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Feed resources assessment, laboratory evaluation of chemical composition of feeds and livestock feed balance in *enset (Ensete ventricosum)*-based mixed production systems of Gurage zone, southern Ethiopia

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The study was conducted in four districts of Gurage zone, Sothern Nations Nationalities and People's Region to determine the quantity and quality of available feed resources and to measure the livestock feed balance. A total of 360 households from *dega* (highland) and *weinadega* (midaltitude) peasant associations were selected using proportional sample size determination (Cochran, 1909; Thrustfield, 2013). The DM produced from leaf and leaf midribs of *enset* (*Ensete ventricosum*), crop reissues and natural grasses in tons, respectively, were 506.4 (52.73%), 312.33 (32.52%) and 141.62 (14.75%) in *dega* and 662.96 (49.36%), 472.83 (35.2%) and 207.33 (15.44%) in *weinadega.* The DCP produced from *enset* leaf and leaf midribs, crop residues and natural pasture, respectively, were 51819.91 kg, 8401.16 kg and 10335.43 kg in *dega,* 55217.94 kg, 13799.32 kg and 11490.23 kg in *weinadega.* The ME produced in *dega* was 4420872, 2296269.8 and 1188191.8 MJ whereas it was 6013047.2, 3430459.7 and 1689739.5 MJ in *weinadega* from *enset* parts, crop residues and natural pasture, respectively. The amount of DM, DCP and ME produced by individual household per year in *weinadega* agroecology were significantly higher (p<0.05) than the amount produced in *dega* agroecology. The annual feed supply in the study areas met only (76.81%) DM and (69.9%) DCP of the maintenance requirement of livestock in TLU but available ME was (1.67%) surplus. Conversely, the annual feed supply met only (64.98%) DM, (66.24%) DCP and (85.66%) ME of the maintenance requirement of livestock at *dega* agroecology, whereas in *weinadega,* agroecology about 88.31% DM and 73.46% DCP of the maintenance requirement were met but the estimate of ME was 17.22% above the requirement. This indicates that the livestock in the study areas of Gurage zone are in serious feed deficit which needs a special attention in supplementing the livestock with concentrates of protein sources for both agroecologies and energy for *dega* agroecology to overcome deficiency, especially during dry periods for reasonable livestock production.

Key words: Chemical composition, *Dega*, feed balance, feed resource, Gurage zone, Weinadega.

INTRODUCTION

Throughout their long history, Ethiopians have constantly relied on livestock in order to survive. Livestock in Ethiopia are extremely important as they serve a wide variety of functions in society from social to subsistence purposes (Kimball, 2011; Dereje et al., 2014). Despite relatively low notice they are afforded, livestock are estimated to contribute to the livelihoods of 60 - 70% of the Ethiopian population (Halderman, 2004). As the oldest form of assets in Ethiopia, livestock have and still today serve as a significant indicator of wealth. An estimate indicates that the country is home to about 54 million cattle, 25.5 million sheep, 24.06 million goats, 1.8 million horses, 5.4 million donkeys, 335 thousand mules, 760 thousand camels and 38.1 million poultry (Tilahun and Schmidt, 2012; CSA, 2013a).

Livestock provides a significant nutritional supplement to vulnerable groups, increase the flexibility of smallholder households in the face of food crises, and help to maintain traditional social safety nets (Randolph et al*.,* 2007; Dereje et al., 2014). The agricultural sector contributes 52% to the gross domestic product (GDP) and 90% to the foreign exchange earnings (CSA, 2008). The livestock subsector contributes about 16.5% of the GDP and 36% of the agricultural GDP and the subsector currently support and sustain livelihoods for 80% of all rural population (Metaferia et al., 2011). It also contributes 15% of export earnings and 30% of agricultural employment (Behnke, 2010). Despite high livestock population and existing favorable environmental conditions, the current livestock contribution is below its potential due to various reasons associated with a number of complex and inter-related factors such as feed shortage and disease (Berhanu et al*.,* 2009; Selamawit et al., 2017), less efforts in introducing the appropriate package of improved livestock technologies of cross breeding, improved feed management practices and adequate healthcare services which enhance the current livestock production and productivity (Getahun, 2012) and inadequate feed, water scarcity, poor health management, low productivity of local breeding stock (Dawit et al., 2013).

Based on degree of integration of livestock with crop production, level of input and intensity of production and agroecology, livestock production systems in Ethiopia has been classified into four major production systems of smallholder crop-livestock mixed system, pastoral and agro- pastoral, urban and peri-urban, and intensive dairy farming (Azage and Alemu, 1998). The mixed-farming system occupies the central part of Ethiopia and cover about 40% of the country's land area and 90% of the human population. In this farming system, the entire feed requirement for livestock is derived from native pasture and the balance comes from crop residues and stubble grazing (Tolera, 2009; Funte et al., 2010; Dereje et al., 2014; Selamawit et al., 2017).

Agricultural production systems in Ethiopia are predominantly subsistence smallholder mixed farming, with crop and livestock husbandry typically practiced within the same management unit and the Gurage zone is part and parcel of this system of production where *enset* and livestock have highly been integrated. The integral production components of this *enset*-livestock based production system of the study areas of Gurage zone is milk and manure production followed by meat, draught power and cash income. Though the number of livestock in Gurage area are enormous, shortage of feeds, especially during dry season become a major constraint and affects productivity of livestock. In this study area livestock production constraints and farmers' needs have not yet been fully studied. Improvement in livestock productivity can be achieved through identification of production constraints and introduction of technologies which have capability of improving the existed production bottlenecks and compatible with the system of production.

Therefore, it is important to assess the quantity and quality of the available feed resources in relation to the requirements of livestock on annual basis in a given area. Hence, this study was conducted in *dega* and *weinadega* agroecologies of Gurage zone with the following specific objectives:

1) To identify available livestock feed resources and determine chemical compositions of the major feeds in the study area, and
2) To assess livestock feed balance in the study area.

MATERIALS AND METHODS

Description of the study area

The study area, Gurage zone, is found in the Southern Nations, Nationalities and Peoples' Region (SNNPR) of Ethiopia. It is located between 37° 28' and 38° 38' longitude and 7° 28' and 8° 27' latitude, covering an area of about 5,932 km^2. Based on the data from Gurage zone Department of Finance and Economy Development (DOFED), the zone has thirteen administrative *woreda (*districts) with 412 peasant associations (PAs) and two town administrations. The zone bounds with Oromiya regional state in the north, northeast and northwest, Silti zone in the south east, Hadiya zone in the south, and Yem special woreda in west directions. Wolkite, the capital of the zone, is 155 km away from Addis Ababa in the Addis-Jimma road (DOFED, 2015).

Human population size of the zone is estimated to be 1,624,125(51.4% women and 48.6%, being men) and 88.2% of the population are farmer entirely dependent on subsistent agriculture (CSA, 2013b; DOFED, 2015). Gurage zone is one of the most densely populated areas in the country, with an average of 273.5 people/km^2 mainly concentrated in the agroecology of *dega* (highland) and *weinadega* (midaltitude). *Wirch* (cold) ((4.1%), *dega*

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(27.5%), *weinadega* (65.3%) and *Kola* (hot) (3.1%) are four agroecological zones of the area. Annual rainfall ranges between 801 and 1400 mm (DOFED, 2015). Based on data from the Department of Agriculture and Natural Resource Development of Gurage zone (DANRD), three different zonations with distinct farming systems are identified: First, localities with an altitude above 2200 masl and growing mainly *Enset (Ensete ventricosum*), Barely (Hordeum vulgare), Field pea (*Pisum sativum*) and Fababean (*Phaseolus vulgaris*). Second, altitudinal range between 1800 and 2200 masl and growing major crops of *Enset (E. ventricosum*), *Teff* (*Eragrostis teff*), Maize (*Zea mays*) and Khat *(Catha edulis)*. Third, altitudinal range between 1600 to 1800 masl and growing major crops of *Teff* (*E. teff*) and Maize (*Zea mays*) (DANRD, 2016).

The average annual temperature of the zone is about 18°C. The current land use pattern of the zone, is 398,887 ha of land for crop production, 92,421 ha for grazing, 42,933 ha for forest, 17,168 ha degraded land and 41,791 ha of land for other social services giving institutions. A livestock population of 3,611,159 is found in the zone, of which 1,678,455 cattle, 616,900 sheep, 260,420 goats, 820,269 chickens, 128,532 horses, 9,464 mules and 97,119 donkeys (DOFED, 2015).

Sampling and sample size determination

Information on nature of peasant associations (PAs) in relation to livestock population and other agricultural practices, particularly *enset* (*E. ventricosum*) production was obtained from zonal and each of four selected *woreda* (districts) offices of livestock and fishery resource development and agriculture and natural resource development. PAs were identified after having *enset* and livestock population data at each PA and a total of eight (8) PAs, (2) PAs from each *woreda* (one *dega* and one *weinadega*) were purposively selected based on the number of livestock, enset production and accessibility.

The sample size of households (HHs) were determined using Cochran (1909) and Thrustfield (2013) sample size determination formula: $n = Z^2 * P(1-p)/e^2$; n adjusted = n/ [1+ ((n-1) /N)]; where: n = sample size in the population, Z-score = 1.96 for confidence level 95%, N = total HHs in the 4 study *woreda*, P = proportion of population score of 1= 0.5, 1-p = 0.5 and e = standard error of the proportion = α = 0.05. A total of three hundred and sixty (360) HHs from eight PAs (45 HHs from each PA) were selected for the study. The selected PAs of *dega* and *weinadega* from each *woreda* for the study, respectively, were *Shamene* and *Shehremo* from *Ezia woreda*; *Achene* and *Wukiye* from *Muhir* and *Aklil woreda*; *Moche* and *Yeferezye* from *Cheha woreda* as well as *Agata* and *Kochira* from *Enemor* and *Aner woreda*.

To design the questionnaire used in the study, information was gathered from a total of purposively selected 40 HHs (5 from each PA) through rapid field survey and consultations with experts, DAs from respective zonal and woreda offices. It was summarized and used as a basis to design structured questionnaires to quantify the most important information to the study. The survey questionnaires were also pre-tested with two HHs from each PA and the necessary adjustment was made and translated into local language (Amharic) prior to actual survey based on the pre-test. One-day training was organized for enumerators on how to administer the questionnaire. Interview was done by the researcher together with the enumerators and DAs from HHs of target peasant associations. The interviews was done at the farmer's home to make possible counterchecking of the respondent's response with respect to the types of feed resources, livestock feeding system, number of livestock population, types of species owned, types of annual crop produced, *enset* production and *enset* uses, interaction of livestock-*enset* production, land holding and the overall farming management system of the HH.

Data types and methods of data collection

Primary and secondary data sources were collected from all PAs selected for the study. Secondary sources including: climate, soil, topography, agro-ecology, human population, livestock population, *enset* production and its use, crop production and associated problems were collected from respective zonal and *woreda* offices of livestock and fishery resource development as well as agriculture and natural resource development and through review of different documents. Primary data such as family size, land holding, land use pattern, major livestock feed resources, grain and crop residues produced, seasonal feed resources, herd size and herd structure of HH were generated by field visits, interviews and group discussions. Feed samples taken for laboratory analysis were those feeds used by the HHs of study areas to feed their animals that include: leaf and leaf midribs of *enset* plant, natural grasses, and straws and stubbles of wheat, barley, *teff*, field pea, faba bean as well as stover of maize.

The feed quantity and potentially available crop residues was assessed from December 2016 to March 2017 when almost 100% of annual crops had fully been harvested. Group discussions comprising elder farmers, experts of livestock and crop agriculture and development agent (DA) were made at each *woreda* (district) zonal level to clarify issues not well addressed thought survey and to validate some information collected from individual interview. A total of 32 individuals, 6 (2 farmers, 2 experts and 2DAs) from each *woreda* as well as 8 experts at zonal offices (6 from livestock and 2 from crop agriculture) were participated in the group discussion. The discussion focused on identifying constraints related to feed, livestock and *enset* production.

Feed quantity estimation

The quantity of potentially available DM from leaf and leaf midribs of *enset* (*E. ventricosum*) used for animal consumption was estimated by considering a mean of 8 (eight) tons per year per hectare of enset growing land as reported by Bureau of Agriculture and Rural Development (BoARD, 2009) of SNNPR. The quantity of DM feed obtainable from natural grasses were determined by multiplying the hectare under each land use category by their respective estimated annual DM yield per hectare, that is, 2.0 t/ha (FAO, 1984, 1987). The quantity of available DM from crop residues produced by HHs was estimated by conversion of grain yields to straw ratio using multipliers of 1.5 for wheat, barley and *teff* straws; a multiplier of 1.2 for DM yield of field pea and faba bean straw as suggested by FAO (1987). A multiplier of 2.0 was employed for estimation of DM output from maize stover, as proposed by *De* Leeuw and Tothill (1990). The quantity of crop residues potentially available for animal consumption was estimated by assuming 10% wastage either during utilization or used for other purposes or both (Adugna and Said, 1994). The amount of crops grain yield was quantified by interviewing the HHs and cross checked it with the data recorded by DAs and the respective offices of agriculture and natural resource development for any deviation. The grazing potential of crop stubbles was estimated using a mean of 0.5 ton per hectare of land as reported by FAO (1987).

To determine the potential forage biomass yield and DM production, representative samples of grasses was taken from an enclosure of individual HH holdings of the studied PAs by making transect lines and grasses species was identified together with herders and range experts (Ahmed, 2006). Samples were taken from mid of August, 2017 to mid of September, 2017 when almost all the pasture plants were fully grown to their 50% flowering. From randomly selected HHs, a sample size of 80 quadrants (1 m × 1 m) was considered per agroecological zone (5 HHs per PA and 4 samples per HH). In each quadrant, harvesting was done at the ground level.

Table 1. Characteristics of the households in the study areas of Gurage zone.

Agroecological zones	Household variables (%)		
	Male	Female	Overall
Dega (n=180)	92.8	7.2	100
Weinadega (n=180)	74.4	25.6	100
Total (N = 360)	83.6	16.4	100

Dega = highland, *Weina Dega* = mid altitude, n = sample HHs per agroecology, N = total sample HHs of the study.

To undertake chemical analysis, a composite sample was taken from the bulk.

Assessment of livestock feed requirement

The total annual available feed was compared with the annual requirements of the livestock population. Livestock populations were converted into Tropical Livestock Unit (TLU) as suggested by Gryseels (1988) and Bekele (1991). Nutrients supplied by each feed types was estimated from the total DM output and nutrient contents of that feed on DM basis (Abdinasir, 2000). The total nutrient requirements of crude protein (CP) and metabolizable energy (ME)) per day per TLU were estimated based on the recommendations of Kearl (1982) and McCarthy (1986) for one tropical livestock unit.

Chemical analysis of sample feeds

Representative samples of feed resources of leaf and leaf midribs of *enset (E. ventricosum)*, crop residues (stover, straws and stubbles) and natural grasses from *dega* and *weinadega* agroecological zones were collected, bulked, dried, sub-sampled and ground to pass through 1 mm mesh sieve and packed in an airtight clean plastic bag and stored until required for determination of (DM), ash, organic matter (OM), nitrogen (N), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and *in vitro* dry matter digestibility (IVDMD). The DM content of feed samples was determined by an oven at 60°C for 72 h until constant weight before chemical analysis. Sub samples from partially dried sample feeds were taken and ignited in a muffle furnace at 550°C for 6 h to determine the ash and OM contents of each feed following the methods described by AOAC (1990).

Chemical analysis of each feed for Ca and P were performed at Wolkite Regional Soil Analysis Laboratory by atomic absorption spectrophotometer following the methods described by Perkin (1982). Determination of (IVDMD) from feed samples was performed at Holetta Agricultural Research Center's Animal Nutrition Laboratory following the modified Tilley and Terry method (Van Soest and Robertson, 1985).A chemical analysis on (ADF), (ADL) and, (NDF) in the sample feeds were performed at Animal Nutrition Laboratory of College of Agriculture and Veterinary Medicine of Jimma University, following the procedures of Goering and Van Soest (1970). Similarly, (N) content of feed samples was determined at Animal Nutrition Laboratory of College of Agriculture and Veterinary Medicine of Jimma University using Kjeldahl method and crude protein (CP) was calculated as N × 6.25 (AOAC, 1995).

Metabolizable energy (ME) and digestible crude protein (DCP) content of a particular feed was estimated from (IVDMD) and (CP) contents, respectively, as per the following equations:

A. ME (MJ/kg DM) = 0.015*IVDMD (g/kg) (MAFF, 1984)

B. DCP (g) = 0.929*CP (g/kg) -3.48 (Church and Pond, 1982)

Data analysis

The collected data were analyzed in such a way that they meet research objectives and answer research questions. Statistical package for social sciences (SPSS, version 20) was used for the analysis of collected data after checking, correcting and coding. Descriptive statistics such as table, figures or charts, percentage, mean, and standard error was used to present the results.

RESULTS AND DISCUSION

Characteristics of household

In the study area of *dega,,* agroecology male HHs accounted for 92.8% whereas female HHs accounted for 7.2%. In the *weinadega* agroecology, however, 74.4% HHs were male and the remaining 25.6% were female headed (Table 1). Overall, average of male headed HHs (83.6%) in current study is higher than the result (67%) made by Azage (2004) in Addis Ababa, 52.3% for Hawassa town was reported by Haile et al. (2012) as well as (75.9%) in Jimma town reported by Belay and Janssens (2016). The observed difference in the percentage of female headed HHs among *weinadega* and *dega* rural areas in particular and in the study areas of Gurage zone in general (Table 1), respectively, could probably be attributed to the greater rate of evacuation of males from *weinadega* to the different cities and towns of the country in search of job opportunity leaving the rural HH occupation to their wives and cultural issues might force females to get married and/or push aside the females from being having power of bargaining on economic motives (Group Discussion).

As indicated in the Table 2, about 65% of the farmers in *dega* areas have got better opportunity of education when compared to those 57.3% HHs found in *weinadega areas*. The overall mean of 61.1% observed in the current study for educated HHs is lower than the result 98.1% reported by Belay and Janssens (2016) in Jimma town. The differences observed in level of education between the study areas of Gurage zone as well as between Gurage zone and that of Jimma area could be attributed to difference in access to schools. Group discussion with experts with different fields of studies in agriculture was made whether or not education has importance for HHs on performing different agricultural activities. All group members of discussion agreed on the advantages of education to improve production and productivity of HHs through utilizing different technologies of production.

In most cases, literate HHs are supposed to be very eager to accept extension services and other income generating activities which enable them to enhance their productivity and production level. Ekwe and Nwachukwu

Table 2. Level of education of households in the study areas of Gurage zone.

Agroecological zones	Level of education of household head (%)				
	Illiterate	Grade 1-6	Grade 7-8	Grade9-10	Grade ≥ 11
Dega (n=180)	35.0	57.2	3.3	3.9	(0.6)
Weinadega (n=180)	42.7	42.8	6.7	7.8	0.0
Over all (N = 360)	38.9	50.0	5.0	5.8	0.3

Dega = highland, *Weinadega* = mid altitude, n = number of sample HHs per agroecology, N = total sample HHs of the study.

Table 3. Mean (±SE) family size of HHs in sex and age group in the study areas of Gurage zone.

Agroecological zones	Age of HHs	Family size of HHs in sex and age group				
		Total	Male	Female	Age between 15 and 65	Age ≤14 and ≥65
Dega	49.44±0.7	7.34±0.25[b]	3.64±0.13[b]	3.63±0.13[b]	5.66±0.18	1.68±0.1[b]
Weinadega	48.44±0.6	8.09±0.25[a]	4.02±0.14[a]	4.07±0.14[a]	6.03±0.18	2.04±0.11[a]
Total	48.94±0.5	7.71±0.18	3.83±0.1	3.85±0.13	5.85±0.13	1.86±0.07

[a-b] Means in the same column sharing different letters of superscripts are significantly different (P<0.05), *Dega* = highland, *Weinadega* = mid altitude, HHs = households

Table 4. Households keeping local and cross cattle breed in the study areas of Gurage zone.

Agroecological zones	Types of cattle breeds owned by households (%)	
	Local cattle only	Both local and cross cattle
Dega(n = 180)	85.0	15.0
Weinadega(n = 180)	88.3	11.7
Overall (N= 360)	86.7	13.3

Dega = highland, *Weinadega* = midaltitude, n = sample HH per agroecology, N = total sample HHs of the study.

(2006) reported that farmers with educated background adopt usually new technologies more rapidly and easily than uneducated farmers to ensure good results. Similarly, Mulugeta (2005) indicated that HHs with low level of education can have an influence on the transfer of agricultural technologies and their participation in development which is in line with the result of current study.

The average family size per HH across the agroecologies of *dega* and *weinadega* was 7.71 (Table 3). The family size in the *weinadega* agroecology was significantly higher (P<0.05) than the *dega* areas. The average size of the family members in the study area is lower than the average family size of 9.92 reported from Adami Tullu Jiddo Kombolcha district of east Showa zone of Oromiya region by Dawit et al. (2013). However, it is higher than the average family size of 6.2 reported from highland and midaltitude of Basona worana woreda of north Shoa (Ahmed, 2006); 7.05 reported from Aleta Chukko *woreda* of Sidama zone in southern Ethiopia by Beriso et al. (2015); 6.02 reported from Jimma area by Belay and Janssens (2016) and 6.6 reported from north Achefer district in Amhara region by Selamawit et al. (2017). The large family size in the study areas of Gurage zone could probably be related to the agricultural activities (*enset*) which are relatively labor intensive.

About 15 and 11.7% of the HHs in the *dega* and *weinadega* agroecology, respectively, possessed some crossbred cattle along with their indigenous cattle and most of these crossbred animals are of calves of 1 - 2 years and heifers of younger age majority of which are obtained by purchase from neighboring zones and region. Conversely, 85% of farmers in *dega* and 88.3% in *weinadega* agroecology kept indigenous cattle breeds only (Table 4). Though the level of products obtained from indigenous cattle are low, the nature of cattle association with production of *enset* (*E. ventricosum*) and to overcome risks and calamities of nature, HHs of the study areas urged to keep these low productive indigenous cattle breeds. Major bottlenecks and uncertainties which forced HHs to manage indigenous cattle were lack of advantages of AI services and opportunities of getting appropriate technologies to improve livestock productivity which corresponds with

Table 5. Mean (±SE) landholdings and land use pattern in both agroecology of Gurage zone.

Land allocation for different activities in hectare	Agroecological zones		
	***Dega* (n =180)**	***Weinadega* (n =180)**	**Overall (N= 360)**
Land holding per HH	1.44±0.04[b]	2.08±0.09[a]	1.75±0.05
Annual crops	0.58±0.02[b]	0.71±0.04[a]	0.64±0.02
Khat, coffee and fruits	--	0.20±0.01	0.10±0.01
Enset	0.29±0.01[b]	0.46±0.02[a]	0.37±0.01
Grazing	0.35±0.02[b]	0.51±0.03[a]	0.43±0.02
Forest	0.12±0.01[b]	0.20±0.01[a]	0.16±0.01
Potato and vegetables	0.10±0.01	--	0.05±0.00

[a-b] means in the same row with different letter of superscripts are significantly different (P<0.05), n = number of respondents, *Dega* = highland, *Weinadega* = mid altitude, -- = not available.

Minale and Yilkal (2015), who reported that the owner of the cattle in southern Ethiopia at Chencha and Kucha districts had a problem of getting AI services through which they can upgrade the genetic makeup of their low producing dairy animals.

Average landholdings and land use pattern

Households of Gurage zone included in this study are engaged in a mixed crop-livestock production systems and have possessed their own land which is used for different activities of livestock and crop agriculture. Out of the total land holdings of HHs in the *weinadega* agroecology, 0.71, 0.46, 0.51, 0.20 and 0.20 ha were allocated for the production of cereal crop, *enset* (*E. ventricosum*), grazing, forest and perennial crops of *Khat*, coffee and fruits, respectively. Similarly, the allocation of land by HHs in the *dega* agroecology was 0.58, 0.29, 0.35, 0.12 and 0.10 ha for cereal crop, *enset*, grazing, forest and potato and vegetables production (Table 5). Of the total land holdings owned by HHs across the study areas the average of land allocated for *enset (E. ventricosum)* production was 0.37 ha.

The average land holding per HH in *weinadega* agroecology was 2.08 and 1.44 ha for *dega* agroecology. The overall average land holding, average land holding for *enset* production and grazing per HH per agroecology was significantly higher (P<0.05) for *weinadega* than the *dega* agroecology of the study area. The overall average land holding per household across the agroecologies of study areas was 1.75 ha (Table 5) which is more comparable with the result of 2.18 ha reported by Selamawit et al. (2017) from north *Achefer* district in Amhara region but is much lower than the value of 3.3 ha reported by Yitaye et al. (2007) in the highland areas of *Amhara* region; 2.5 ha by Yeshitila (2008) in southern Ethiopia at *Alaba* district; 2.34 ha reported by Misgana et al. (2015) at selected districts of east Wollega Zone; 4.25 and 2.75 ha by Dereje et al. (2014), respectively, from *Humbo* and *Dembi* villages of Diga woreda in east Wollega zone of Oromiya Region.

Grain and crop residues production in the study areas

The average grain yield of field crops and their residues in both *dega* and *weinadega* agroecologies in the study areas of Gurage zone are very limited in type and it is not more than three crops grown in each agroecology and that limit the amount of crop yield for human and crop residues used in livestock feeding. In the study areas, farmers have mainly focused on the production of *enset (E. ventricosum*) which provides not only the food for the family but also major source of feed for the livestock particularly of cattle (Table 11). During the study period, group discussion was made with farmers from each of agroecology engaged in crop production and experts of livestock and crop agriculture. The discussants disclosed that the main reason of farmers to focus on *enset* production is due to reduced available land for grazing and crop cultivation as well as lack of appropriate farming technologies to produce enough food crops to feed the family and crop residues that can support their livestock which agreed with the report of Risse et al. (2006), who reported that in *enset* production systems there is a shortage of grazing as well as arable land, which in turn tends to limit production of annual crops and/or pastures that contributed to shortage of livestock feed resources.

Herd size and structure between agroecologies

Cattle ownership varies depending on the type of agroecology, wealth status and the overall farm production objectives. The average cattle holding per household in both *dega* and *weinadega* agroecologies in the study areas of Gurage zone, respectively, was 3.34 TLU and 3.37 TLU with overall mean of 3.35 whereas the average number of cattle owned by HH of *dega* and *weinadega* agroecology, respectively, was 4.86 and 4.88

Table 6. Grain and crop residue yield (t HH^{-1}) for common field crops grown in *dega* and *weinadega* agroecologies of the study areas of *Gurage* zone.

Crop types	Agroecologies of the study area					
	Dega		*Weinadega*		Overall	Overall
	Grain	Straw	Grain	Straw	Grain	Straw
Wheat	0.15±0.02[b]	0.23±0.02[b]	0.21±0.02[a]	0.31±0.03[a]	0.18±0.01	0.27±0.02
Barely	0.65±0.02	0.97±0.03	--	--	0.32±0.02	0.49±0.03
Teff	--	--	0.51±0.02	0.77±0.06	0.26±0.02	0.38±0.04
Field pea	0.16±0.01	0.19±0.01	--	--	0.08±0.01	0.09±0.01
Fababean	0.06±0.01	0.07±0.01	--	--	0.03±0.00	0.03±0.00
Maize	--	--	0.65±0.03	1.3±0.06	0.32±0.02	0.65±0.05

[a-b] means in the same row with different letter of superscripts are significantly different (P<0.05), -- = not available, tHH^{-1} = ton per HH, *Dega* = highland, *Weinadega*= mid altitude.

with the overall average of 4.87 as indicated in Table 7. The average number of cattle per household for current study (4.87) is a bit higher than the average cattle number of 4 at Akaki and Lemu, central Ethiopia reported by Bayush et al. (2008); however, it is tremendously lesser than 15.5 in mixed crop livestock production system of Central Rift Valley, 17.9 around Debre Birhan and 19.4 cattle around Ziway Central Rift Valley, 8.27 at Adami Tullu Jiddo Kombolcha district in Oromiya Region, respectively, reported by Lemma et al. (2005), Ahmed (2006), Zewdie (2010) and Dawit et al. (2013).

There was no significant difference (P> 0.05) on the average cattle holding per household in both agroecologies. However, marked difference (P<0.05) was observed on the average holdings of sheep, goats, horses, and donkeys per HHs. Sheep and horses per HH were higher (P<0.05) in *dega* agroecology whereas goats and donkeys were higher (P<0.05) at *weinadega* agroecology of the study area of Gurage zone (Table 7). The differences observed in the average number of sheep and horses in the *dega* as well as goats and donkeys in the *weinadega* agroecologies could be due to suitable weather conditions, availability of feeds suitable for the specific classes of livestock in each agroecology. Moreover, the owning of higher average number of horses in *dega* as well as donkeys in *weinadega* agroecology, could be related to the animals suitability to overcome the transport problems of people and luggage associated with rugged terrains.

Major constraints affecting livestock production

As indicated in Table 8, about 87% of HHs in the study areas indicated feed shortage as the first major constraint in affecting livestock production and productivity. This is mainly due to shortage of land for grazing and fodder production as the result of expansion of crop agriculture in the expense of grazing land. It was also indicated during group discussion that the quantity and quality of natural grass is very low to meet the nutrient requirement of animals. Prolonged dry period, erratic rainfall and uneven distribution of rainfall affected growth performance of natural grass and residues from crop production. Moreover, absence or inadequate forage seeds availability and extension service rendered to this regard was almost insignificant which aggravated the shortage of livestock feed in the study area. According to the perceptions of participants, introduction of extension service on storage and efficient utilization of crop residues, establishment and management practices of improved forages and providing technical interventions to improve the existing grazing lands were some of the recommendations of the participants to alleviate livestock feed shortage.

Low performance of local cattle was the second important problem prioritized by 65% of the participants (Table 8). It was emphasized that indigenous animals of the area are generally characterized by small in size, low milk yield, slow growth rate and remain unproductive for long period. The amount of milk obtained/cow/day was not more than 1.5 L on average, which is insufficient to satisfy family consumption. The report of group discussion revealed that uncontrolled mating system and mating between relatives which are common in the area together with feed shortage considered as major causative factor for low productivity of these animals.

Fifty-five (55%) of the HH respondents ranked water as the third major problem for livestock production (Table 8). For most HHs especially

Table 7. (Mean ±SE) herd size and structure per HH in the *dega* and *Weinadega* agroecologies in the study area of *Gurage* zone.

Livestock species	Herd size and structure (in number)			Herd size and structure (in TLU)		
	Dega	***Weinadega***	**Overall**	***Dega***	***Weinadega***	**Overall**
Cattle	4.86±0.17	4.88±0.18	4.87±0.12	3.34±0.12	3.37±.14	3.35±0.1
Cows	2.08±0.070	2.21±0.094	2.14±0.059	1.78±0.068	1.87±.088	1.82±0.06
Oxen	0.23±0.032	0.21±0.033	0.22±0.023	0.26±0.035	0.23±0.037	0.24±0.03
Bulls	0.61±0.039	0.57±0.040	0.59±0.028	0.67±0.043	0.62±0.044	0.65±0.03
Heifers	0.73±0.058	0.83±0.065	0.78±0.044	0.38±0.031	0.43±0.034	0.40±0.02
Calves	1.21±0.068	1.07±0.052	1.14±0.043	0.25±0.015	0.22±0.012	0.24±0.01
Sheep	1.94±0.079[a]	.56±0.066[b]	1.25±0.063	0.19±0.007[x]	0.06±0.006[y]	0.12±0.01
Goats	.01±0.006[b]	1.42±0.103[a]	0.71±0.063	0.01±0.001[y]	0.14±0.010[x]	0.07±0.01
Horses	0.55±0.04[a]	0.02±0.010[b]	0.28±0.024	0.44±0.031[x]	0.01±0.008[y]	0.23±0.02
Mules	-	0.47±0.037	0.24±0.022	-	0.38±0.030	0.19±0.02
Donkeys	0.09±0.021[b]	0.35±0.036[a]	0.22±0.022	0.04±0.011[y]	0.18±0.018[x]	0.11±0.01
Total herd	-	-	-	4.02±0.029	4.14±0.03	4.07±0.03

[a-b] means with different letters of superscripts in the same row for *Dega* and *Weinadega* agroecologies differ significantly (P<0.05) for livestock number, [x-y] means with different letters of superscripts in the same row for *Dega* and *Weinadega* agroecologies differ significantly (P<0.05) for TLU, TLU = Tropical Livestock Unit, *Dega*= highland, *Weinadega*= mid altitude.

Table 8. Major problems hindering livestock production in study area of Gurage zone.

Major constraints (N = 360)	Priority levels (n)					Rank
	1	2	3	4	5	
Feed shortage	313(87)	27(7.5)	20(5.5)	-	-	1st
Performance of local animals	62(17.2)	234 (65)	14(3.9)	19(5.3)	31(8.6)	2nd
Water scarcity in dry season	59(20)	53(10)	187(55)	32(5)	29(8.1)	3rd
Livestock diseases	54(15)	38(10.5)	54(15)	180(50)	34 (9.5)	4th
Land degradation	73(20.3)	49(13.6)	43(11.9)	51(14.2)	144(40)	5th

N = total sample population of the study, n = number of respondents, number in the brackets indicate the percentage of respondent HHs of the study.

living in *dega* (highland) agroecology and for those living far from permanent rivers, water supply was crucial for survival of their animals particularly during dry periods. Members of group discussion suggested that moving livestock to distant places in search of drinking water is time consuming, tedious work, causes energy loss and needs intervention on the use of different water harvesting techniques to harvest runoff in the wet season to partially solve the problem and construction of appropriate water harvesting structures like deep wells and pond construction by making common theme among every concerned body of government, non-government organizations and the community.

Animal disease was the fourth constraint prioritized by 50% of the participants (Table 8) and prevalent diseases of the study area include: Anthrax, Blackleg, Foot and Mouth Disease (FMD), Bovine Pasteurollosis, Lump Skin Disease (LSD) and most of these diseases have mostly occurred between months of July to December. However, Anthrax was reported to occur during dry season of the year (November to April) when the conditions of animals become poor due to inadequate feeding. Mastitis, pneumonia and metritis are other common disease of livestock and these diseases have no common time to occur but they can attack the animals at any time within the year when the environments become suitable.

Ecto parasites of tick, lice, fleas, minge mites were common in the area and their infestation was also reported to be high immediately after long rainy season (October to December) of the year. The other parasitic diseases in the study area were the internal parasites including Faciolla (liver fluke), Lung worm and Ascaris which was common in wet season of the year (early June to September).In most of the cases, measures of disease prevention and control have been undertaken by the regional and local government bodies which is in line with the report of MoARD (2008), which revealed that those vaccines and medicines required for the handling of livestock are typically provided on a highly subsidized basis by the Veterinary Department of the Regional Agricultural Bureaus and sometimes through project finance.

Table 9. Percentage of grasses, forage legumes and forbs from area closure in the study areas of Gurage zone.

Production systems	Total grazing land (ha)	Proportion of sample grasses in dry matter (kg) and percent							
		Grasses		Forage legumes		Forbs		Total	
		%	DM (kg)	%	DM (kg)	%	DM (kg)	%	DM (kg)
Dega	84.94	89	126121.9	4.2	5951.82	6.8	9636.28	100	141710
Weinadega	127.39	86	178286.6	3.1	6426.61	10.9	22596.79	100	207310
Overall	212.33	87.5	304408.5	3.65	12378.43	8.85	32233.07	100	349020

Dega = highland, *Weinadega* = mid altitude, DM =dry matter, kg = kilogram, ha = hectare.

Groups that participated in the discussion indicated the existence of complaints on low preventive capability of (LSD) vaccine which is the only imported one and free of charge. In addition to inability of having drugs and vaccines with enough quantity as well as in a scheduled manner (in time), livestock owners in the study area were forced to buy and utilize some drugs and vaccines delivered by illegal traders which were not good enough to heal sick animals and to protect the animals from being affected. The constraints of livestock production identified in current study corresponds with the results made by Berhanu et al. (2009), Negassa et al. (2011), Getahun (2012), Dawit et al. (2013) and Dereje et al. (2014) who reported that the inadequacy of feed, water scarcity, disease prevalence, low productivity of local breeding stock are the main livestock production constraints in different parts of Ethiopia.

Seasonal availability of feed resources

Feed resources available at the different months of a year for both *dega* and *weinadega* agroecological zones in the study areas are strongly influenced by seasonality of the year. Gryseels (1988) and Gashaw (1992) observed similar trends of seasonal availability of feed resources in the central highlands of Ethiopia. In the study areas of Gurage zone leaf and leaf midribs of *enset (E. ventricosum)*, crop residues and natural pasture were the major feed resources for livestock feeding in different seasons. Among feed resources leaf and leaf midribs of *enset* took the largest share and the most common feed used by HHs to feed their animals mainly of cattle in dry seasons covering about eight (8) months within a year between (October to May).

The amount of DM feed produced from *enset* leaf and leaf midribs from *dega* and *weinadega* agroecology, respectively, were 506.4 tons (52.73%) and 662.96 tons (49.36%) from a total feed dry matter available for livestock feeding (Table 11). The result of current study agreed with the result reported by Brandt et al. (1997), who forwarded that following harvest, crop residues are given to the cattle, and among all *enset* growing groups *enset* leaves form an integral part of the dry season cattle diet and they may be used for as long as seven to eight months, depending on area and ethnic group. This indicates that *enset* plant is not only the plant that provides staple food (*kocho*) to the farming families but it is also the plant that safeguards life of cattle thereby keeping the livelihood of HH from being at risk. Feed problem is one of the major factors that hinders the development and expansion of livestock production. There was a definite time to utilize grazing land in the study area and it was dominantly utilized in the wet season of the year, mainly between the months of late August to December. Crop residues (straws of barley, field pea, wheat and faba bean) in *dega* and (*teff* and wheat straws as well as maize stover) in *weinadega* agroecology were also used as main feed during both dry and rainy seasons of the year (December to August). The result of the current study corresponds with the report of Alemayehu (2004), Tolera et al. (2012), Dereje et al. (2014) and Selamawit et al. (2017), who stated natural pasture and crop residues to be the major feed resources in different areas of Ethiopia.

Composition of natural grasses in the study areas

Measurement was made on the potential biomass yield and DM production of grasses and herbaceous species. Grasses species represented 89 and 86%, whereas legumes represented 4.2 and 3.1% DM biomass production from *dega* and *weinadega* agroecology, respectively. Biomass yield of grasses, forage legumes and forbs in kilogram, respectively, was 1484.84, 70.07 and 113.45 for *dega,* whereas it was 1399.53, 50.45 and 177.38 for *weinadega* areas per hectare of land (Table 9).

The lower proportion of legumes monitored in the study areas might probably be due to sprawling nature of growth of the legumes which make them more susceptible to be lost through grazing. Furthermore, the percent biomass composition of legumes in *weinadega* agroecology area was found to be lower than that in the *dega* agroecology. The variation observed among *dega* and *weinadega* areas of the study might be associated with the altitudinal differences in elevation of highland and midaltitude. This result is in line with the results made by Alemu (1990) and Alemayehu (2005), who reported that the proportion of legumes tends to increase with increasing altitude and particularly above 2,200 masl and at lower altitudes, native legumes are less abundant.

Feeding priority of cattle

Feeding strategy depends on the nature of the farming system, objective of herding animals and the availability of feed resources in specific area which is to be affordable by the farmers. In line with this, farmers were ranked feeding priority of crop residues and supplements to their livestock. From a total of 360 HHs that participated in the study, about 188(52.2%) of HHs were given priority of feeding to lactating cow-calf-week animal-oxen. Whereas, around 141(39.2%) of the HHs gave more attention to lactating cow-calf-oxen-week animal while the rest 31(8.6%) of HHs gave priority of feeding for plowing oxen-lactating cow-calf-weak animal. The mode of feeding priority in the current study area has given more attention to the lactating cows, calves, weak animals than the plowing oxen which is different from the report made by Mekuanint and Girma (2017) in *Gasera* and *Ginnir* districts in Bale zone of Oromiya region.

Group discussion on feeding priority of cattle was made and the report of group discussion confirmed that most HHs in the study areas (*enset* growers) have given first priority to lactating cows because of its advantage in providing: milk and milk products for home consumption with *kocho* (food prepared from a mixture of scraped pulp of the enset pseudo stem excluding the fibers and decorticated *Amicho* (corm of *enset*) and other purposes, manure to fertilize the *enset* garden and calf for replacing the herd. The calves were given the second priority because of their advantages for permanent milk production of the milking cows (if the calf dies, the cow will stop giving milk) and to produce replacement stock in the herd. Furthermore, as the land holding by individual HH is limited, most of the HHs have given less attention to produce annual cereal and pulse crops by giving more attention for *enset* (*E. ventricosum*) cultivation to produce *kocho* enough to feed the family members and this *enset* production system encourages the use of human labor to cultivate the land than the utilization of oxen for plowing.

Chemical composition and nutritive value

Dry matter (DM) and ash content

Chemical composition and nutritive value of the major feedstuffs utilized for livestock feeding in the study areas of Gurage zone was analyzed (Table10) and the dry matter (DM) content of the feeds available for livestock feeding in both *dega* and *weinadega* agroecologies was above 90%, which corresponds with the reported results of different scholars in different parts of the country (Ahmed, 2006; Sisay, 2006). The ash content of the major cereal crop residues in the study area ranged from (6.49 to 9.32%) for straws and from (4.23 to 9.81%) for stubbles. Wheat straw had the highest ash content (9.32%) in *weinadega*, followed by barely straw (9.02%) in *dega* agroecology (Table 10). The value reported for barely straw in this study was lower than the value (14.6%) reported by Yitaye (1999) and (19.7%) by Solomon (2004) but comparable with the value (9.11%) reported by Mekuanint and Girma (2017). On the other hand, the value of ash content for wheat straw (9.32%) was similar with (9.34%) reported by Mekuanint and Girma (2017), but higher than (8.94%) reported by Alemu et al. (1989) and (8.22%) reported by Solomon (2004). The ash content of maize stover recorded in this work (9.98%) is far greater than the result reported by Yitaye (1999), which was 7%. The variations observed on ash contents of crop residues of cereal crops could be associated with environmental factors of rainfall, soil character, temperature, and contamination of the residues by other external factors. The ash content of native grasses was 10.88% for *dega* and 11.97% for *weinadega* agroecology (Table 10). The variation observed could possibly be due to variation in agroecology of the study areas that corresponds with the report of Little (1982), who stated that the ash content of natural grasses increase as elevation in altitude decreases and such variations could possibly arise from difference in climate and soil types. However, Mekuanint and Girma (2017) reported (10.99%) ash content of native grasses from highland (*dega*) and (9.89%) from midaltitude (*weinadega*) which disagreed with the statement made by Little (1982) and the results recorded in the current study.

Crude protein (CP)

The crude protein (CP) content of crop straws varied from barley (2.63%) to field pea (5.54%). Lower CP value for barley straw reported in this study agrees with the report of Yitaye (1999), Solomon (2004) and Ahmed (2006). In general, the percentage of CP obtained from crop straws that are considered as available feed resources for livestock feeding in the study areas is much lower than that set as a minimum level of nitrogen (7%) to limit intake (Milford and Minson, 1966; Van Soest, 1982). The stubbles of barely, wheat, field pea and faba bean in the study areas had higher CP content than that of their corresponding straws (Table 10). Even though, there are findings that crop stubbles have lower leaf to stem ratio than the corresponding straws that limits the CP contents of the stubbles to minimum level (Ørskov 1988), the content of CP found in most of the stubbles in the current study was found to be higher than the CP content of the corresponding straws. This may be associated with the presence of grasses and other species of legumes that had grown on the crop field and left aside with the stubbles

Table 10. Chemical composition and nutritive value of feedstuffs in the study areas of Gurage zone.

Feedstuffs (*dega*)	Chemical composition of feedstuffs (%)							Nutritive value of feedstuffs				
	DM	Ash	OM	NDF	ADF	ADL	CP	DCP (g/kg)	IVDMD (%)	ME (MJ /kg DM)	Ca (g/kg)	P (g/kg)
Field pea straw	92.3	6.53	93.47	55.64	63.2	14.44	5.54	47.99	52.64	7.90	3.0	1.57
Field pea stubble	91.22	4.23	95.77	55.88	65.6	13.31	4.96	42.60	47.91	7.19	2.6	1.07
Faba bean straw	94.05	6.49	93.51	65	47.2	12.62	3.50	29.04	55.5	8.33	2.0	1.12
Fababean stubble	93.01	4.28	95.72	51.4	45.6	11.02	5.84	50.77	48.23	7.24	0.5	1.01
Barley straw	93.44	9.02	90.98	48.94	50.2	10.5	2.63	20.95	50.99	7.65	2.99	1.4
Barley stubble	92.13	6.1	93.9	57.44	35.2	9.49	3.79	31.76	44.89	6.73	1.7	1.07
Wheat straw	93.22	9.11	90.89	67.6	66	10.62	2.92	23.65	40.74	6.11	2.99	0.41
Wheat stubble	92.31	6.38	93.62	56.4	49.2	8.22	3.38	27.92	36.38	5.46	2.5	1.4
Enset leaf	92.65	7.12	92.88	64.92	38.34	6.37	11.39	102.33	58.18	8.73	3.99	1.28
Natural pasture	92.54	10.88	89.12	74.1	40.01	7.69	8.23	72.98	55.91	8.39	1.12	1.51
Feedstuffs *(Weinadega)*												
Wheat straw	93.62	9.32	90.68	62.4	64.4	10.62	3.19	26.16	40.74	6.11	2.80	0.37
Wheat stubble	92.01	5.97	94.03	55.08	51.4	8.46	2.34	18.26	35.68	5.35	2.36	1.23
Maize stover	94.03	9.98	90.02	68.8	47.6	10.59	3.79	31.73	49.93	7.49	2.0	0.47
Tef straw	93.12	9.07	90.93	69.4	49.2	10.12	3.5	29.04	51.02	7.65	2.61	0.9
Tef stubble	93.18	9.81	90.19	61.26	46	6.95	2.63	20.95	43.13	6.47	1.8	0.35
Enset leaf	92.40	7.31	92.69	61.06	39.18	6.31	9.34	83.29	60.45	9.07	3.29	1.09
Natural pasture	92.60	11.97	88.03	75.54	41.08	7.81	6.34	55.42	54.35	8.15	1.05	1.35

Dega = highland, *Weinadega* = mid altitude, DM = dry matter, OM = organic matter, NDF = neutral detergent fiber, ADF = acid detergent fiber, ADL = acid detergent lignin, CP = crude protein, DCP = digestible crude protein, IVDMD = In vitro dry matter digestibility, ME = metabolizable energy, MJ = mega joule.

of crops on crop grown fields during harvest. The CP content reported in current study from all residues of crops (Table 10), however, is at lower level to fulfill the optimum CP requirement of livestock which agreed with the general statement made by Preston and Leng (1984) which indicated that all cereal crop residues have low nitrogen content and are composed of cell wall components with little soluble cell contents.

Grasses from *dega* and *weinadega* agro-ecologies of the study areas, respectively, had CP content of (8.23%) and (6.34%). The value for CP content of grasses from *dega* agroecology was higher than that of *weinadega* area. Such differences may be associated with the reduction in the proportion of legumes in the pasture with a decrease in altitude and this is in line with the finding of Alemayehu (1985) and Mekuanint and Girma (2017). The CP values from natural grasses are closer to the minimum value reported by Milford and Minson (1966) and Van Soest (1982), required for optimum rumen microbial function, hence, can support maintenance requirement of ruminants with slight supplementation. Conversely, 11.39 and 9.34% CP contents (Table 10) were recorded from leaf and leaf midribs of *enset* (*E. ventricosum*) in *dega* and *weinadega* agroecology, respectively. The CP values obtained from *enset* parts in both agro ecologies have been far exceeded from all available livestock feeds in the study area and also higher than the minimum value (7%), required for optimum rumen microbial function that can support maintenance requirement of ruminants.

Neutral detergent fiber (NDF)

The neutral detergent fiber (NDF) content of straws of cereal crops in current study was between *teff* (69.4%) to barley (48.94%). Stubbles of most cereal crops had slightly lower NDF contents than their straws (Table 10). Sisay (2006) reported greater than 70% average NDF contents for cereal crop residues. Similar results of 79.4 and 72.98% were reported for the straws of cereal crops, respectively, by Alemu et al. (1989) and Solomon (2004). The NDF content of 78.6, 81.5 and 82.13%, respectively, for wheat straw, *teff* straw and maize stover were reported by Chalchissa et al. (2014). Solomon (2004) also reported 79.7% NDF content for cereal crops stubbles. Roughage feeds with NDF content of less than 45% categorized as high quality, 45 - 65% as medium quality and those with more than 65% as low quality (Singh and Oosting, 1992). The NDF content of straws of field pea, faba bean, barley and all crop stubbles identified in this study (Table 10) is found in the range of 45 - 65% and could be classified as medium quality roughages that may not impose drawbacks on animal performance. The NDF content of leaf and leaf midribs of *enset* was 64.92% for *dega* and 61.26% for *weinadega* agroecology which was laid between the ranges of 45 - 65% and it could be classified under medium quality livestock feed (Singh and Oosting, 1992). The NDF content of maize stover of current study (68.8%) is much lesser than the NDF content of maize stover (82.13%) reported by Chalchissa et al. (2014). NDF content of native grass reported in this study (74.1%) in *dega* and (75.54%) in *weinadega* were closer to the values reported by Ahmed (2006) and Solomon (2004). The higher NDF content could be a limiting factor on feed intake, since voluntary feed intake and NDF content are negatively correlated (Ensminger et al., 1990) and therefore, feeds with NDF content of greater than 65% in current study could be classified as low roughages, which could impose limitations on feed intake and animal production.

Acid detergent fiber (ADF)

The ADF content of crop straws varied from 47.2% in faba bean to 66% in wheat, whereas ADF content of crop stubbles ranged from 35.2% in barley to 65.6% in field pea. The ADF content for both crop straws and stubbles are within the range reported by Solomon (2004), Ahmed (2006) and Solomon et al. (2008). Conversely, the ADF content for native grass for *dega* and *weinadega* agroecologies, respectively, was 40.01 and 41.08%. The ADF content of maize stover was 47.6%. Kellems and Church (1998) categorized roughages with less than 40% ADF as high quality and above 40% as low quality. The results of ADF content of feeds in current study was higher than the ADF values reported by Yitaye (1999), for barley straw (39.45%), native grasses (29.98%) and maize stover (44.22%). Variation in ADF content could be attributed to differences in temperature, crop management and soil type. The ADF content of maize stover 51.72% reported by Chalchissa et al. (2014) was higher than the reported ADF value of 47.6% in current study whereas the ADF content of *teff* straw (46.8%) and wheat straw (58.1%) reported by the same authors was lower than the results of current study (Table 10). The percentage level of ADF on leaf and leaf midribs of *enset* (*E. ventricosum*) was as low as 38.34% in *dega* and 39.18% in *weinadega* (Table 10), which is lower than the higher limit category (40%) of ADF for high quality roughages (Kellems and Church, 1998) and the leaf and leaf midribs of *enset* can possibly be grouped under high quality roughages used in livestock particularly in cattle feeding.

Acid detergent lignin (ADL)

The acid detergent lignin (ADL) contained in different crop residues found in the study areas ranged from 6.95 to 14.44%. The highest concentration of lignin was found in field pea straw (14.44%) followed by faba bean straw (12.62%). The lignin content of field pea and faba bean straws found in this study is comparable with the results of 13.64 and 12.72% for pulse crops reported, respectively, from Gassera and Ginnir districts of Bale zone of Oromiya region by Mekuanint and Girma (2017). However, the results (16.37%) and (13.21%) reported, respectively, for field pea and faba bean straws by Solomon (2004) and 15.85 and 15.42% reported by Ahmed (2006) were higher than the results reported in current study. The percentage of lignin in crop stubbles reported in the current study also varies between 6.95% in *teff* stubble to 13.31% in field pea stubble. The highest lignin percentage was observed in the stubbles of field pea (13.31%) which is also in line with the ADL content of field pea stubbles (15.82%) as reported by Ahmed (2006).

The ADL content of legume crop residues recorded in this study (14.44) and (12.62) for field pea and faba bean straw as well as 13.31 and 11.02% for stubbles of field pea and faba bean (Table 10), respectively, were imperatively higher than the maximum level (7%) that limits DM intake and livestock production (Reed et al., 1986). This indicates the existence of large differences in lignification between crops residues of cereals (monocotyledons) and legumes (dicotyledons). The level of IVDMD and the ME produced from residues of legumes of the current study, however, are much better than those residues from cereal crops of non-legume origin (monocots) that could be associated with intrinsic nature of these two crop families. As reported in current study, non-legumes species (monocots) have much higher fiber concentrations (ADF and NDF) than legumes (dicots) and conversely grasses have lower concentration of readily digestible cell contents.

The result of current study is well comparable with the report of Buxton and Russell (1988), who reported that the most important difference existed between grasses (monocots) and legumes (dicots) in the concentration of fiber. Even though lignin has a negative impact on the fiber digestibility of legumes, the fact that legumes contain much lesser fiber (ADF and NDF) than grasses lessens its impact on overall digestible energy concentration. For this reason, lignin concentration is not a good indicator of digestible energy when making comparisons between grasses and legumes (Buxton and Russell, 1988). The lignin percentage in maize stover of the study area was found to be 10.59 while the percent lignin of native grasses of *dega* and *weinadega* agroecologies, respectively, was 7.69 and 7.87%, which are greater than limiting lignin content of 7%. The ADL in leaf and leaf midribs of *enset* (*E. ventricosum*) in the current study was 6.37% for *dega* and 6.31% for *weinadega agroecology* with the overall average lignin content of 6.34% for both agroecologies which is free of fear and lower than the maximum level of 7%.

In vitro **dry matter digestibility (IVDMD)**

The *in vitro* dry matter digestibility (IVDMD) for maize stover was 49.93% which is lower than the value reported for maize stover (58.65%) by Chalchissa et al. (2014). The level of IVDMD from leaf and leaf midribs of *enset* was about 58.18 and 60.45%, whereas it was 55.91 and 54.35% for natural grasses in *dega* and *weinadega* agroecologies, respectively. The IVDMD of straws of cereal crops ranged from 40.74 to 55.5% in which the faba bean straw had the highest (55.5%) content followed by field pea straw (52.64%). The value reported for wheat straw (40.74%) in this work (Table 10) was lower than that from all reported values for the straws of cereal crops of current study and similar results (41.92%) in Gassera and (42.22%) in Ginnir districts in Bale zone of Oromiya region was reported by Mekuanint and Girma (2017). Similarly, IVDMD content of corresponding cereal crops stubbles ranged from 35.68 to 48.23%. The highest value was recorded for the faba bean stubble (48.23%) and the lowest value recorded for wheat stubble (35.68%). From crop residues utilized for livestock feeding in the study areas, greater value of IVDMD was recorded for those straws and stubbles of legume origin. The results of the current study on IVDMD of crop residues was in line with the report of Buxton and Russell (1988) and Seyoum and Fekede (2008), who reported that cereal crop residues are normally characterized by low digestibility and energy value, which are both inherent in their chemical composition.

Metabolizable energy (ME)

The energy content of annual crops residues in the current study ranged from 5.35 MJ/kg DM (wheat stubble) to 8.33 MJ/kg DM (faba bean straw). Comparing the average energy content of residues of legume in one hand and that of other cereal crops on the other hand, the average energy content of (8.12 MJ/kg DM straw and 7.23 MJ/kg DM stubbles) of legume origin were higher in energy content than those of non-legume origin (7.14 MJ/kg DM for straws and 6 MJ/kg DM for stubbles). The average energy contents for crop straws and stubbles in this study were within the range reported by Solomon (2004) and Yitaye (1999) but the ME recorded in current study is much higher than the ME content of 5.96 MJ/kg DM for wheat straw reported by Chalchissa et al. (2014). The energy content of native grass in current study was (8.39 MJ/kg DM) in *dega* and (8.15 MJ/kg DM) in *weinadega* agroecology which is comparable with the report of Zinash et al. (1995) (8.19 MJ/kg DM) and Yitaye (1999), (8.17 MJ/kg DM). The energy content of maize stover in the study area (7.49 MJ/kg DM) was comparable with the report of Yitaye (1999) which was (7.33 MJ/ kg DM) but lower than that reported by Chalchissa et al. (2014) which was 8.79 MJ/kg DM. The energy value contained in leaf and leaf midribs of *enset* (*E. ventricosum*) from *dega* and *weinadega* agroecological zones, respectively, were 8.73 MJ/kg DM and 9.07 MJ/kg DM (Table 10). The observed variations on the value of energy content of leaf and leaf midribs of *enset* among agroecologies could probably be associated with differences in the agroecology and the type of *enset* landraces (clones) grown in each agroecology.

Calcium (Ca) and Phosphorus (P) content

Of the minerals, calcium and phosphorus are the two determining minerals in both function and amount in the production and productivity of livestock. The Ca content of crop residues in the current study for both agroecologies varied from 0.5 g/kg DM in faba bean stubble to 3 g/kg DM in field pea straw. The Ca content for natural pasture was 1.12 g in *dega* and 1.05 g/kg DM in *weinadega* agroecology. The maize stover had a Ca content of 2 g/kg DM whereas 3.99 and 3.29 g/kg DM (Table 10) was for leaf and leaf midribs of *enset (E. ventricosum) from dega* and *weinadega* agroecologies, respectively. The P in the crop residues in both agroecologies ranges from 0.35 g/kg DM (*teff* straw) to 1.57 g/kg DM (straw). The P content in natural grass from *dega* was 1.51 g/kg DM and 1.35 g/kg DM in *weinadega* agroecology. The P content of maize stover was 0.47 g/kg DM. The P in *enset* leaf and leaf midribs was 1.28 g/kg DM in *dega* and 1.09 g/kg DM in *weinadega* agroecology (Table 10). Ca Concentrations in majority of feeds except those grasses and stubbles of faba bean, barley and *tef* were at normal range. Conversely, P concentrations of nearly all feeds in the study areas were low when compared with the recommendations made by McDonald et al. (1995) and Kellems and Church (1998), (< 2 g/kg DM low, 2-3.5 g/kg DM normal and > 4 g/kg DM high) for both Calcium and Phosphorus.

Table 11. Estimated annual DM, DCP and ME produced in *dega* and *Weinadega* agroecologies in the study areas of Gurage zone.

Feedstuffs	Agroecological zones					
	Dega			***Weinadega***		
	DM(t)	**DCP (kg)**	**ME (MJ)**	**DM(t)**	**DCP (kg)**	**ME ('MJ)**
Field pea straw	33.26	1596.15	262754	--	--	--
Field pea stubble	12.61	537.17	90665.9	--	--	--
Faba bean straw	11.89	345.29	99043.7	--	--	--
Fababean stubble	4.13	209.68	29901.2	--	--	--
Barley straw	175.05	3667.3	1339132.5	--	--	--
Barley stubble	29.18	926.76	196381.4	--	--	--
Wheat straw	40.13	949.07	245194.3	55.18	1443.51	337149.8
Wheat stubble	6.08	169.75	33196.8	8.36	152.65	44726
Maize stover	--	--	--	233.14	7397.53	1746218.6
Tef straw	--	--	--	137.86	4003.45	1054629
Tef stubble	--	--	--	38.29	802.18	247736.3
Enset leaf	506.4	51819.91	4420872	662.96	55217.94	6013047.2
Natural pasture	141.62	10335.43	1188191.8	207.33	11490.23	1689739.5
Total	960.35	70556.5	7905333.6	1343.12	80507.49	11133246.4

Dega= highland, *Weinadega* = mid altitude, -- = not present, DM = dry matter, DCP = digestible crude protein, ME = metabolizable energy, t = ton, kg = kilogram, MJ = mega joule.

Estimated annual feed availability in both *dega* and *weinadega* agroecologies

Households in both agroecologies substantially depend on leaves and leaf midribs of *enset* (*E. ventricosum*) to feed their livestock particularly of cattle. The largest portion of dry DM was obtained from this *enset* parts which accounted for 506.4 tons (52.73%) of the total dry matter (TDM) produced in *dega* and 662.96 tons (49.36%) of the TDM produced in *weinadega* agroecology. In general, the amount of DM produced from *enset* parts in both agroecologies of the study areas accounted for 1169.36 tons (50.77%) of the total dry mater (TDM) of (2303.47 tons) which is greater than half of total feed produced and available for livestock feeding (Table 11).

The amount of dry matter produced from leaf and leaf midribs of *enset* in each study PA of *Shamene, Achene, Moche, Agata, Shehremo, Wukiye, Yeferezye* and *Kochira* of Gurage zone, respectively, in tons was 90.5(42.15%), 99(56.91%), 198(56.09%), 118(54.16%), 145.7(54.37%), 146.3(55.6%), 180.48(48.67%) and 190.4(49.35%). The result of current study on the leaf and leaf midribs of *enset (E. ventricosum)* is in line with reports of Brandt et al. (1997), who stated that among all *enset* growing groups *enset* leaves form an integral part of the dry season cattle diet and may be used for as long as seven to eight months of the dry season. Similar statement was made by Dereje (1996) and Menbere (2014), who reported that *enset* leaves are the major source of feed to the cattle; during the dry season cattle are substantially dependent on parts of the enset not normally eaten by humans, particularly the leaf, and leaf sheaths (midribs).

Dry matter produced from natural grass in the *dega* system was 141.62 tons (14.75%) while in the *weinadega* agroecology it was 207.33 tons (15.44%) from TDM produced in each agroecology. The DM production from maize stover accounted for 233.14 tons (17.36%). Crop straws of barley, wheat and field pea in *dega* and *teff* and wheat straws in *weinadega* agroecology represented the largest share of DM produced and used mainly as dry season feed which is in line with the report of Dereje et al. (2014) from Diga woreda of east Wollega zone indicated that crop residues are used as major sources of livestock feed during the dry season. As indicated in Table 11, the wheat straw in the study areas provided 40.13 tons (4.19%) DM; 926.76 kg (1.31%) DCP and 245194.3 MJ (3.1%) ME in *dega* as well as 55.18 tons (4.11%) DM; 1443.51 kg (1.79%) DCP and 337149.8 MJ (3.03%) ME in *weinadega* agroecology. However, HHs hardly provided wheat straw to their livestock when there is enough feed to sustain their animals but it is stored together with other crop residues as feed reserve and provided to their livestock when they were encountered in feed shortage which is similar with the report of Mekuanint and Girma (2017) from Gassera and Diga districts of Bale zone in Oromiya region. Use of improved fodder trees and those of agro industrial byproducts in the study areas were negligible, which is in agreement with the report of Alemayehu (2005), who reported that the production of improved pasture and forages in most parts of Ethiopia is insignificant and the contribution of agro industrial by products is also minimal and restricted

Table 12. Mean (± SE) DM, DCP and ME produced/HH in both agroecologies of Gurage zone.

Description	Agroecological zones				
	Dega	***Weinadega***	**Overall**	**Minimum**	**Maximum**
DM produced (t)	5.99±.19[b]	8.09±.30[a]	7.04±.19	1.456	25.980
DCP produced (kg)	397.26±14[b]	447.26±16[a]	422.26±11	100.61	1266.9
ME produced (Mj)	44951±1490[b]	61851±2232[a]	53401±1412	10939	187594

[a-b] Means in the same row sharing different letters of superscripts are significantly different (*P*<0.05), *Dega* = highland, *Weinadega*= midaltitude, HH = household, DM = dry matter, DCP = digestible crude protein, ME = metabolizable energy, t = ton, kg = kilogram, MJ = mega joule.

to some urban and peri urban farms. Similarly Dereje et al. (2014) indicated the importance of fodder crops as livestock feed, but farmers in the Humbo, Dapo and Dembi villages of Diga woreda in east Wollega zone hardly grow improved forage crops and the extension service to support forage development in the area appears to be weak and non-functional.

The total estimated digestible crude protein (TDCP) per annum in kilogram (Table 11) was 70,556.5 and 80,507.49 in the case of *dega* and *weinadega* agroecology*,* respectively*.* Similarly, the amount of total metabolizable energy (TME) produced in both *dega* and *weinadega* agroecologies of the study area in MJ, respectively, was 7,905,333.6 and 11,133,246.4. The annual TDM, TDCP and TME produced in each study PA of *dega* agroecology were 214.71 tons, 14177.1 kg and 1751200 MJ from *Shamene* PA; 174 tons, 13249.6 kg and 1443185 MJ from *Achene* PA; 353 tons, 27078 kg and 2924047 MJ from *Moche* PA; and 218.54 tons, 15966 kg and 1788124 MJ from Agata PA. Simultaneously, the annual TDM, TDCP and TME produced in each study PA of *weinadega* agroecology including Shehremo, Wukiye, Yeferezye and Kochira of Gurage zone, respectively, was 275 tons, 16974.8 kg and 2299757 MJ; 269.3 tons, 167344 kg and 22578814 MJ; 394.1 tons, 23037.2 kg and 3238484 MJ and 405 tons, 23736 kg and 3337348MJ (Table 13).

The mean feed DM in tons, digestible CP in kilogram and ME in mega joule produced per year per individual household in both *dega* and *weinadega* agroecological zones of Gurage zone was analyzed (Table 12). The average tons of DM produced per individual household in *dega* and *weinadega* agroecology, respectively, was 5.99 tons and 8.09 tons with the overall mean of 7.04 tons per farmer per annum. The amount of feed DM produced in the *weinadega* agroecology was significantly higher (p<0.05) than the mean annual produced feed DM in *dega* agroecology.

At the same time, the kilogram of DCP produced by individual household found in both agroecology was also analyzed and there was a significant difference (*P*<0.05) among the two agroecologies with the overall mean of 422.26 kg. Similar analysis on the mean annual production of ME was undertaken and the amount of ME in mega joule per individual HH of *dega* and *weinadega* agroecology, respectively, was 44951 and 61851 with the overall mean of 53401 MJ and significant difference (*P*<0.05) among the HHs of the two agroecologies was observed (Table 12).

Annual feed balance estimate in both *dega* and *weinadega* agroecology

The annual available feed was compared with the annual requirements of the livestock population. The daily requirement of DM, DCP and ME per TLU for maintenance were estimated based on the recommendations of Kearl (1982) and McCarthy (1986) for TLU. The overall estimated feed supply in the study area met only 76.81% and 69.9% of the maintenance DM and DCP requirement of livestock while the total estimate of ME were 1.67% in surplus per year (Table 13). Estimation on the amount of available feed supply and demand per year per agroecology of *dega* and *weinadega* were also made and there were differences in the available feed demand and supply (Table 13). In *dega* agroecology the available feed supply met only about 65.13% DM, 66.24% DCP and 85.66% ME of the maintenance requirement of livestock per farm per year. In *weinadega* agroecology, on the other hand, the available feed supply satisfied about 87.53% DM and 72.98% DCP of the maintenance requirement of livestock and the total ME estimates was 16.28% surplus per year (Table 13).

Within *dega* agroecology, the available feed on year round basis in *Moche* PA satisfied about 97.18% DM and 96.08% DCP maintenance requirement, whereas the estimated (ME) was 28.84% in surplus. On the rest of three PAs of *dega* agroecology (*Shamene, Achene and Agata)*, however, livestock were in serious negative feed balance and the available feeds could only satisfy the maintenance requirements of 53.06, 52.88 and 57.40 %DM; 48.61, 55.86 and 58.40% DCP and (69.29, 70.23 and 75.2% ME), respectively. However, there was relatively better feed availability in PAs of *weinadega* agroecology in which the available feed resources met about (79.47, 76.63, 95.61 and 98.39% DM), (68.25,

Table 13. Estimated annual nutrient supply, requirement (demand) and nutrient balance of livestock per peasant association in the study areas of Gurage zone.

Study PAs	Annual nutrient supply			Annual nutrient demand			Annual nutrient supply and demand balance		
	TDM (t)	TDCP (t)	TME (MJ)	TDM (t)	TDCP (t)	TME (MJ)	TDM (t)	TDCP (t)	TME (MJ)
Shamene TLU=198	214.71	14.18	1751200	404.72	29.17	2527282	-190 (46.94)	-15. (51.39)	-776081.9 (30.71)
Achene TLU=161	174.00	13.28	1443185.5	329.08	23.72	2055012	- 155.1(47.12)	-10.5(44.14)	-611826.6 (29.77)
Moche TLU=177.8	353.10	27.08	2924046.5	363.42	26.19	2269448.1	- 10.24 (2.82)	+0.91 (3.92)	+654598.4(28.84)
Agata TLU=186.3	218.54	15.99	1788123.7	380.80	27.45	2377942.2	- 162.31(42.6)	-11.41(41.6)	-589818.5(24.80)
Shehremo TLU=169.1	274.70	16.97	2299757.6	345.64	24.91	2158400.9	-70.96 (20.53)	-7.91(31.75)	+141356.74 (6.6)
Wukiye TLU=171.9	269.30	16.76	2257881.2	351.36	25.32	2194140.2	-82.1 (23.37)	-8.58 (33.89)	+63741.01(2.91)
Yeferezye TLU=201.7	394.10	23.04	3238484.3	412.27	29.71	2574508.9	-18.1 (4.39)	-6.67 (22.45)	+663975.4(25.79)
Kochira TLU=201.4	405.02	23.74	3337348	411.66	29.67	2570679.7	-6.62 (1.61)	-5.93 (19.98)	+766668.3 (29.8)
Total 1467.2	2303.5	151.04	19040027	2999	216.14	18727414	-695.5(23.19)	-65.1(30.1)	+312613(1.67)

Dega=highlands, *Weinadega* = mid altitude, TLU= tropical livestock unit, TDM = total dry matter, TDCP = total digestible crude protein, TME = total metabolizable energy, t =ton, kg = kilogram, MJ =mega joule, numbers in the brackets indicate the percentage of differences in annual TDM,TDCP and TME supply and demand balance between the study peasant associations.

66.11, 77.55 and 80.02% DCP) and the estimated (ME) was (6.6, 2.91, 25.79 and 29.82%) in surplus in *Shehremo, Wukiye, Yeferezye* and *Kochira* PAs (Table 13), respectively. The reason for betterment of available livestock feed in the *weinadega* agroecology might be associated with relative better availability of land for grazing, cropping and production of *enset* (*E. ventricosum*).

It was indicated in Table 13 that the total estimated annual feed supply in the study area of Gurage zone met only about 76.81% (DM) and 69.9% (DCP) maintenance requirement of livestock. The greater feed deficit encountered might be associated with poor quality of roughages and absence of supplements of different agro industrial by products. The observed negative feed balance in DM requirement in the current study agrees with earlier work of (Adugna and Said, 1994) reported for different areas in the country; the result reported by Dawit et al. (2013) from selected Kebeles of Adami Tullu Jiddo Kombolcha District of East Showa Zone in Oromiya region and feed deficit reported by Selamawit et al. (2017) from north Achefer district in Amhara region. However, it disagrees with the report of Sisay (2006) reported surplus DM supply than the total annual livestock requirement in North Gondar zone of Ethiopia.

Conclusion

To enhance the productivity and contribution of the livestock resources to the livelihood of the households in the study PAs in particular and in Gurage zone in general, it would be necessary to alleviate the prevailing livestock production constraints. From a total of feed produced in the study areas of both agroecologies of Gurage zone, feed from leaf and leaf midribs of *enset (E. ventricosum)* received the greatest share accounting for 506.4 tons in *dega* and 662.96 tons in *weinadega* with overall production of 1169.36 tons (50.77%). Grasses and residues altogether provided a DM of 453.95 tons in *dega* and 680.16 tons in *weinadega* agroecology. *Enset* leaf and leaf midribs supplied 51819.91 kg of DCP and 4420872 MJ of ME in *dega* as well as 55217.94 kg DCP and 6013047.2 MJ (ME) in *weinadega* leading the champion from livestock feeds which came from grasses and residues. The availability and use of improved forages and concentrate feeds in the areas was almost nil. The available feed in general and amount of protein in particular did not satisfy the maintenance requirements of livestock of study areas. The scarcity of feed was more serious in *dega* (highland) PAs particularly in dry season of the year together with water scarcity which aggravates low productivity. To this effect, it is suggested that future interventions take the following issues into account:

a) *Enset* is not only plant that provides food (*kocho*) to the farming families but it also safeguards life of cattle and keep the livelihood of farmers from being at risk. Intervention to words improving productivity as well as reducing the risks associated with *enset* production should be in place with full involvement of all stakeholders and development actors.
b) Empower farmers through awareness creation on storage, treatment and efficient utilization of crop residues, on establishment and management practices of improved forages and improving the existing grazing lands.
c) The quality and quantity of available basal roughage feed is generally low hence strategic supplementation of protein and energy rich feeds should be required and alternative means of dry season feed production and supply should be in place.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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