Yadessa *et al*., 2016). These feed resources were reported to have very low Crude Protein (CP) content to maintain animal body condition, as CP determines the quality of feeds (Abazinab *et al*., 2024; Yami *et al*., 2013). Hence, feed shortage is frequently mentioned as a severe problem in the extensively cultivated areas (Geleti *et al*., 2013; Kebede *et al*., 2016; Desta, 2024). Nowadays, feed is the major input, and the most limited resource that is paramount to obtain optimum product from livestock. This implies that current and future livestock feeding strategies call for a systematic approach to maintain livestock productivity. The Bale Highlands of southeast Ethiopia represent one of the country's most important intensive mixed farming zones, where crop-livestock integration is the dominant agricultural practice. The area is known for its high potential for cereal production and livestock rearing; however, the increasing conversion of productive grasslands into cropland has significantly reduced feed biomass availability (Hailemariam *et al*., 2016; Abdulahi *et al*., 2025). Although previous studies (Gebremariam and Belay, 2023; Abate *et al*., 2012) have examined feed resources and livestock systems in Bale and other Ethiopian highlands, updated evidence on feed resource potential, nutrient composition, and annual nutrient balance under the current intensified land-use system remains limited (Defar *et al*., 2025; Abdulahi *et al*., 2025; Desta, 2024). Similarly, different studies confirmed that there is a persistent occurrence of annual feed deficit at farm level in the Ethiopian highlands (Hassen *et al*., 2010; Tahir *et al*., 2018; Abera *et al*., 2014).

Given the continuing competition between crop production and livestock feed resources, there is a pressing need to reassess the availability, quality, and utilization efficiency of existing feed resources in the Bale Highlands (Abdulahi *et al*., 2025). Therefore, it is imperative to look at available feed resources and nutrient content across the wealth groups to suggest the appropriate solutions for the future livestock production, which is an input for the policy makers, and livestock development intervention actors. With this background, this study was initiated to identify major feed resources, their nutrient content, and the annual feed balance in the area.

Materials and Methods

Study area description: The study was conducted in the Bale zone, Southeast of Ethiopia. Recent demographic report revealed that the human population of the zone is estimated at 1,616,061, of which, 87.3% live in the rural area (BoFED, 2020). The zone holds three town administrations, and 18 rural districts from which 9 fall under the mixed farming system, and the rest 9 are pastoral, and agro-pastoral. The study area was situated at the highland altitude with mean annual rainfall of 860.00 mm, average minimum, and maximum daily temperatures were 9.4 °C and 25.2 °C, respectively. The rainfall pattern of the study area is bimodal type namely: *Belg* (extends March to July), and *Meher* (extends August to January) (BoFED, 2020).

Major crops cultivated in the area are wheat, barley, emmer wheat, *teff*, faba bean, field pea, and maize while the area has simultaneously large livestock resources. The major livestock species reared by the inhabitants include cattle, sheep, donkey, horse and chicken (CSA, 2021). The districts chosen for this study were among the first few potential mixed farming districts of the Zone known for their extensive cultivation, and raising high livestock population.

Sampling procedure and data collection: Three potential mixed farming districts namely Sinana, Agarfa, and Gasera were purposively selected based on cropland cover, and livestock population. A total of 9 *kebeles* (farmers' associations) namely: *Hamida, Hora-Boka, Weltei-Berisa, Ali, Mokonna-Chefe, Ambentu, Nake, Chifaro and Birbirsa*), 3 from each districts were randomly selected for data collection. The households (HHs) were stratified into three different wealth groups on the basis of their basic livelihoods asset (livestock, and land) owned, and capacity of the farmers to satisfy basic needs of their family. This stratification was done in consultation with development agents, district experts, and community representatives in accordance with Eba (2012). The groups were better wealth (≥ 4.25 hectare land, > 15 TLU Tropical Livestock Units); medium wealth (2.25-4.25 hectare land, > 5, and ≤ 15 TLU), and low wealth (≤ 2.25 hectare land, ≤ 5 TLU). Total sample size of 156 HHs [N = (0.25/SE2)] was used to represent the study population (Arsham, 2007). The proportional number of respondents was 26% (better), 54% (medium), and 20% (low) wealth groups, derived from the existing proportion of the HHs according to the 'Probability Proportional to Size' sampling technique (Alam *et al*., 2015).

A survey using pre-tested semi-structured interview schedule was carried out and data were collected through personal interview technique covering landholding, cropping pattern, livestock holding, and herd composition, and major livestock feeds used. Besides focus group discussions (FGDs) and field observations were used. Feed samples were also collected for analysis.

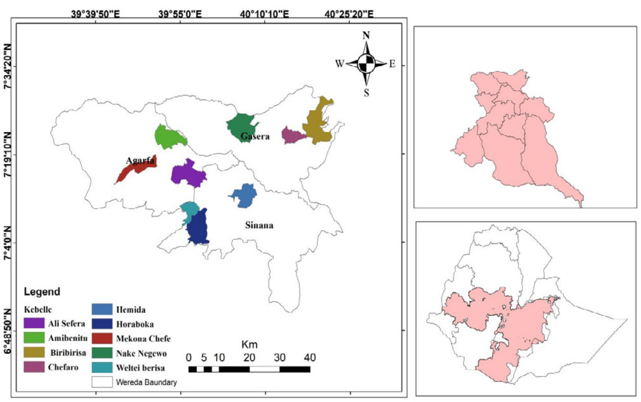

Fig 1. Location map of the study area

Feed sample collection and chemical composition analysis: Mixed natural pasture herbages from protected private grazing, and fallow land of the wealth groups (9 *kebeles* * 3 wealth groups * 3 quadrants) at the midway mature age were harvested from 1m * 1m quadrant (Tessema *et al*., 2011), and samples from the wealth groups bulked, and dried under shade for further chemical analysis. The dominant herbage species were: *Cypenus rigidifolius, Andropogona abisinica, Hyperrhenia rufa, Digitaria and Trifolium*. Major crop straws wheat (*Triticum sativum*), barley (*Hondrium vulgare*), emmer wheat (*Triticale species*), teff (*Eragrostis teff*), and highland pulses (*Vicia faba and Pisum sativum*) used as livestock feed were collected from straw stacks owned by the respondents (9 *kebeles* * 3 wealth groups * 3 straw stacks). The collected feed samples were manually chopped into small size, and ground to pass through 1mm screen sieve, and samples from the nine *kebeles* were pooled to their respective categories, and mixed thoroughly. Then, representative sub-samples were taken per the feed type, packed in a paper bag at room temperature, pending chemical analysis at Holeta Agricultural Research Center's Animal Nutrition Laboratory.

The samples were dried in air draft oven at 65°C for 72 hours to determine herbage DM. The DM, and ash contents were determined by oven drying at 105°C overnight and igniting in a muffle furnace at 500°C for 6 hours, respectively. Nitrogen (N) content was determined by the Kjeldahl method, and crude protein (CP) was calculated as N * 6.25 (AOAC, 1995). The NDF, ADF, and ADL were analyzed. The *in-vitro* digestibility of organic matter in the dry matter (IVDOMD) was determined by Tilley and Terry method as modified by Van Soest and Robertson (1985). The ME and DCP contents of a given feed were estimated from IVDOMD and CP contents, respectively, employing the following formulae:

ME (MJ kg-1 DM) = [0.15*IVDOMD (%)] (Beever and Mould, 2000)

DCP (g) = [0.929 * CP (g/kg DM) - 3.48] (Church and Pond, 1982). Where, IVDOMD = *In-vitro* organic matter digestibility and DCP = digestible crude protein.

The contribution of major feeds to annual ME and DCP supply was estimated by multiplying the quantity of each feed (DM) by the corresponding nutrient constituent obtained from laboratory analysis.

Estimation of major feeds annual biomass yield: The quantity of feed DM obtained annually from the different land use types was calculated by multiplying the hectare of the land under each land use type by its conversion factors (CF) FAO (1987). The CFs of 2.0 and 0.5 tons DM per hectare per year were used for the communal and crop aftermath grazing, respectively. The herbage DM from fallow and private grazing lands was calculated from harvested feed samples DM. The quantities of crop residues produced by the HHs were estimated by converting grain yield to straw yield. Accordingly, for a ton of wheat, barley, emmer wheat, and teff straw, a multiplier of 1.5; for the highland pulse (faba bean and field pea): 1.2, and for oilseeds: 4.0 CFs were used (FAO, 1987). The quantity of potentially available crop residues for animal consumption was estimated by considering 10% wastage due to collection, transport, storage, processing, and other alternative uses (Tolera and Said, 1994).

Estimation of livestock nutrient requirement: The study HHs livestock population was converted to tropical livestock unit (TLU). The TLU conversion factors (Jahnke, 1982; Gryseels, 1988) for ox/bull, cow, heifer, steer, calf, sheep, horse, and donkey were 1.1, 0.8, 0.5, 0.6, 0.2, 0.1, 0.8, and 0.5, respectively. The daily maintenance DM used for the standard TLU of 250 kg at 2.5% of the body weight (6.25 kg per day) suggested by Jahnke (1982) was used. The ME and DCP maintenance requirements for the livestock were estimated according to the daily average recommendations (Kearl, 1982).

Data analysis: The data were analyzed using Statistical Packages for Social Sciences (SPSS) software version 20.0 (Morgan *et al*., 2004). Descriptive statistics (means and frequencies) were used to quantify the data. To compare the differences between the wealth group landholding, livestock holding, area under different land use types, annual feed DM yield, and nutrient balance: one-way analysis of variance (ANOVA) was used. The tests were done at a 95% level of confidence ($\alpha = 0.05$) and Tukey's HSD mean comparison procedure was used to test mean differences.

Results and Discussion

Household resource holding and utilization: Table 1 presents different types of land owned, and the utilization pattern by the different wealth group HHs in the study area. The average land allotted for crop cultivation and total land holding were significantly ($p < 0.001$) higher for the better wealth group, while the area of land for grazing and forage crops production was significantly different ($p < 0.05$) between the better and low groups. The study revealed that more land, 81.5%, 84.5%, and 89.0%, was allocated for crop cultivation by the wealth groups and confirmed that more land is utilized for cultivation compared to grazing. In terms of cropping pattern, the average land allotted to different crops, and total cropland holding were significantly different ($p < 0.05$) and ($p < 0.001$), respectively, between the wealth groups. The average land allotted to the wheat crop was the highest (60.1%), followed by barley (25.9%). A major area of the land owned by the wealth groups is used for cultivation, where extensive cultivation affects animal feed sources due to a small area of grazing land (Table 1). Similarly, more area of the land was allocated for cultivation in the central part of Ethiopia (Assefa *et al*., 2013; Hailesilassie *et al*., 2024; Abdulahi *et al*., 2025). The more land dominated by wheat crop was due to suitable agro-ecology, and availability of better input packages compared to other crops. Concomitantly, increased DM of the straw proportional to grain yield from the wheat crop was observed. Moreover, the present finding agrees with recent reports from the Bale highlands and other Ethiopian mixed farming systems, where progressive cropland expansion has increasingly encroached upon communal and private grazing areas, leading to seasonal feed scarcity (Abdulahi *et al*., 2025; Mekuria *et al*., 2018).

Table 2 depicts the mean livestock categories and herd structures of the HHs in TLU. The mean total cattle, cow, ox and heifer were significantly ($P< 0.001$) different between the wealth groups. The mean steer and sheep TLU holding was significantly ($P< 0.01$) different between the better and the other groups, while horse and donkey were significantly ($P< 0.001$) higher for the better wealth HHs. From the total livestock owned by the wealth groups, cattle accounted for the largest number at the HH level, while from the cattle herd structure, oxen (48.8%) and cows (31.0%) are more common. In the Bale highland area, mixed farming is the livelihood pillar of the community, and it is based on the size of the land and livestock possessed, where livestock production has been a subsistence and important component of the system. The greater the number of TLU possessed by the better wealth group accounted for the difference in the grazing land owned. Cattle were the dominant stock, while the number of oxen was still pronounced within the herd across the wealth groups that are important for cultivation. It is credited to the established facts that cattle were primarily used for draught power in the area, like elsewhere in Ethiopia. The livestock herd proportions indicated that better HHs had raised a greater number of diversified herd categories compared to the other wealth groups (Table 2), and this observed difference validated diversity when planning sustainable livestock development programs (McDermott *et al*., 2010). In the semi-arid region of India, livestock units varied across landholding categories (Biradar *et al*., 2013). The small number of steers reported compared to other categories was because of early-age sale to manage the feed shortage. Similarly, recent evidence from rangeland and agroforestry systems indicates that herd size is strongly influenced by landholding size and access to feed resources (Abdulahi *et al*., 2025).

Major feed types and their biomass yield: Summary of major livestock feed resources and actual biomass yield from the land use types are indicated in Table 3.

Table 1. Land holding and use types (ha HH^{-1}) in the study area

Description of variables	Wealth group			Overall mean(156)	*P-value*
	Better (40)	Medium(85)	Low (31)		
	Mean(SE)	Mean(SE)	Mean(SE)	Mean(SE)	
Land use type					
Grazing land	$0.59(0.1)^{a}$	$0.32(0.0)^{ab}$	$0.10(0.0)^{b}$	0.34(0.0)	*
Cropland	$4.17(0.1)^{a}$	$3.09(0.9)^{b}$	$1.89(0.1)^{c}$	3.13(0.1)	***
Fallow land	0.27(0.1)	0.23(0.0)	0.13(0.0)	0.22(0.0)	ns
Forage crops land	$0.12(0.0)^{a}$	$0.04(0.0)^{b}$	$0.01(0.0)^{b}$	0.06(0.0)	*
Rented in/out cropland	0.14(0.1)	0.13(0.1)	0.06(0.0)	0.12(0.0)	ns
Total land holding	$5.29(0.2)^{a}$	$3.81(0.3)^{b}$	$2.19(0.1)^{c}$	3.87(0.2)	***
Total cropland (%)	81.5	84.5	89.0	83.9	
Cropping pattern					
Wheat	$2.33(0.2)^{a}$	$1.85(0.1)^{b}$	$1.36(0.1)^{c}$	1.88(0.1)	*
Barley	$1.07(0.1)^{a}$	$0.80(0.1)^{ab}$	$0.51(0.01)^{b}$	0.81(0.0)	*
Emmer wheat	$0.32(0.1)^{a}$	$0.26(0.0)^{ab}$	$0.17(0.0)^{b}$	0.26(0.0)	*
Teff	0.13(0.0)	0.15(0.0)	0.0(0.0)	0.14(0.0)	ns
Pulses	$0.48(0.1)^{a}$	$0.36(0.0)^{ab}$	$0.18(0.0)^{b}$	0.36(0.0)	**
Oilseed crops	0.18(0.0)	0.11(0.0)	0.02(0.0)	0.11(0.0)	ns

***(P≤0.001); **(P≤0.01); *(P≤0.05); ns: non-significant; abc: means within the same row with different superscripts are significantly different

Table 2. Livestock herd structure (TLU per HH) in the study area

Livestock category	Herd structure	Wealth group			Overall mean (156)	*p-value*
		Better (40)	Medium(85)	Low (31)		
		Mean(SE)	Mean(SE)	Mean(SE)	Mean(SE)	
Cattle	Total	13.9(0.4)[a]	7.6(0.3)[b]	3.5(0.2)[c]	8.4(0.4)	***
	Cow	4.8(0.1)[a]	2.2(0.1)[b]	0.9(0.1)[c]	2.6(0.1)	***
	Ox	6.2(0.2)[a]	3.9(0.1)[b]	1.9(0.1)[c]	4.1(0.2)	***
	Heifer	1.3(0.1)[a]	0.7(0.1)[b]	0.2(0.1)[c]	0.8(0.1)	***
	Steer	1.4(0.2)[a]	0.4(0.1)[b]	0.2(0.1)[b]	0.6(0.1)	**
	Calf	0.6(0.0)[a]	0.3(0.0)[ab]	0.1(0.0)[b]	0.4(0.0)	*
Sheep		0.5(0.1)[a]	0.3(0.0)[ab]	0.1(0.0)[b]	0.3(0.0)	**
Horse		0.9(0.1)[a]	0.3(0.0)[b]	0.2(0.1)[b]	0.5(0.0)	*
Donkey		1.2(0.1)[a]	0.7(0.0)[b]	0.3(0.1)[b]	0.7(0.0)	*
Cattle (%)		81.9	85.9	89.9	84.3	

***(P≤0.001); **(P≤0.01); *(P≤0.05); ns: Non-significant; abc: means within the same row with different superscripts are significantly different; TLU: Tropical livestock unit

Private grazing land and cereal straw DM yield were highly significant (p <0.001) for the better wealth group, while crop aftermath (p < 0.001) and HMCs DM were significantly (p <0.05) different between the better and the other groups. Fallow land and pulse straw DM yield were higher (p <0.01) and (p <0.05) for the better compared to the low groups. Cereal straw takes the major share of annual DM yield, while the DM contributions of forage crops and HMC to the HH feed supply were very low compared to the other roughage feeds. Collectively, straw (cereals and pulses), crop aftermath and mixed native pasture DM yields contributed 96.9% to the total household annual feed supply.

The type and quantity of feeds used showed variation across the wealth groups related to the feed resource basis. The major area of the land owned was covered by crops, and only a small area of land not suitable for cultivation was used as grazing (Table 3). This indicates that the DM supply of green forage was estimated to be 12.4% of annual feed balance, and comparable with the report from India (Raju *et al*., 2017). Hence, the contribution of crop residue to livestock feed presumably takes the major DM supply. A similar scenario is reported from Mali (Ayantunde *et al*., 2015), while grazing is restricted to areas not suitable for cultivation in the study area. In accordance, Mengistu *et al* (2017) and Kebede *et*

Table 3. Households' major livestock feed resources and annual dry matter yield (tons)

Feed resource type	Wealth group			Overall mean (156)	*P-value*	Total DM	% DM
	Better (40)	Medium (85)	Low (31)				
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)			
Private grazing	2.3(0.3)[a]	1.1(0.1)[b]	0.3(0.1)[c]	1.3(0.1)	***	5.6	12.4
Communal grazing	0.1(0.0)	0.1(0.0)	0.2(0.0)	0.1(0.0)	ns		
Fallow land	0.7(0.1)[a]	0.5(0.1)[ab]	0.3(0.7)[b]	0.5(0.1)	**		
Crop aftermath	2.7(0.3)[a]	1.9(0.1)[b]	1.3(0.1)[b]	1.9(0.1)	***	5.9	13.0
Cereal straws	13.4(0.9)[a]	10.4(0.5)[b]	6.5(0.4)[c]	10.4(0.4)	***	30.3	66.7
Pulse straws	0.9(0.1)[a]	0.7(0.1)[ab]	0.4(0.1)[b]	0.7(0.1)	*	2.1	4.6
Forage crops	0.9(0.2)[a]	0.3(0.1)[b]	0.2(0.0)[b]	0.4(0.1)	*	1.3	2.9
HMC	0.2(0.0)[a]	0.1(0.0)[b]	0.1(0.0)[b]	0.1(0.0)	*	0.2	0.5
Total DM	21.3	15.2	9.0	15.2		45.4	100.0

***(P≤0.001); **(P≤0.01); *(P≤0.05); ns: non-significant; abc: means within the same row with different superscripts are significantly different; HMC: Homemade concentrates; DM: Dry matter *al* (2016) reported that grasslands significantly dwindled, were highly fragmented, and were limited to areas where conditions are adverse for cropping. Hence, the meager land left for grazing had become overgrazed and degraded through time unless restoration actions were implemented urgently. During critical feed problems (cropping season), livestock rely mainly on straws that are low in feeding value, and similar situations were reported in the other production areas of Ethiopia (Tolera *et al*., 2012; Tadesse *et al*., 2016). Forage crops (oat and maize), and HMCs fed selectively to oxen, lactating cows, calves and equines (pulling cart) by setting priority to the importance of the animals during the critical feed problem (quantity and quality). The crops (maize and oat) are cultivated as a buffer crop and restricted too few *Kebeles* in the area. Actually, livestock owners follow different feeding strategies for efficient utilization of available resources throughout the year. Contrary to the bulkiness of the straw, its nutrient content was low due to its inherent high fiber content and management practice. Mainly, wheat straw was by far the largest feed component with poor feed value, as farmers complained about its palatability and intake. Therefore, address the problem of feed scarcity through improved forage cultivation around homesteads and degraded areas (Wolkaro and Tesfaye, 2025; Hussein, 2024).

Nutritional quality of major feed resources: Chemical composition and nutritive value of the major livestock feeds in the study area are shown in Table 4. Marked variation in nutrient composition was observed among feed types and across wealth groups, reflecting differences in feed sourcing, management intensity, and crop-livestock integration practices in the Bale highlands (Debela, 2021; Hussein, 2024). The CP content of the mixed natural pasture, straws (barley and pulse) and emmer wheat straw showed some variations between the wealth groups. Wheat and emmer wheat straw have the lowest CP compared to barley, *teff* and pulse. The relatively low NDF content of mixed natural pasture from low-wealth HHs might be linked to the type of vegetation grown (species and maturity) and other prevailing factors. The NDF content of cereal straws and crop aftermath was high, compared to pulse straw (categorized as medium-quality roughages). Mean ADF values of the mixed natural pasture and wheat straw of the better wealth group were lower compared to the other cereal straws and crop aftermath of the groups. The ADL content of roughage feeds ranges from 4.2% (*teff* straw) to 11.2% DM (crop aftermath) across the entire wealth groups (Table 4). The IVDOMD from the mixed natural pasture was better than other feeds (straws and crop aftermath), followed by the pulse straw across the wealth groups. The lower IVDOMD% was recorded for emmer wheat from the medium wealth group, while the highest IVDOMD% was recorded for the barley straw of better groups that might be directly/indirectly associated with farm inputs and land preparation.

Based on the chemical composition analysis of the feeds, CP of mixed native pasture for the wealth groups was lower than 6.4% of native grass hay in Ethiopia Tolera *et al.,* 2012). The difference might be attributed to agro-ecology, and forage species. All the investigated feeds, except HMCs, had less than the minimum level of 7% CP requirement for optimum rumen microbial function. To achieve the maximum intake of straw, a CP content of 66-85 g per kg DM is necessary and lower CP feeds should be compensated by supplementation of protein feeds to meet the requirement (Keftesa, 1988). This agrees with recent findings that cereal straws in intensively cultivated highland systems are generally poor in protein due to advanced maturity at harvest and removal of leaf fractions during threshing (Galchu and Wondater, 2024; Abebe, 2024). The relatively higher CP observed in mixed natural pasture under better wealth households likely reflects better pasture access management and relatively improved vegetation composition compared to degraded communal grazing lands (Ketemaw *et al*., 2025). The present study feeds NDF content confirmed the low intake reported by Van Soest (1967) of NDF above 55%, that limit DM intake. The feeds IVDOMD value ranges between 49.9 and 54.7% for cereal straw and 54.2 to 57.0% for pulse straw across the wealth groups. The native pasture digestibility was within the range of roughage feeds IVDOMD values to maintain the voluntary intake of the animals, though the annual DM yield from native pasture was too low.

When compared with standard nutritional requirements, the CP content of most evaluated feeds was below the minimum threshold required for optimal rumen microbial activity (7% CP), except for homemade concentrates (Van Soest, 1994; Hussein, 2024). This indicates that the majority of basal diets in the study area are protein-deficient and require supplementation (Defar *et al*., 2025) to support efficient microbial fermentation and livestock productivity. Recent studies in Ethiopian highland mixed farming systems similarly report widespread protein deficiency in crop residues and native pastures (Abebe, 2024; Hussein, 2024). In general, low CP and ME content, necessitating strategic supplementation with improved forages, protein-rich concentrates, or legume integration to enhance livestock production sustainability (Debela 2021; Hussein, 2024), characterize the dominant feed resources comprising crop residues, natural pasture, and aftermath grazing.

Nutrient availability and deficits: The estimated annual maintenance DM, ME, and DCP requirements of the study HHs' livestock are presented in Table 5. The total DM requirement for the livestock herded by the wealth groups was different based on the number of animals owned and differences in requirements. The overall mean

Table 4. Chemical composition of major feeds

Wealth group	Feed type	DM%	%DM						
			OM	Ash	CP	NDF	ADF	ADL	IVDOMD
Better (40)	MNP	93.2	91.4	9.3	6.3	67.1	33.7	6.1	62.6
	Wheat S	92.4	91.6	8.5	2.9	76.9	39.4	5.8	50.2
	Barley S	92.5	91.8	8.2	3.5	74.6	46.0	6.1	54.7
	EWS	92.4	91.1	8.9	2.6	77.3	52.8	6.9	50.0
	Teff S	90.1	91.7	8.3	3.6	77.9	46.7	4.2	54.2
	Pulse S	90.7	90.2	9.5	5.8	53.9	42.6	8.68	57.0
	CA	94.6	90.9	9.1	3.8	79.8	56.3	11.2	40.4
	HMC	93.7	91.1	8.9	19.4	48.9	18.9	6.3	65.2
Medium (85)	MNP	92.8	90.5	9.5	5.3	65.9	39.3	5.3	58.3
	Wheat S	93.2	91.4	8.6	2.9	76.9	46.1	6.3	50.1
	Barley S	92.6	91.9	8.1	3.5	74.0	45.7	6.3	54.4
	EWS	92.3	91.7	8.3	2.7	76.9	52.5	6.8	49.9
	Teff S	90.1	91.9	8.1	3.3	76.5	49.1	4.7	53.3
	Pulse S	90.9	90.4	9.3	5.8	54.4	42.5	8.6	54.2
	CA	94.6	90.9	9.1	3.8	79.8	56.3	11.2	40.4
	HMC	94.7	91.4	7.0	19.1	49.5	19.8	6.5	64.9
Low (31)	MNP	93.2	92.5	8.9	6.6	58.9	37.3	6.5	59.8
	Wheat S	92.4	91.2	8.8	2.9	77.0	52.9	6.8	50.0
	Barley S	92.4	91.7	8.3	3.4	71.0	43.3	5.9	54.0
	EWS	92.4	90.8	9.1	2.7	77.0	52.7	6.8	49.9
	Pulse S	90.8	90.3	9.4	5.8	53.6	42.5	8.6	55.6
	CA	94.6	90.9	9.1	3.8	79.8	56.3	11.2	40.4
	HMC	94.8	90.9	8.2	18.8	49.9	19.9	6.7	63.4

MNP: Mixed native pasture; EWS: Emmer wheat straw; S: Straw, CA: Crop aftermath; HMC: Homemade concentrate; DM: Dry matter; OM: Organic matter; CP: Crude protein, NDF: Neutral detergent fiber; ADF: Acid detergent fiber; ADL: Acid detergent lignin; IVDOMD: *In-vitro* digestible organic matter in the dry matter

DM requirement at the farm level was comparable to the medium HH animals' total requirement. In the study area, feed demand varied markedly among households due to differences in herd composition, herd size, and production objectives. Similar patterns of heterogeneous feed demand across wealth strata in mixed crop-livestock systems have been widely reported in intensive highland farming areas (Dejene *et al*., 2024; Tahir *et al*., 2018). The estimated ME requirement of the wealth groups varied due to their differences in herd categories owned and the type of products or services obtained from the animals, which demanded a variable amount of energy in addition to maintenance. The highest ME (MJ) deficit (24.2%) belongs to the better wealth group, while the ME of the medium and low groups was found to have some extra energy. These differences accounted for the herd size belonging to the wealth groups and the energy concentration of the feed sources. On the other hand, the excess annual ME nutrient supply of the feeds (especially straws) was in question since wheat straws in the area claimed for poor palatability and intake. The medium group's total DCP requirement deficit approximated to less than half of the better group's requirement. This might be attributed to the relatively higher TLU number owned by the better group. The deficit seen in the low wealth group appears to be compromised to fill the gap with some opportunistic and unconventional feeds when available. Though the major input cost of livestock production is feed supply, the differences in farmland use type and cropping pattern between the wealth groups brought disparity in nutrient balance. Hence, livestock feed requirement is principally adjusted for major nutrients from the available feeds to minimize nutrient lose, and meet the requirement. The observed DM and DCP deficits, particularly among better-off households, indicate that available feed resources are insufficient

Table 5. Estimated variability for household level maintenance dry matter, energy and digestible crude protein requirements for the livestock

Livestock category	Wealth group households: Better (40)			Medium (85)			Low (31)			Overall mean (156)		
	DM (ton)	ME ('000MJ)	DCP (Kg)	DM (ton)	ME ('000MJ)	DCP (Kg)	DM (ton)	ME ('000MJ)	DCP (Kg)	DM (ton)	ME ('000MJ)	DCP (Kg)
Cow	10.9	65.0	498.9	5.1	29.7	227.8	2.0	11.5	88.1	5.9	35.1	269.4
Ox/bull	14.2	68.4	749.1	8.9	42.6	465.5	4.5	21.3	233.4	9.4	44.9	491.9
Heifer	3.1	21.6	231.2	1.6	10.8	115.2	0.5	3.6	38.1	1.7	12.1	129.6
Steer	3.2	20.3	217.6	1.0	6.5	69.6	0.3	2.3	25.2	1.4	9.2	98.7
Calf	1.2	14.0	155.1	0.7	7.7	85.2	0.3	3.4	37.3	0.8	8.5	93.6
Sheep	1.2	8.0	98.7	0.6	4.7	58.2	0.3	2.1	25.5	0.7	5.1	62.1
Horse	2.2	12.4	179.8	0.7	29.7	61.4	0.3	1.1	27.8	1.1	5.8	84.8
Donkey	2.8	12.7	163.7	1.5	42.5	90.6	0.7	3.3	42.9	1.7	7.7	99.8
Requirement	38.8	222.4	2293.9	20.1	174.1	1173.5	8.9	49.4	518.3	22.7	128.4	1329.7
Available	21.3	168.7	763.5	15.2	181.8	482.5	8.9	66.6	220.4	15.2	117.3	488.8
Deficit	17.5 (-)	53.8 (-)	1530.5 (-)	4.9 (-)	7.7 (+)	691.0 (-)	0.0	17.2 (+)	297.9 (-)	7.5(-)	11.2 (-)	840.9 (-)
% deficit	45.1	24.2	66.7	24.4	Excess	58.9	Excess	Excess	57.5	33.0	8.7	63.2

DM: Dry matter; ME: Metabolizable energy; DCP: Digestible crude protein; -: Deficit; +: Excess

to sustain maintenance requirements year-round. This aligns with findings from similar highland systems where feed scarcity is a major determinant of livestock productivity constraints (Abebe, 2024; Gebremariam and Belay, 2023).

The existence of feed deficit also reflected on the body condition of the herds, while studies revealed livestock constrained due to feed deficit (Assefa *et al*., 2013; Gizaw *et al*., 2017). The deficit might be compensated for by opportunistic and unconventional feeds (peels of vegetables, crop thinning, household wastes) considered for this particular study, while herd seasonal mobility is also a remedy. Such feeds might be more nutritious to compensate for the deficit to a significant level. The higher ME deficit belongs to the better wealth, while there was a significant excess in the low groups, and the total mean ME annual coverage was 91.3% (Table 5). However, the argument is that "whether all the available energy is utilized or/not due to the lignocellulose complex of the feeds" to provide energy for maintenance (Abate *et al*., 2012). The result implies there was a thrilling scarcity of annual DCP for maintenance that contributed to the slow growth rate of the animal. Although seasonal mobility of the herd to other areas, use of opportunistic feeds, and microbial protein synthesis in the rumen may partially offset nutrient shortages, they are insufficient to compensate for the persistent DCP deficits (Desta, 2024). Furthermore, household wastes, occasionally purchased green forages from the market, and splitting the herds were compulsory. The DCP deficit in the present study was comparable with the previous report (Abera *et al*., 2014) in Ethiopia. As far as roughage feeds' low nutrient content found in excess, backyard *ad lib* straw feeding has emerged, and let the animals to feed more time than usual. In addition, as herd size per HH becomes small, such a feeding system is practiced, and animals are able to attain a maintenance condition over time. The small amount of green feed, bulk straws, less adoption of forage crops, and inaccessibility of industrial by-products were the major contributors to animal feed imbalances in the area.

Conclusion

Livestock production is a cornerstone of smallholder livelihoods in the Bale Highlands, where strong crop–livestock integration supports household resilience. Despite this interaction, the livestock sector faces chronic feed shortages in both quantity and quality, driven by extensive cultivation, population pressure, and land-use change. Cattle, which constitute the largest share of household herds, play a central role in livelihoods, yet their productivity is constrained by degraded grazing lands, poor-quality crop residues, and significant feed losses during periods of surplus and conservation. Although cereal straws represent the dominant feed resource, contributing substantially to total feed supply and their low digestibility (IVDOMD: 49.9-54.7%) limits intake and nutrient availability. Digestible crude protein supply remains critically deficient, particularly in households with larger herd sizes, leading to reduced animal productivity. These findings highlight the urgent need for targeted interventions to improve feed resource utilization through better management of crop residues, promotion of improved forage cultivation and strategic use of concentrate feeds to enhance nutrient balance and livestock productivity.

Acknowledgment

The authors would like to acknowledge Addis Ababa University and Madda Walabu University for logistics and input cost support. The authors would like to thank the staff of the study area districts' agriculture and rural development offices, development agents who assisted in data collection, and farmers of the study area for their cooperation.

References

Abate, D., S. Belete, T. Wegi, S. Usman, J. Wamatu and A. J. Duncan. 2012. *Characterization of the livestock production systems and the potential of feed-based interventions for improving livestock productivity in Sinana district, Bale Highlands, Ethiopia.* International Livestock Research Institute (ILRI), Nairobi, Kenya. 45 pp.

Abazinab, H. B. and E. Muleta. 2024. The effect of agro-ecological zone on the chemical composition of feed resources in the Gera district, southwest Ethiopia. *Discover Agriculture 2*(1): 68.

Abdulahi, M. M., F. Fiona and A. Angassa. 2025. Evaluation of livestock feed supply and demand in districts surrounding Bale Mountain National Park, Ethiopia: A strategy for biodiversity conservation. *Range Management and Agroforestry 46*(1): 23-30.

Abebe, M. 2024. Evaluation of replacing wheat bran with Ensete Ventricosum Corm on feed intake, weight gain, *in-vitro* digestibility and economic efficiency of Doyogena sheep. Doctoral Dissertation, Wachemo University.

Abera, M., A. Tolera and G. Assefa. 2014. Feed resource assessment and utilization in Baresa watershed, Ethiopia. *International Journal of Science and Research* 3(2): 66-72.

Alam, M., S. A. Sumy and Y. A. Parh. 2015. Selection of the samples with probability proportional to size. *Science Journal of Applied Mathematics and Statistics* 3(5): 230-233.

AOAC. 1995. *Official Methods of Analysis*. 15th edn. Association of Official Analytical Chemists, Washington, DC, USA. pp. 1094.

Arsham, H. 2007. Questionnaire design and survey sampling. Web-based technical report, Merrick School of Business, University of Baltimore, Baltimore, MD, USA. Available at: http://home.ubalt.edu/ntsbarsh/stat-data/Surveys.htm (accessed on April 24, 2024).

Assefa, D., A. Nurfeta and S. Banerjee. 2013. Assessment of feed resource availability and livestock production constraints in selected kebeles of Adami Tullu Jiddo Kombolcha district, Ethiopia. *African Journal of Agricultural Research* 8(29): 4067–4073.

Ayantunde, A. A., C. Umutoni and G. J. Sawadogo. 2015. Evaluation of feed resources in mixed crop-livestock systems in Sudano-Sahelian zone of Mali in West Africa. *International Journal of Livestock Research* 5(8): 27-36.

Beever, D. E. and F. L. Mould. 2000. Forage evaluation for efficient ruminant livestock production. *In:* D.L. Givens, E. Owen, R.F.E. Axford and H.M. Omed (eds.), *Forage Evaluation in Ruminant Nutrition*. CABI Publishing, Wallingford, UK. pp. 15-42.

Biradar, N., P. Sharma, S. Pandey, Satyapriya, M. Singh and S. Radotra. 2013. Livelihood analysis of livestock farmers in arid region of Deccan Plateau. *Range Management and Agroforestry* 34(1): 131-136.

BoFED. 2020. Socio-economic profile of Bale zone. *Working paper (unpublished report).* Bureau of Finance and Economic Development, Bale Zone, Oromia Region, Ethiopia.

Church, D. C. and W. G. Pond. 1982. *Basic Animal Nutrition and Feeding*. 2nd edn. John Wiley and Sons, New York, USA. pp. 1-564.

CSA. 2021. *Agricultural Sample Survey: Livestock and Livestock Characteristics*. Bulletin 583, Vol. II. Central Statistical Agency, Addis Ababa, Ethiopia.

Debela, T. 2021. Assessment of available livestock feed resources in South Gondar zone, Amhara National Regional State, Ethiopia. *American Journal of Agriculture and Forestry* 9(4): 269-275.

Defar, G., T. Tesfaye, T. Amene and M. Guyo. 2025. Effects of nitrogen fertilizer application rate on desho grass (*Pennisetum glaucifolium*) herbage yield and nutritional compositions across harvest days. *Range Management and Agroforestry* 46(2): 292-300.

Dejene, M., H. Beshir, G. Tadesse. 2024. *Animal Feed Policies and Feeding Practices in Ethiopia*. Kigali: AKADEMIYA2063, 2024. In: AKADEMIYA2063 Working Paper, 12.

Desta, A. G. 2024. Seasonality, balance and coping mechanisms of livestock feed in Northwestern Ethiopia. *Cogent Food and Agriculture 10*(1): Article 2343895. https://doi.org/10.1080/23311932.2024.2343895.

Eba, B. 2012. *Study of smallholder farms livestock feed sourcing and feeding strategies and their implication on livestock water productivity in mixed crop-livestock systems in the highlands of the Blue Nile Basin, Ethiopia.* Ph.D. Dissertation, Haramaya University, Haramaya, Ethiopia. pp. 139 pp.

FAO. 1987. *Land Use, Production Regions, and Farming*

Systems Inventory. Technical Report No. 3, Vol. 1. FAO, Addis Ababa, Ethiopia.

Galchu, T. U. and W. B. Wondater. 2024. Evaluation of nutritional composition of major available feed resources for backyard sheep fattening. *Online Journal of Animal Feed Research* 14(6): 410-423.

Gebremariam, T. and S. Belay. 2023. Livestock nutrition and feed balance on smallholder farms in Tanqua-Abergelle district, northern Ethiopia. *Heliyon* 9: e22131. https://doi.org/10.1016/j.heliyon.2023.e22131.

Geleti, D., M. Hailemariam, A. Mengistu and A. Tolera. 2013. Herbage yield and quality of selected accessions of Centrosema species grown under sub-humid climatic conditions of western Oromia, Ethiopia. *Global Veterinaria* 11: 735-741.

Gizaw, S., A. Ebro, Y. Tesfaye, Z. Mekuriaw, Y. Mekasha, D. Hoekstra and A. Tegegne. 2017. Feed resources in the highlands of Ethiopia: a value chain assessment and intervention options. *International Livestock Research Institute (ILRI) Working Paper*, International Livestock Research Institute, Addis Ababa, Ethiopia. pp. 58.

Gryseels, G. 1988. *Role of livestock on mixed smallholder farms in the woredas near Debre Berhan*. PhD Thesis, Wageningen Agricultural University, Wageningen, The Netherlands. pp. 220.

Gurmessa, K., T. Tolemariam, A. Tolera, F. Beyene and S. Demeke. 2015. Feed resources and livestock production situation in the highland and mid-altitude areas of Horro and Guduru districts of Oromia Regional State, western Ethiopia. *Science, Technology and Arts Research Journal* 4(3): 111-116.

Hailemariam, S. N., S. Teshome and T. Demel. 2016. Land use/land cover change in the Bale Mountain eco-region of Ethiopia during 1985–2015. *Land* 5(41): 1-22.

Hailesilassie, A., M. T. Taye, M. Diyessa and W. Mekuria. 2024. Land use and land cover changes and their effect on ecosystem service values in the Bale Ecoregion, southeastern Ethiopia. *Frontiers in Environmental Science* 12:1386026. https://doi10.3389/fenvs.2024.1386026.

Hassen, A., A. Ebro, M. Kurtu and A. C. Treydte. 2010. Livestock feed resources utilization and management as influenced by altitude in the central highlands of Ethiopia. *Livestock Research for Rural Development* 22: Article 229.

Hussein, A. 2024. Climate smart agriculture strategies for enhanced agricultural resilience and food security under a changing climate in Ethiopia. *Sustainable Environment* 10: Article 2345433. https://doi.org/10.1080/27658511.2024.2345433.

Jahnke, H. E. 1982. *Livestock Production Systems and Livestock Development in Tropical Africa*. Kieler Wissenschaftsverlag Vauk, Kiel, Germany. pp. 343.

Kearl, L. C. 1982. *Nutrient Requirements of Ruminants in Developing Countries*. International Feedstuffs Institute, Utah Agricultural Experiment Station, Utah State University, Logan, Utah, USA. pp. 381.

Kebede, G., F. Feyissa, G. Assefa, M. Alemayehu, A. Mengistu, A. Kehaliew and M. Abera. 2016. Chemical composition and *in-vitro* organic matter digestibility of Napier grass accessions in mid and highland areas of Ethiopia. *International Journal of Livestock Research* 6(4): 41-59.

Keftesa, D. 1988. Role of crop residue as livestock feed in Ethiopian highlands. In: *Proceedings of the Third PANESA Workshop on African Feed Resources Network*, Arusha, Tanzania. International Livestock Centre for Africa (ILCA), Addis Ababa, Ethiopia. pp. 430-439.

Ketemaw, H., B. Asmare and Y. Mekuriaw. 2025. Assessment of farmers' perception and forage species diversity of grazing lands in area enclosures and non-enclosures in the highlands of Ethiopia. *Journal of Agricultural and Environmental Science* 10(2): 16-34.

Mamo, B., A. Mengistu and B. Shenkute. 2023. Feed resources potential and nutritional quality of major feed stuffs in the three agro-ecological zones of mixed farming system in Arsi zone, Ethiopia. *Asian Journal of Research in Animal and Veterinary Sciences* 6(3): 241-252. https://doi.org/10.9734/ajravs/2023/v6i3251.

McDermott, J. J., S. J. Staal, H. A. Freeman, M. Herrero and J. A. Van de Steeg. 2010. Sustaining intensification of smallholder livestock systems in the tropics. *Livestock Science* 130(1-3): 95-109.

Mekasha, A., K. Gerard, L. Tesfaye, L. Nigatu and A. J. Duncan. 2014. Interconnection between land use/land cover change and livestock feed resource management strategies. *Agriculture, Ecosystems and Environment* 188: 150-162.

Mekonnen, K., P. Thorne, M. Gebreyes, J. Hammond, M. Bezabih, S. A. Kemal, L. Tamene, G. Agegnehu, R. Yahaya, A. Gebrekirstos, M. Thai, K. Sharma, A. Adie and A. Whitbread. 2023. Research for development approaches in mixed crop-livestock systems of the Ethiopian highlands. *Frontiers in Sustainable Food Systems 7:* 1080725. https://doi.org/10.3389/fsufs.2023.1080725.

Mekuria, W., K. Mekonnen, P. Thorne, M. Bezabih, L. Tamene and W. Abera. 2018. Competition for land resources: Driving forces and consequences in crop-livestock production systems of the Ethiopian highlands. *Ecological Processes 7:* 30. https://doi.org/10.1186/s13717-018-0143-7.

Mengistu, A., G. Kebede, F. Feyissa and G. Assefa. 2017. Review on major feed resources in Ethiopia: Conditions, challenges and opportunities. *Academic Research Journal of Agricultural Science and Research* 5(3): 176-185.

Morgan, G. A., N. L. Leech, G. W. Gloeckner and K. C. Barrett. 2004. *SPSS (Statistical Packages for Social Sciences) for Introductory Statistics: Use and Interpretation.*

Psychology Press, London/New York.

Raju, J., P. Reddy, A. Reddy, C. Kumar and I. Hyder. 2017. Livestock feed resources in surplus rainfall agro-ecological zones of Andhra Pradesh. *International Journal of Livestock Research* 7(2): 148-163.

Seré, C., H. Steinfeld and J. Groenewold. 1996. *World Livestock Production Systems*. FAO Animal Production and Health Paper No. 127. Food and Agriculture Organization of the United Nations, Rome, Italy.

Shapiro, B. I., G. Gebru, S. Desta, A. Negassa, K. Negussie, G. Aboset and H. Mechal. 2015. *Ethiopia Livestock Master Plan: Roadmaps for Growth and Transformation*. Working Paper. International Livestock Research Institute (ILRI) and Ministry of Agriculture, Addis Ababa, Ethiopia.

Tadesse, Y., A. Abebe, S. Zerihun, T. Debelu and W. Tezera. 2016. Characterization of goat production systems in western Ethiopia. *International Journal of Livestock Research* 6(7): 24-37.

Tahir, M. B., A. M. Wossen and B. T. Mersso. 2018. Evaluation of livestock feed balance under mixed crop–livestock production system in the central highlands of Ethiopia. *Agriculture and Food Security* 7: 19. https://doi.org/10.1186/s40066-018-0170-8.

Tessema, Z. K., W. F. De Boer, R .D. Baars and H. T. Prins. 2011. Changes in soil nutrients and vegetation in response to grazing. *Journal of Arid Environments* 75(7): 662–670.

Tolemariam, A. and M. Jaleta. 2015. *A Diagnostic Study of Crop–Livestock Interactions in Ethiopia*. International Livestock Research Institute (ILRI), Working Paper, Addis Ababa, Ethiopia.

Tolera, A., A. Yami and D. Alemu. 2012. Livestock Feed Resources in Ethiopia: Challenges, Opportunities and the Need for Transformation. *Working Paper*, Ethiopia Animal Feed Industry Association, Addis Ababa, Ethiopia. pp. 48.

Tolera, A. and A. N. Said. 1994. Assessment of feed resources in Welayta Sodo. Unpublished Report/ Working Paper, Ethiopia.

Van Soest, P. J. 1967. Development of a comprehensive system of feed analyses. *Journal of Animal Science* 26(1): 119-128.

Van Soest, P. J. 1994. *Nutritional Ecology of the Ruminant. 2nd edn.* Cornell University Press, Ithaca, New York, USA. 476 pp.

Van Soest, P. J. and J. B. Robertson. 1985. *Analysis of Forages and Fibrous Foods*. Cornell University Agricultural Experiment Station, Cornell University, Ithaca, New York, USA.

Wolkaro, T. and G. Tesfaye. 2025. Role of forage legumes in enhancing soil fertility and livestock nutrition in Ethiopia. *American Journal of Applied Scientific Research* 11(3): 145-151.

Yadessa, E., A. Ebro, L. Fita and G. Asefa. 2016. Livestock feed production and feed balance in Meta-Robi district, Ethiopia. *Academic Research Journal of Agricultural Science and Research* 4: 45-54.

Yami M., B. Bedada and T. Teklemedihin. 2013. Enhancing livestock productivity in Ethiopian highlands. *African Journal of Water Conservation and Sustainability* 1(1): 14-29.