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Livestock-feed balance in small and fragmented land holdings: The case of Wolayta zone, Southern Ethiopia

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Ethiopia owns immense but largely untapped livestock resources scattered over diverse agro-ecologies. Feed scarcity is one of the major technical constraints in livestock production and thus challenges the economic contribution of the livestock sub-sector. For optimum and sustainable livestock productivity, the available feed resource should match with the animal population in a given area. This study was aimed at assessing livestock feeds and analyzing the balance between feed supply and demand in small and fragmented land holdings of three different agro-ecologies (Dega, Woina-dega and Kolla) of Wolayta zone, southern Ethiopia. Data were collected through discussions with individuals, groups and key informants, observations and formal surveys and analyzed using R software. The dry matter (DM) requirements of the livestock population were calculated according to the daily DM requirements for maintenance of 1 tropical livestock units (TLU) (250 kg livestock consumes 2.5% of its body weight (BW) (6.25 kg DM/d). Livestock holding in TLU and total DM productions from all feed resources were not significantly different across all agro-ecologies ($P > 0.05$). However; land which was the most important production factor in the study site was significantly ($P < 0.05$) different with average ownership of 1.5 ± 0.081 ha. The largest proportion of feed (517.35 ton of DM/year, 58.9%) came from crop production followed by natural pasture (356.62 ton of DM/year, 40.6%). The remaining small amount of feed was obtained from trees and shrubs (3.36 ton of DM/year, 0.5%) as farmers lop the leaves and branches of various trees and shrubs and feed them to their animals during the dry season. Total amount of feed obtained from all sources was 877.33 ton/year in DM and the total livestock population of the sampled households was 602.24 TLU. The total feed required for this amount of TLU in terms of DM was therefore, 1373.1 ton/year (with negative balance of 495.77 ton DM). Thus, the total feed available addressed only 63.9% of the annual DM requirement which was able to support existing stocks for only 7.7 months. The feed gap was significantly ($P<0.05$) higher at Woina-Dega, followed by Dega and it was better comparatively at Kolla agro-ecology. Hence, feed shortage was a big problem in terms of quality and quantity in the study site which needs due attention from all responsible bodies.

Key words: Feed availability, feed shortage, requirement, dry matter, feed-gap.

INTRODUCTION

Ethiopia owns immense but largely untapped livestock resources scattered over diverse agro-ecologies. According to Desta et al., 2000, inadequate feed, spread of diseases, poor breeding stock and inadequate

livestock policies with respect to credit, extension, marketing and infrastructure are the major constraints affecting livestock performance in Ethiopia. Feed scarcity is one of the major technical constraints in livestock production and thus it challenges the economic contribution of the livestock sub-sector. Feed resources are classified as natural pasture, crop residue, improved pasture and forage, agro-industrial by-products, other by-products like food and vegetable refusal, of which the first two contribute the largest feed type (Alemayehu, 2005); Adugna et al., 2012). In the highlands, crop residues and agro-industrial by-products augment natural pasture and in the pastoral system, livestock production is almost totally dependent on native pasture and woody plants (Daniel and Tesfaye, 1996; Zinash et al., 1998).

For optimum and sustainable livestock productivity, the available feed resource should match with the animal population in a given area (Kechero and Geert, 2014). The major feed resources in Wolayta zone are natural pasture, stubble grazing, crop residues and some non-conventional feeds like enset parts, kitchen wastes and fruit and vegetable rejects. Farmers also lop the leaves and branches of various trees and shrubs and feed them to their animals during the dry season. They also collect herbaceous wild plants, mostly legumes, as feed for lactating cows (Adugna 1990). Though there are many studies on the availability and type of feeds in the Wolayta, limited work has been done to identify current gap between demand and supply of feed in terms of dry matter. This, on the other hand, creates a great problem to stakeholders at different levels to recommend possible solutions for livestock production improvement. Therefore, it is very imperative to assess the already existing feed resources in relation to the annual requirements of livestock in order to suggest either improving the existing feed resources, introduce another feed alternatives or suggest development and policy intervention options. The objectives of this study were therefore, to assess livestock feeds and analyze the balance between feed supply and demand in small and fragmented land holdings of Wolayta zone, southern Ethiopia.

MATERIALS AND METHODS

Description of the study area

The study was conducted in four districts/woredas of Wolayta zone, Southern Nation Nationalities Regional State, Ethiopia (Figure 1) from November 2016 to October, 2017. Wolayta zone (6.40 - 7.10 N and 37.40 - 38.20E) is located 390 km southwest of Addis Ababa. The zone has a total area of 4,541 km^2 and is composed of 12 woredas and 3 registered towns. It is approximately 2000 m above sea level and its altitude ranges from 700 - 2900 m above sea level. The population of Wolayta zone is about 1,527,908 million of which 49.3% are males and 51.7% are females. Out of these, 11.7% live in towns and the rest 88.3% live in rural areas. The annual population growth rate of the zone is 2.3%. It is one of the most densely populated areas in the country with an average of 290 people per km^2 (Thrustfield 2005). The area is divided into three ecological zones: *Kolla* (lowland <1500 m), *Woina-Dega* (mid-altitude 1500-2300 m) and *Dega* (highland > 2300 m) with the most of the area lies within the mid altitude zone (Berhanu 2012).

Wolayta had a bi-modal rainfall pattern that extends from March to October. The first rainy period occurs in March to May, while the second rainy period covers July to October, with its peak in July/August. The average annual rainfall over 43 years is 1,014 mm (Gian 2017). Mean monthly temperature vary from 26°C in January to 11°C in August (Ayele and Shanmugaratnam 2008).

Soils (Eutric Nitisols associated with Humic Nitisols, which are dark reddish brown with deep profiles and vertisoils), are the most prevalent types in Wolayta zone (Tesfaye 2003; Ayele and Shanmugaratnam, 2008]. Primary occupation of the zone is farming. Also, mixed crop-livestock production predominates the farming system, but there are some pastoralists in the lowlands. Livestock production in Wolayta zone includes cattle (oxen, milking cows and young stock), goats and sheep, equines (horses and donkeys), poultry (local and improved breeds). Cattle that are kept for milk production, draught power, cash and manure, dominate livestock numerically. Animals are fed in open grazing, stall feeding and tethered (small area of open grazing left in front of a house). Generally, the climatic condition is conducive to livestock production (Berhanu, 2012).

Sampling techniques

Multi-stage sampling procedure was used to collect series of data. In the first stage, Wolayta zone was selected purposively taking into account livestock production and feeding problems, representation of mixed crop-livestock farming systems in small and fragmented plot of lands in southern Ethiopia as well as logistic and coordination issues. Based on (Berhanu, 2012), the 12 woredas of Wolayta zone were stratified in to three agro-ecologies (strata), namely *Kolla, Dega* and *Woina-Dega*. Accordingly, four woredas (one from each of *Kolla* and *Dega,* and two from *Woina-Dega* agro-ecology) were randomly selected as most of the area lies with in mid altitude (*Woina-Dega*). From the selected 4 woredas, a total of 8 kebeles (PAs*),* two from each were taken randomly. Subsequently, a total of 176 farmers that owned any livestock species from the 8 kebeles/PAs (22 farmers from each kebeles) were interviewed (Figure 2). The total number of households sampled for the study was calculated based on the formula given by Kechero and Geert, 2014; Cochran 1977; Thrustfield 2005. A precision level of 5 and 95% confidence interval was used to calculate the sample size using the $n= (Z^2pq)/d^2$, where, n, desired sample size; Z, abscissa of the normal curve (The acceptable likelihood of error of 5%): 1.96, the value of Z at 95% confidence interval; P, estimated proportion that one is trying to estimate the population; q, is 1-P; d, desired absolute precision level at 95% confidence interval, the probability of Type I error (Called alpha).

Data sources and collection procedures

Both quantitative and qualitative data types were used in

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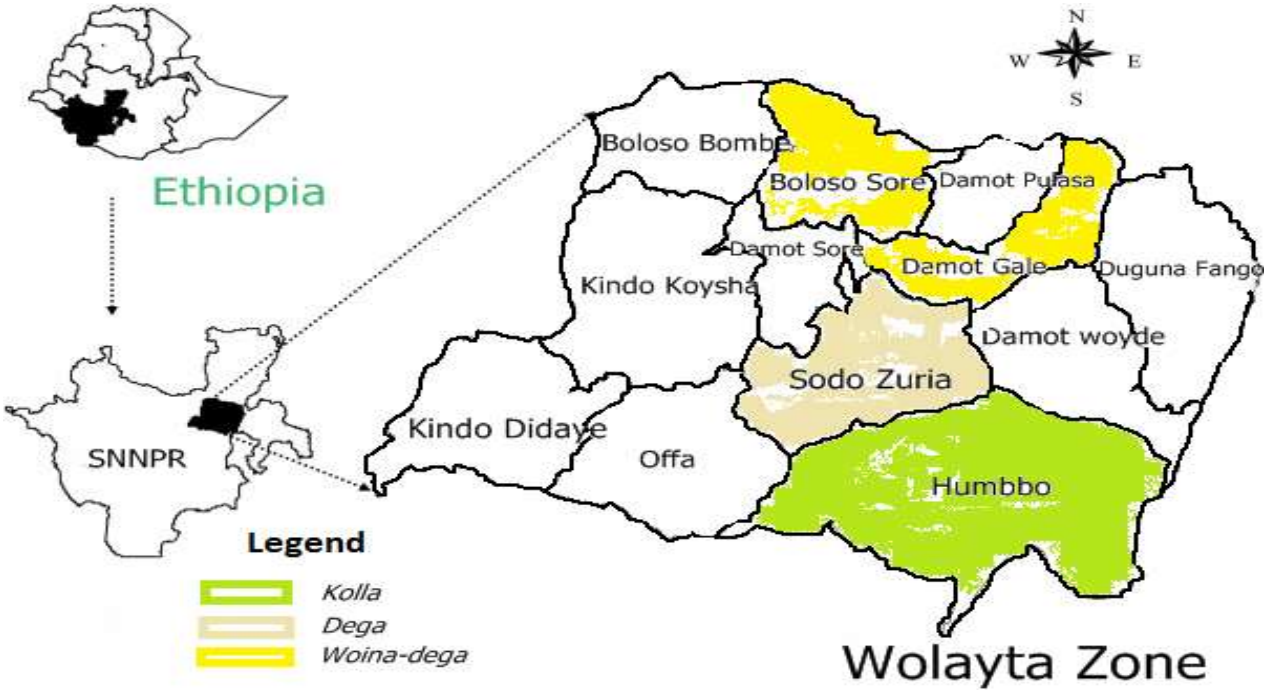

Figure 1. Map of Wolayta zone.

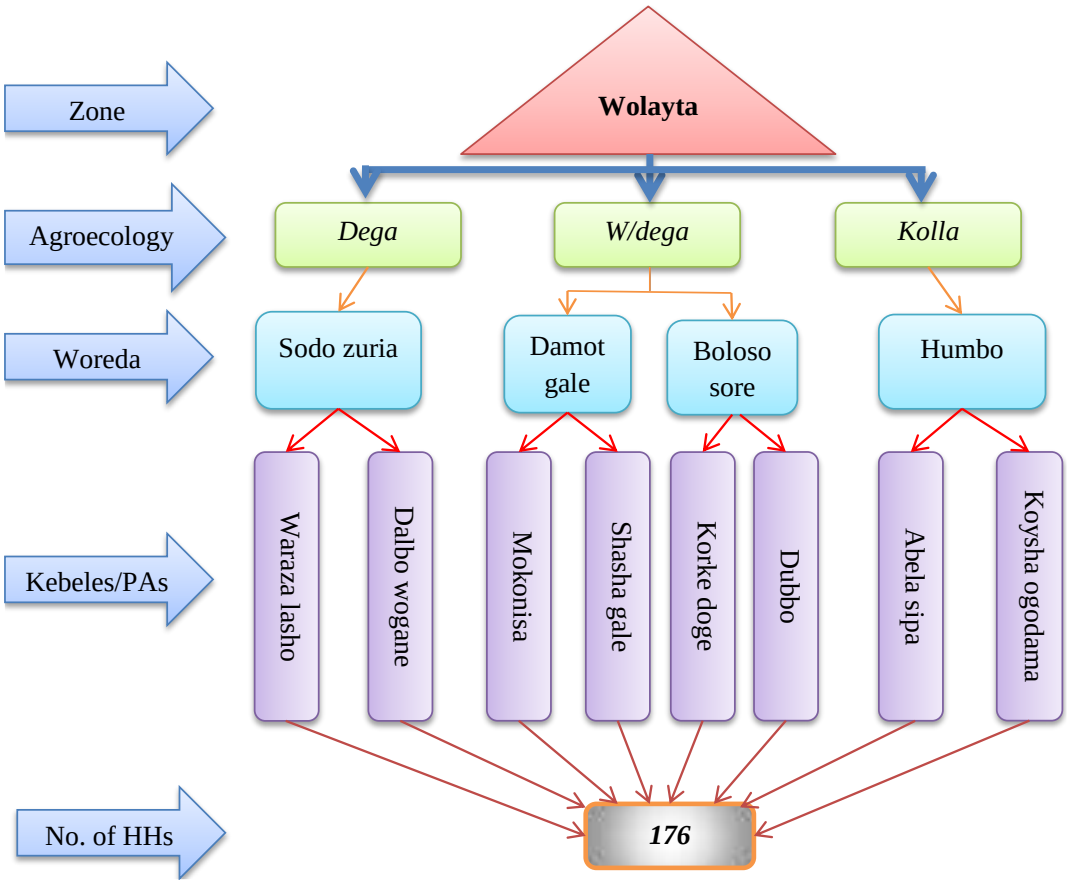

Figure 2. Schematic diagram of selection procedures of study site and sample households.

this study. In order to generate these data types, both secondary and primary data sources were used. Primary data sources include information on crop, livestock and livestock feed production from individuals, zonal and woreda offices, visual observations, livestock farmers and experts from woreda and zonal offices. Secondary sources include reports from zonal and woreda offices, journals, books and internet browsing, among others. Survey questionnaire were prepared and pre-tested for feed types, sources, amount, months of availability and feeding practices. Using the questionnaire, interviews were conducted to gather data on household characteristics, socioeconomic and demographic characteristics, farm information, and livestock holdings. Trained and experienced enumerators (development agents who have diploma in animal husbandry) were hired to collect data from selected livestock farmers. Detailed descriptions of the data collection methods used were presented below.

Estimation of available feed resources

Dry matter yield of natural pasture: The total amount of dry matter (DM) available in natural pasture was determined by multiplying the average value of grazing land holding with the per hectare DM yield of the natural pastures with conversion factor of 2 t DM/ha/year (FAO, 1987); (FAO, 1995). The amount of DM obtained from communal grazing land was factored into total communal grazing areas for each total households and their associated TLU eligible to graze on this land unit.

Crop residue, fallow land and after math grazing: The quantity of available crop residues (DM basis) was estimated from the total crop yields of the households, which was obtained from questionnaire survey, according to conversion factors. The conversion factors are 1.5 for barley, wheat, teff (Eragrostis tef); 2 for maize, 1.2 for pulse and oil crop straws and 2.5 for sorghum. The quantities of available DM in fallow land and aftermath grazing was determined by multiplying the available land by the conversion factors of 1.8 for fallow land and 0.5 for grazing aftermath (FAO, 1987).

Quantity of trees and shrubs: The dry matter from browsing trees and shrubs of leaf biomass was estimated at 1.2 ton ha-1(FAO, 1987).

Estimating available concentrates: The quantity (DM basis) of non-conventional concentrates (supplements) available for each household was obtained by interviewing the farmers during the cross-sectional questionnaire survey.

Estimation of annual feed requirements for livestock in terms of DM

Data of livestock population in the sampled households was obtained from the interview of household heads during the survey. The number of livestock population was converted into tropical livestock unit (TLU) using the conversion factors of (Varvikko et al., 1993). The DM requirements of the livestock population was calculated according to the daily DM requirements for maintenance of 1 TLU (250 kg livestock consumes 2.5% of its BW (6.25 kg DM/d) or 2.28 tones/year/TLU (Kearl 1982).

Statistical analysis

Data were analyzed using R software version 3.3.3. Mean comparisons of the three agro-ecologies were carried out using Tukey test. Levels of significance were considered at $P < 0.05$. Accordingly, values of parameters that differed significantly for the Three agro-ecologies of the studied woredas were separately presented. The statistical model used for data analysis was:

$$Yij = \mu + Li + eij$$

Where, Y_{ij}, total dry matter yield obtained from grazing, crop residue, green harvests, feed supplements, fodder trees and shrubs; μ, overall mean; L_i is the effect of i^{th} location (agro-ecology), $i = 1\ldots 3$; e_{ij}, random error

RESULTS

Household characteristics

A total of 176 households were interviewed for this survey from which, 89.6 and 10.4 were male and female headed households respectively. Average age of the household heads was 45.3 and average household size of the study site was 6.8. The household size significantly ($P<0.05$) differed across all agro-ecologies. It was higher in *Kolla* agro-ecology (7.61 ± 0.36), followed by *Woina-Dega* (6.77 ± 0.19) and *Dega* (6.18 ± 0.29). The education status of the households heads also showed significant ($P<0.05$) difference across the agro-ecologies. From the total sampled household heads, 22.7% were illiterate, 47.7% completed primary school, 23.9% completed secondary school and 5.7% completed post-secondary school.

Land holdings and land use systems

Land holdings per households showed significant ($P<0.05$) difference across the three agro-ecologies. Average land holding for the sample households was 1.5 ± 0.081 ha. Crops mostly produced in the study area included maize, teff, wheat, barley, sorghum, bean and pea. In addition, sweet potato, potato, cassava, yam, taro and enset were also common root crops. Rate of land allocation for crops showed a reduced trend from year to year due to increased human population and the consequent reduction in land holdings per household. The highest land was allocated for maize (0.4 ± 0.031) followed by teff (0.19 ± 0.028) and peas (0.16 ± 0.012). From the root crops, cassava production accounted for the highest proportion (0.12 ± 0.11) followed by taro (0.11 ± 0.11) and enset (0.08 ± 0.10). Land allocation for feed production/feeding had also been diminishing in size due to population growth which resulted from the use of grazing lands for crop production. The sampled households owned on average (0.14 ± 0.0.17 ha) permanent grazing land and (0.8 ± 0.0.14 ha) fallow land. The proportion of communal grazing land (4.37 ± 0.79 ha) also showed significant ($P<0.05$) difference across all three agro-ecologies. The *Kolla* agro-ecology (11.82 ± 2.82 ha) had the highest communal land ownership than *Woina-Dega* (2.83 ± 0.31 ha) agro-ecology and the *Dega* agro-ecology had no communal grazing land observed at all.

Table 1. Total livestock population of the sampled households in TLU.

Livestock type	Conversion factor	Total population	Total sum (TLU)
Cattle	0.7	696	487.20
Sheep	0.1	289	28.90
Goat	0.1	199	19.90
Mule	0.7	4	2.80
Donkeys	0.6	85	51.00
Poultry	0.01	1244	12.44
Total			602.24

TLU: Tropical Livestock Unit.

Table 2. Total feed from natural pasture, fallow land and aftermath grazing in tonne.

Feed source	Conversion factor	Total sum (ha)	Total DM (tonne)
Fallow land	1.8	47.33	85.19
After math	0.5	21.9	10.95
Permanent grazing land	2	53.15	106.30
Communal grazing land	2	3472	45.72*
Forest land	1.2	1.52	1.82
Road side grazing	2	34.5	69.00
River side grazing	2	18.82	37.64
Total		3649.22	356.62

*****DM obtained from total communal area was factored to total livestock (TLU) grazing this unit of land.

Livestock holding and composition

Farmers in this study site kept a mix of cattle, sheep, goats, equines and chicken. Most of the households owned local cattle breed. Average livestock ownership in terms of Tropical Livestock Unit (TLU) was 3.42, which was not significantly ($P>0.05$) different across all the three agro-ecologies. However, average cattle holding was significantly ($P<0.05$) higher in *Dega* agro-ecology (4.36 ± 0.19) than, *Woina-Dega* agro-ecology (4.1 ± 0.12) and *Kolla* agro-ecology (3.25 ± 0.27) (Table 1).

Feed resources and availability

Quantity estimation of available feed resource

Dry matter yield of natural pasture, fallow land and aftermath grazing: The total amount of DM obtained from natural pasture (private and communal grazing areas), fallow land and aftermath grazing was 356.62 ton/year (Table 2).

Crop residues: The total amount of feed produced from all crops for sampled household was 517.35 ton/year (Table 3).

Quantity of trees and shrubs: Farmers used different trees and shrubs as source of feed for animals especially at times of drought and feed shortage. About 2.8 ha of land was covered by trees and shrubs used for livestock feeding in the sample households, producing 3.36 tons of DM feed per year.

Estimating available concentrates: Parts of enset plant contributed a lot as basal feed as well as supplement especially for draught animals and milking cows. Small amount of mineral-rich soil locally called (*Aduwa*), kitchen wastes, coffee leaf prepared in liquid form, residues of local drinks like coffee*, chat,* fruits and vegetables rejects were also other concentrates used in the area. In addition to these, there were also other locally available feeds given as concentrate to improve quality and yield of milk and milk products. The common name of such feeds in the area is called *manache maatta.* These feeds are cooked in the pot (used for milk churning (*manaachiya*)), and given to the cows. It also improved the odor, taste and texture of milk and its products as it is cooked in the pot and fed to the animals.

Livestock feed balance

Total available DM obtained from all sources was

Table 3. Total feed produced from crop production in tonne.

Crop	Conversion factor	Total sum (ha)	Total DM (tonne)
Maize	2	113.63	227.25
Teff	1.5	37.28	55.92
Wheat	1.5	16.00	24.00
Sorghum	2.5	25.63	64.16
Barley	1.5	23.75	35.63
Bean	1.2	28.25	33.90
Pea	1.2	20.16	24.20
Sweet Potato	0.3	40.13	12.04
Potato	0.3	22.25	6.67
Taro	0.3	19.42	5.83
Cassava	1.0	20.43	20.40
Coffee	0.4	9.50	3.80
Irrigation area	0.3	6.07	3.64*
Enset	NA	15.00	
Banana	NA	7.35	
Total		404.84	517.35

* Irrigation areas produce twice within a year.

Table 4. Feed balance analysis from all sources.

Feed supply	Area (ha)	DM (tonne)
Natural pasture, fallow land and after math grazing	3649.22	356.62
Crop residues	404.84	517.35
Trees and shrubs	2.8	3.36
Total feed supply	4057.33	877.33 (1)
Feed requirement		
Total HHH		176 = (2)
No of TLU/ HHH		3.42 = (3/2)
Total no of TLU		602.24 = (3)
DM required/TLU/ year		2.28 given = (4)
Total annual DM required		1373.1072 5= (3*4)
Feed balance		**-495.77 (1-5)**
Proportion of feed gap (%)		36.10

compared to the annual DM requirements of the livestock population in the sampled households. The available feed source addressed only 63.9% of the annual DM requirements with the proportion of feed gap of 36.1%. Overall livestock-feed balance of the sampled households was summarized in (Table 4).

DISCUSSION

Household characteristics

Wolayta zone has always been characterized by densely populated and intensively cultivated mid-altitude area of Ethiopia for many studies found the average household size of 6.56 (Yishak 2017), 6.74 (Tsedeke and Endrias, 2011) and 5.1 (Leza and Kuma, 2015). The average household size of the zone in this study was 6.8. The household size significantly ($P<0.05$) differed across agro-ecologies. It was higher in *Kolla* agro-ecology (7.61± 0.36), followed by *Woina-Dega* (6.77 ± 0.19) and then *Dega* (6.18 ± 0.29). Education is another important variable with regard to its association with demographic behavior. The education status of the households heads also showed significant ($P<0.05$) difference across agro-ecologies. It was higher in *Woina-Dega* areas than *Dega*

and *Kolla,* which could be related to the geographic location advantage of *Woina-Dega* agro-ecology (Sodo zuria woreda) to the central town (Sodo) of the zone. From the total 176 households interviewed for this survey, 89.6 and 10.4 were male and female headed households respectively. Average age of the household heads was 45.3.

Land holdings and land use systems

The average land holding of the study area was 1.5 ± 0.081 ha. Land was the most important limiting production factor in the study area and the quality and quantity of land available greatly determined the amount of production. Because of the high population density, land holdings per households were small in the study area. Even though there were different studies with varied figures showing land holding of the area like 1.41 ha of (Ayele and Shanmugaratnam, 2008), and 0.62 ha of (Gian, 2017), land in Wolayta continued to be an extremely scarce asset. Crops mostly produced in the study area included maize, teff, wheat, barley, sorghum, bean and pea. In addition, sweet potato, potato, cassava, yam, taro and enset were also common root crops in this area. Rate of land allocation for crops showed a reduced trend from year to year due to increased human population and the consequent reduction in land holdings per household. Rate of land allocation for crops showed a reduced trend from year to year due to increased human population and the consequent reduction in land holdings per household. In line with this, the report by (Yonas, 2011) concluded that population growth and land fragmentation are forcing Wolayta farmers to gradually change the age old traditional land management schemes, cropping strategies and land use patterns and further making the farming system vulnerable.

Livestock holding and composition

Farmers in the study site kept a mix of cattle, sheep, goats, equines and chicken. Most of the households in the study site owned local cattle breed. Average livestock ownership in terms of Tropical Livestock Unit (TLU) was 3.42 which agreed with the finding of (Gian, 2017).

Feed resources and availability

Total DM yield estimates from grazing land (pasture, road, river side and fallow), crop residues, foliage of fodder trees and shrubs, green forages as well as non-conventional feed supplements were considered in this study. The largest proportion of feed (517.35 ton of DM/year, 58.9%) came from crop production. Natural pasture was the second most important feed source for animals (356.62 ton of DM/year, 40.6%) that disagreed with the findings of (Adugna and Said, 1992) and (Zereu and Lijalem, 2016) who concluded that natural pasture was the main source of feed for Wolayta zone. The reason for higher amount of feed to come from crop residues than natural pasture could be population pressure, urbanization and increased cultivation of grazing lands for crop production. Some small amount of feed was obtained from trees and shrubs (3.36 ton of DM/year, 0.5%) as farmers lop the leaves and branches of various trees and shrubs and feed them to their animals during the dry season. The famers in Wolayta zone also collect herbaceous wild plants, mostly legumes, as feed for lactating cows as reported by (Adugna, 1990). The use of concentrate feeds was very limited in the area as some small amount of kitchen wastes, coffee leaf prepared in liquid form, fruits and vegetable rejects were used. The degree by which local residues were produced and used was quite small and the share of it in the total dry matter is of due consideration but needs a clear system of quantifying the dry matter percentages of each residues. In addition to this, crops like inset and banana lacks conversion factor, which could increase the total DM yield.

Livestock feed balance

The total amount of feed obtained from all sources was 877.33 ton/year in DM and the total livestock population of the sampled households was 602.24 TLU. The total amount feed required for this amount of TLU in terms of DM was therefore, 1373.1 ton/year (With negative balance of 495.77 ton DM) regardless of the nutritional content of the DM yield. That means the total feed available addressed only 63.9% of the annual DM requirement which was able to support existing stock for 7.7 months. Similarly, in most parts of the country livestock-feed balance showed negative balance as reported by (Tadesse and Solomon, 2014) at Gumara-Rib watershed; Amahara region, (Funte et al., 2010) in southern Ethiopia, (Tessema et al., 2003) in Belesa district of Amhara region, (Bedasa, 2012) at highlands of the Blue Nile basin, (Kechero and Geert, 2014) at Jimma; south western Ethiopia, (Yeshitila, 2008); at Halaba; southern Ethiopia, and (Adugna and Said, 1992) at Wolayta; southern Ethiopia. Contrary to these results, (Shitahun, 2009) reported that the existing feed supply on a year round basis accounted for about 104.79% of the maintenance DM requirement of livestock per household in Bure district, Oromia regional state (Endale, 2015).

To fill the feed gap (36.1%), farmers used different strategies like mixed cropping of many plants species with in the same (small) plot of land and using these plants/crops for food and feed production as shown in (Figure 3a). Crops produced in the mix included maize, banana, pigeon pea, and cassava. Thus such type of

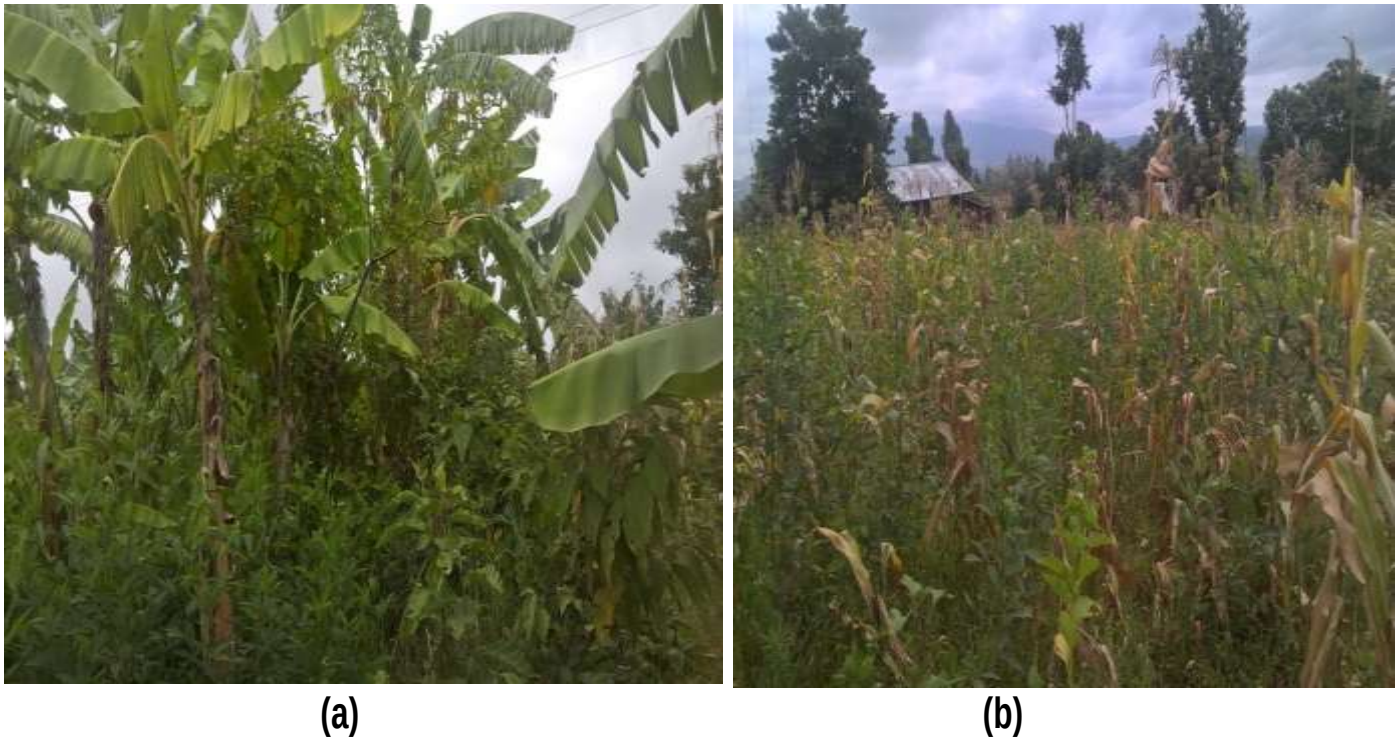

Figure 3. Mixed cropping of (a) cassava-banana-pigeon pea and (b) maize-pigeon pea.

cropping helps to make livestock production bearable through improved feeding as farmers in the area own small and fragmented lands. In some parts of the area, maize was constantly intercropped with pegion pea (Figure 3b). The most common mixed cropping system in the area included maize-cassava, maize-pegion pea, banana-pegion pea, banana-cassava-pegion pea, maize-pegion pea-cassava.

In some other parts of the area, households were producing pigeon pea (*Cajanus cajan*) as source of income in addition to feeding animals and using for home consumption. The other feed being produced as cash crop and/or animal feed was *desho grass* (*Brachiaria brizantha)*. Different governmental or non-governmental organizations were working on improving animal production through improved feeding by purchasing and distributing different crops/grasses from producing households to other areas at times of drought and feed scarcity.

Conclusion

The findings of this study affirm that Wolayta zone is a densely populated and intensively cultivated mid-altitude area of Ethiopia. Because of the high population density, land holdings per household were small in the study area. Crops mostly produced in the study area included maize, teff, wheat, barley, sorghum, bean and pea. In addition sweet potato, potato, cassava, yam, taro and enset are also common root crops in this area. Rate of land allocation for crops has been reduced from year to year due to reduction in land holding per household. Land allocation for feed production/feeding has also been diminishing on size due to population growth which has resulted in use of grazing lands for crop production. Farmers in the study site kept a mix of cattle, sheep, goat, equines and chicken. Most of the households in the study site owned local cattle. The total amount of DM obtained from all sources addressed only 63.9% of the annual DM requirement. All feed sources were compared for the three agro-ecologies and most of them showed significant ($P<0.05$) difference as shown in (Table 5).

Even though there was overall livestock feed imbalance in the study area, the gap was not similar throughout all agro-ecologies. The feed gap was significantly ($P<0.05$) higher at *Woina-Dega* followed by *Dega* agro-ecology. It was better comparatively at *Kolla* agro-ecology as shown in (Table 6).

To fill the gap (36.1%), farmers used different strategies from using uncommon feeds such as trees and shrubs to purchasing feed and practicing new mixed cropping system. However, it was observed that feed is still a big problem for livestock production in Wolayta zone as most of the households reported to have purchased feed in the year 2016/17. In addition to this, the above negative balance between supply and demand of feed in terms of DM shows that livestock feeding still

Table 5. Feed resources category and their supply according to agro-ecology.

Feed supply by source	Agro-ecology mean			Overall		
	***Dega* (n=44)**	***Woina-Dega* (n=88)**	***Kolla* (n=44)**	**Mean**	**SEM**	**P**
Maize production (t)	1.15[a]	1.11[a]	1.80[b]	1.29	0.063	***
Teff production (t)	0.18[a]	0.22[a]	0.66[b]	0.32	0.035	***
Wheat production (t)	0.33[b]	0.11[a]	0.00[a]	0.14	0.028	***
Sorghum production (t)	0.47	0.25	0.49	0.36	0.048	NS
Barley production (t)	0.26[a]	0.18[b]	0.20[ab]	0.20	0.012	*
Bean production (t)	0.06[b]	0.26[a]	0.19[a]	0.19	0.015	***
Pea production (t)	0.05[b]	0.16[a]	0.18[a]	0.14	0.011	***
Sweet potato production (t)	0.09[a]	0.08[a]	0.03[b]	0.07	0.004	***
Potato production (t)	0.04	0.04	0.04	0.04	0.003	NS
Taro production (t)	0.04	0.03	0.03	0.03	0.003	NS
Cassava production (t)	0.10	0.12	0.12	0.12	0.011	NS
Coffee production (t)	0.02	0.02	0.03	0.02	0.003	NS
Irrigated land (t)	0.00[b]	0.04[a]	0.00[b]	0.02	0.004	***
Fallow land (t)	0.05	0.05	0.09	0.06	0.007	NS
Permanent grazing land (t)	0.39	0.55	0.45	0.48	0.032	NS
Forest and wood land (t)	0.00[b]	0.02[a]	0.00[b]	0.01	0.003	***
Communal grazing land (t)	0.00[c]	0.42[a]	0.21[b]	0.26	0.029	***
Tree and shrubs (t)	0.02[a]	0.01[b]	0.02[a]	0.02	0.001	***
Roadside grazing (t)	0.35[b]	0.61[a]	0.00[c]	0.39	0.037	***
Riverside grazing (t)	0.15	0.24	0.23	0.21	0.026	NS

[a,b,c] Means with different letters in the row are significantly different (P=0.05); SEM, standard error of means; *P=0.05; ** P=0.01; *** P=0.001.

Table 6. Average yearly difference in the balance between feed supply and requirement.

Feed supply	Agro-ecology mean			Overall		
	Dega	***Woina-Dega***	***Kolla***	**Mean**	**SEM**	**P**
Available (tons)	4.39	5.09	5.37	4.98	0.168	NS
Required (tons)	8.04[ab]	8.20[a]	6.77[b]	7.80	0.195	**
Balance (tons)	-3.11[a]	-3.66[a]	-1.39[b]	-2.82	0.211	***

[a,b,c] Means with different letters in the row are significantly different (P=0.05); SEM, standard error of means; *P=0.05; ** P=0.01; *** *P*=0.001

requires owed attention in the study area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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