NUTRITIONAL QUALITY, ANIMAL PREFERENCES AND SEASONAL AVAILABILITY OF FEED RESOURCES AND LIVESTOCK- FEED BALANCE IN SMALL AND FRAGMENTED LANDHOLDINGS OF WOLAYTA ZONE, SOUTHERN ETHIOPIA

PhD Dissertation

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A Dissertation submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Animal Production

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As members of the Examining Board of the final PhD open defense, we certify that we have read and evaluated the Dissertation prepared by Tibebu Kochare Anjulo titled: '**Nutritional quality, animal preferences and seasonal availability of feed resources and livestock- feed balance in small and fragmented landholdings of Wolayta zone, Southern Ethiopia'** and recommend that it be accepted as fulfilling the Dissertation requirement for the Doctor of Philosophy in Animal Production.

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I hereby certify that I have read the revised version of this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

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BIOGRAPHICAL SKETCH

I, the author of this dissertation was born in the Wolayta zone of Southern Ethiopia in 1986. I attended my primary education at Adecha Elementary School, secondary education at Bedessa High School and Preparatory at the Wolayta Sodo Comprehensive High School. After completion of my high school education, I joined the Jimma University College of Agriculture and Veterinary Medicine in 2006 and was awarded a BSc Degree in **Animal Sciences** on June 12, 2008. Soon after graduation, I was employed by Humbo Woreda Office of Agricultural Development, Wolayta Zone, Southern Ethiopia and served as an expert for forage production and development. After a year of effective service in the Woreda, I joined, the Samara University as a Graduate Assistant in the Department of Animal Sciences. After a year of experience, I then, joined Mekelle University to pursue my MSc degree in **Livestock Production and Pastoral Development** in 2011 and completed in 2012. I also received an international diploma in '**Animal Nutrition**' from PTC+, the Netherlands. Currently I am an academic staff of Samara University. Over the past eight years of services in teaching, I have taught several animal science courses and published three scientific articles in reputable international journals. I joined Addis Ababa University, College of Veterinary Medicine and Animal Production Studies, Department of Animal Production Studies to study my PhD in 2014.

STATEMENT OF THE AUTHOR

First of all, I declare that this thesis is my *bonafide* work and that all sources of materials used in this thesis have been duly acknowledged. This thesis has been submitted in fulfillment of the requirements for the PhD degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the College library to be made available to borrowers under the rules of the Library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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Date of Submission: _________________________

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LIST OF ABBREVIATIONS

AA	Amino acid
ADF	Acid detergent fiber
ADG	Average daily gain
ADL	Acid detergent lignin
AOAC	Association of analytical chemists
CP	Crude protein
CSA	Central statistical agency
DDMI	Digestible dry matter intake
DE	Digestible energy
DM	Dry matter
DMI	Dry matter intake
DS	Stem diameter
DT	Trunk diameter
EARO	Ethiopian Agricultural Research Organization
FAO	Food and Agriculture Organization of the United Nations
FTS	Fodder trees and shrubs
HH	Households
HP	Highly palatable
LP	Less palatable
MP	Most palatable
NDF	Neutral detergent fiber
NIRS	Near infrared reflectance spectroscopy
NP	Non palatable
RF	Rainfall
RP	Rarely palatable
SEM	Standard error of mean
TLU	Tropical livestock unit
HSD	Honest significant difference
ANOVA	Analysis of variance

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ABSTRACT

Livestock production in the Wolayta zone is at risk due to recurrent drought, population growth and very small and fragmented average landholdings. This study was aimed at assessing livestock feeds in terms of quality and quantity, analyze the balance between feed demand and supply, assess palatability, seasonal availability and animal preference of feeds in small and fragmented landholdings of three different agro-ecologies (Dega, Woina-dega and Kolla) of Wolayta zone, southern Ethiopia for one year from November 2016 to October, 2017. Data were collected through discussions with groups and key informants, observations, formal surveys, laboratory analysis and other secondary sources and analyzed using R software. Results showed that, the average household size in the zone is 6.8 and households own very small average land of 0.98 ± 0.081 ha. A total of 145 palatable plant species were identified in the study area, from which, 48 (33.1%) were trees, 27 (18.6%) were shrubs and the remaining 70 (48.3%) were herbs. Of the 145 recorded species, 82 (56.6%) were highly palatable, 25 (17.2%) were mostly palatable, 24 (16.6%) were less palatable, and 14 (9.6) were rarely palatable. Goats preferred most of the forage species (139 species, 95.8%), followed by cattle (121 species, 83.4%), sheep (106 species, 73.1%) and donkeys (67 species, 46.2%). Goats preferred herbs (66 species, 47.5%), trees (46 species, 33.1%) and shrubs (27 species, 19.4%). Cattle preferred herbs (67 species, 54.0%), trees (34 species, 28.1%) and shrubs (20 species, 16.5%). Sheep preferred herbs (64 species, 60.4 %), trees (24 species, 22.6 %) and shrubs (18 species, 17.0 %). Most of the animals preferred the leaf part of plants (78 species, 53.8 %), shoots/whole parts (53 species, 36.5 %), fruits and/or flowers (53 species, 36.5 %), twigs (41 species, 28.3 %) and roots (6 species, 4.1 %). The highest numbers of palatable plant species were recorded in March (133 species, 91.7%), in which short rainy season started in the study area. The evergreen perennial species like Vernonia amygdalina, Dovyilas abssynica, Ehertia cymosa, Vangueria apiculata and Persea americana were found throughout the growing season. Generally, January and February were the two months where feed is rarely available and animals were forced to eat *poor quality and less palatable species. Livestock holding in TLU and total DM production 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 different ($P < 0.05$) across all the three agro-ecologies. 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%) for the sampled households. 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. The chemical compositions of sampled trees and shrub species showed that the DM content of P. thonningii, M.esculenta, G. occidentalis, P. americana, T.indica, R. vulgaris were 96.35, 95.63, 95.71, 96.07, 97.00 and 96.74% respectively. The CP content of the trees and shrubs considered varied from 20.15 (M.esculenta) to 10.03 (P. americana). The concentration of calcium in P.americana (3.82) was higher compared to M.esculenta (3.31) and it was very small in P.thonningii (2.08). The NDF content of T.indica (67.83) was the highest compared to others, but M.esculenta contained the highest ADF (37.4) and ADL (14.5). 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 higher ($P<0.05$) at Woina-dega, followed by Dega. This shortage of feed in the study area has resulted in increased mortality, reduced milk yield, increased abortion, weight loss and weakness of any livestock species as reported by the respondents. The respondents used different mechanisms to cope with shortage of feed and reduce its impact on their animals. Some households used mixed cropping of many crops within very small plot of land, while others used improved forage production, trees and shrubs, feed and food crop production, feed conservation in addition to buying feeds. Hence, feed shortage was a big problem in terms of quality (the use of concentrate supplement was not commonly practiced). The quantity (which showed negative balance) in the study site also needs due attention from all responsible bodies.*

Key words*:* Differential palatability; feed preference; feed quality; livestock feed-balance; seasonal feed availability; Wolayta.

1. INTRODUCTION

Livestock production employs 1.3 billion people and sustains livelihoods of about 900 million poor people worldwide (Escarcha, 2018). Ethiopia has one of the largest livestock population in Africa with the estimated domestic animal number of 57.83 million cattle, 28 million sheep, 28.6 million goat, 1.23 million camels, 60.5 million poultry, 2.1 million horses, 0.4 million mules and 7.88 million donkeys (CSA, 2016). This immense but largely untapped livestock resource is scattered over diverse agro-ecologies. This livestock sub sector still has an enormous contribution to Ethiopia's national economy and livelihoods of many Ethiopians, and is promising to rally around the economic development of the country. Livestock plays vital roles in generating income to farmers, creating job opportunities, ensuring food security, providing services, contributing to asset, social, cultural and environmental values, and sustain livelihoods (CSA, 2017; FAO, 2017).

Despite huge livestock population and existing favorable environmental conditions, the current livestock output of the country is little. This is associated with a number of complex and inter-related factors such as inadequate feed and nutrition, widespread diseases, poor genetic potential of local breeds, market problem, and inefficiency of livestock development services with respect to credit, extension, marketing, and infrastructure (Belay *et al*., 2013; Ahmed *et al*., 2016). According to Desta *et al*. (2000), Ahmed *et al*. (2010), and Yisehak and Janssens (2014), 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 to livestock production and thus it challenges the economic contribution of the livestock sub-sector. The availability and relative importance of different feed resources varies from place to place and from time to time depending on agro-ecology, livestock production systems and seasons of the year (Beyene *et al*., 2011; Endale, 2015). Moreover, progressive decline of average farm sizes in response to rising human populations, encroachment of cropping land onto erstwhile grazing areas and onto less fertile and more easily erodible lands, and expansion of degraded lands, which can no longer support either annual crops and pastures contribute to shortage of feed resources (Alemayehu, 2005; Menbere, 2014; Negash, 2018). Feed supply from natural pasture fluctuates following seasonal dynamics of rainfall (Endale, 2015).

Feed availability and quality are not predictable year round and hence gains made in the wet season are totally or partially lost in the dry season in different parts of Ethiopia (Dereje *et al*., 2014; Kassahun, 2016). The essential feed nutrients of the herbaceous plants declines during the dry season, leading to prolonged periods of under-nutrition of livestock reared in such environmental conditions. Moreover, the adoption and use of improved feed technologies remained limited (Deribe *et al*., 2013; CSA, 2013), calling for exploring the utilization pattern of available feed resources (Deribe *et al*., 2013). Most of earlier research works that have focused on the assessment of feed resources in different parts of the country indicate the shortage of feed resources without quantifying the amount of dry matter (DM), metabolizable energy (ME) and crude protein (CP) obtained from feed resources and whether these were adequate to the total number of livestock available to that particular study area. Whether feed resources in a particular area are adequate or inadequate for livestock, qualification of supply of feed resources based on total dry matter yield, protein and energy is quite a necessary step. Deficiency or surplus of feed resources for a given area is then known by calculating the supply and animal requirements (Yisehak and Janssens, 2014).

Wolayta Zone is one of the drought prone areas in southern Ethiopia. Yet, livestock production contributes significantly to the economy of the Zone. Like other parts of the country, feed shortage due to recurrent drought and small and fragmented landholdings hinder the production and productivity of livestock in the zone (Pound and Jonfa 2006; Zereu and Lijalem 2016; Asrat *et al*., 2016). Though there are many studies on the availability and type of feed resources in the Wolayta Zone, limited work has been done to find current balance between demand and supply of feed in terms of DM yield, energy and protein yields. In addition data on seasonality of feed resources and preference of feeds by different livestock species has been lacking. This has created great problem to know and recommend a possible intervention against a deficit in livestock-feed balance in Wolayta Zone particularly and different parts of Ethiopia in general. Therefore, it is very imperative to assess the existing feed resources in terms of quantity and quality in relation to the requirements of livestock on annual basis, seasonality and animal preference so that it would be very easy to suggest either improvement options of intervening the already existing feed resources, introduce another feed alternatives or suggest other development and policy interventions for each agro-ecology. Therefore, this study was conducted with the following objectives.

1. To assess livestock feed resources and feeding systems in terms of quality and quantity
2. To compute the balance between feed supply and demand for livestock, and
3. To assess seasonal availability and livestock preferences of feeds, in small and fragmented landholdings of Wolayta zone, southern Ethiopia.

2. LITERATURE REVIEW

2.1. Seasonal Availability of Feed Resources in Ethiopia

The performance of any livestock depends on feed availability, nutrient content, feed intake, digestibility and metabolism of the feed digested (Onyeonagu, 2013). Animal feeds in Ethiopia are classified as natural pasture, crop residue, improved pasture and forage and agro industrial by-products of which the first two contribute the largest share in livestock production (Alemayehu, 2003; Berhanu *et al*., 2009; Tolera *et al*., 2012). The feeding systems in the country include communal or private natural grazing and browsing, cut and carry feeding, hay and crop residues (Tesfaye, 2008). Feeding of livestock in different places differs depending on forage availability, climatic variability of a given location or region to mitigate feed shortage problems during worse conditions, season of the year and type of animal the owner prioritize to feed (Beyene *et al*., 2011; Endale, 2015).

Feed resource availability is influenced by seasonal fluctuation of rainfall. In some areas feed is available relatively in higher quantity and better quality during the rainy season and early dry season compared to the long dry season (Kassahun, 2016). The dry season is characterized by inadequacy of grazing resources. As a result, the use of communal grazing lands, private pastures and forest areas as feed resources has declined while the use of crop residues and purchased feed has generally increased (Benin *et al*., 2003). Though increased utilization of agro-industrial by-products has been reported (Benin *et al*., 2004), they are not readily available, affordable or feasible for most of the farmers in the highlands of Ethiopia (Endale, 2015).

Animals have to survive on range that also has a low nutritional value on many parts of the country for most of the year. During the wet season, concentrate supplements and green feeds are the most widely used feed resources, whereas during the dry season the poor quality natural pasture for those who grazed their animals, conserved hay, concentrates, non-conventional feeds are important feed resources (Duguma and Janssens, 2016). Dereje *et al*. (2014) also stated that feed shortage is commonly experienced among most farmers particularly from December onwards. High temperatures in drier seasons lead to feed shortage as grasses dry out and the residues are consumed by termites. Fodder conservation for the dry season is not a common practice. Thus the excess forage available during the rainy season is often wasted by being trampled upon by animals and burning during the dry season. In general, the recurrent drought and climatic variability has exerted great pressure on the availability and use of feed resources in Ethiopia (Assefa *et al.* 2014). Thus feed shortage is a very important problem in the months between December to February and less important from October to November in most highland areas of Ethiopia as indicated in Table 1.

Table 1. Feed calendar in the central Ethiopian highlands

Months	Feed Shortage	Crop Aftermath	Free grazing	Straw cereals	Straw Legumes	Cut and Carry	Demand for improved forage
Dec – Feb	XXX	XXX	X	X			XX
March – June	XX		XX	XX	XX	XX	XXX
July – Sept	XX	X	XXX	XX	XXX	XX	X
Oct – Nov	X	X	X	X		X	X

xxx = very important, xx = important, x = less important (Source: Amede *et al*. 2018)

According to Yeshitila (2008), availability of feeds depends on the season of the year when lands are covered with either Meher or Belg season crops. The duration extending from planting of major Belg and Meher crops until their harvest makes major challenge to the availability of livestock feeds. Belay *et al*. (2012) and Salo (2017) confirmed that feed shortage also occurs in wet season due to water logging of the grazing pasture lands and intensive cropping. Natural pastures support animal productivity in the rainy season, while in the dry season these pastures can hardly maintain the animals as most of the feed resources are less available and of poor nutritional quality. This could be due to the poor practices of feed conservation and flash burning of the feed resources during the dry season. In the wet season natural pasture is the sole sources of livestock feed, while in the dry season, natural pasture, crop residues, stubble grazing and grass hay are the major feed resources. Next to natural pastures, crop residues are other main sources of livestock feed during the dry season (Tesfaye *et al*., 2010).

According to Dereje *et al*. (2014), there is plenty of natural pasture during the wet season, while farmers do not have a tradition of conserving and keeping the excess forage for the dry season, when there is a relative shortage of feed. Salo (2017) also asserted that crop residues are abundantly available at the beginning of the dry season following the harvest and threshing of cereal and pulse crops.

2.2. Nutritional Quality of Feeds

Nutritional quality of feed ingredients is determined by the quantity and digestibility of amino acids (AA), lipids, carbohydrates and minerals in the ingredients. The combined quantities of digestible AA, lipids and carbohydrates also provide the total quantities of digestible energy (DE) in the diet (Stein, 2014). It is also determined by a number of other factors such as odor, texture and taste (Schneider and Flat, 1975). When feed is offered alone and of free choice to animals having production potential, feed quality may be defined in terms of animal performance (e.g., daily gain). Heaney (1970) combined digestibility and intake into a single index as a means of evaluating the feeding value of forages. Raymond (1969) proposed a similar concept, but added utilization of the digested nutrients to the equation, similar to the concept proposed by Mott and Moore (1970).

Climate of an area affects the nutrient composition of the forage species growing in that area. The concentrations of nutrients in forage species depend not only on the prevailing seasonal and environmental conditions but also on the individual plant species (Pandey *et al*., 2011; Onyeonagu and Ukwueze 2012; Onyeonagu *et al*., 2013).

2.3. Seasonal Variations in Feed Quality

Dyness *et al*. (2013) reported that seasonal variations in quantity and quality of the forages are a major concern especially during the dry season throughout the world. Assefu, (2012) also stated that in the dry-season in Ethiopia, the available pastures and crop-residues are usually in short supply and often poor, and are characterized by low concentrations of energy, protein and other nutrients (minerals and vitamins), which are required to maximize rumen microbial activity. Feeds available in the dry season also have a high content of dietary fiber ranging from 35 to 48%, which has a limiting effect on intake and digestibility of feeds. Associated with dietary fiber are the anti-nutritive factors such as lignin and silica, which are known to inhibit microbial fermentation in the rumen as shown in Table 2.

Table 2.Nutritional quality characteristics (%) of the natural pasture as influenced by seasonal climatic changes in Chilanga district of Zambia

Season	Dry matter	Protein[1] (%DM)	Fibre (%DM)	TDM[2]	Energy[3]
Nov-Jan	24.8	8.0	32.6	54	980
Feb-Apr	38.7	4.2	38.0	49	865
May-Jun	51.2	2.1	44.0	26.3	464
Aug-Sept	73.3	1.5	47.6	20.0	351

[1]Digestible crude protein, [2]Total digestible nutrients, [3]in Kcal/kg (Source: Simbaya, 1998)

Chemical composition and nutrient availability of feeds varied tremendously depending on species, ecological zones, seasons of the year and processing techniques, let alone the variations that occur between laboratories during analysis as indicated in Table 3. The crude protein (CP) content of range vegetation is between 8 to 12% of dry matter (DM) at the beginning of rainy season, but drops to 2-4% during dry season, leading to prolonged periods of animal malnutrition (Belete *et al*., 2012).

Table 3. Seasonal effects on nutrient concentrations of forage species in a citrus plantation in Ghana

	Dry matter (%)			**Crude protein (% DM)**		
Species	Dry season	Rainy season	s.e.m.	Dry season	Rainy season	s.e.m.
Asystasia gangetica	37.4	28.8	1.85	20.6	16.9	1.63
Centrosema molle	45.4	44.1	2.56	18.7	19.0	1.15
Citrus leaves	50.2	50.0	1.18	12.8	13.0	0.27
Combretum sp.	54.3	49.2	1.44	19.9	18.2	1.02
Griffonia simplicifolia	47.3	49.6	2.12	17.9	20.1	1.46
Mallotus oppositifolius	43.3	43.4	2.30	17.1	15.6	0.80

Oplismenus burmanii	47.8	39.1	2.71	7.5	10.7	1.28
Panicum repens	46.5	38.8	1.14	8.9	10.8	0.68
Pueraria phaseoloides	43.5	34.8	2.11	18.5	17.5	0.81
Mean	46.2[a]	42.0[b]		15.8[a]	15.5[a]	
	NDF (% DM)			**ADF (% DM)**		
Asystasia gangetica	41.7	43.6	0.95	31.3	33.0	1.46
Centrosema molle	55.2	60.4	0.68	33.4	36.3	2.11
Citrus leaves	45.2	46.8	1.26	27.2	31.1	2.07
Combretum sp.	68.1	67.8	0.63	38.0	45.3	2.25
Griffonia simplicifolia	55.5	57.7	1.16	32.4	35.5	1.48
Mallotus oppositifolius	44.5	45.8	1.14	22.4	27.0	1.50
Oplismenus burmanii	64.4	66.8	2.17	37.2	36.6	1.96
Panicum repens	62.6	68.3	1.73	36.2	36.4	0.70
Pueraria phaseoloides	55.9	61.1	1.53	34.2	37.6	1.34
Mean	54.8[a]	57.5[a]		32.5[a]	35.8[a]	
	Cellulose (% DM)			**Hemicellulose (% DM)**		
Asystasia gangetica	18.6	21.5	1.43	10.5	10.6	1.22
Centrosema molle	18.2	22.9	1.53	21.8	24.1	0.52
Citrus leaves	15.7	20.9	2.17	18.0	15.7	1.34
Combretum sp.	21.8	23.7	1.42	30.2	22.5	1.71
Griffonia simplicifolia	16.7	16.8	0.96	23.1	22.2	1.32
Mallotus oppositifolius	14.2	21.3	1.68	22.2	18.8	1.88
Oplismenus burmanii	27.1	25.7	1.58	27.2	30.2	0.88
Panicum repens	24.8	26.1	0.92	26.5	31.9	1.88
Pueraria phaseoloides	23.7	25.7	1.03	21.7	23.5	0.53
Mean	20.1[a1]	23.0[a]		22.3[a]	22.2[a]	

[1]Means followed by different letters are significantly different ($P<0.05$) (Source: Leonard *et al.*, 2014).

Large seasonal changes in nitrogen (N) and phosphorus (P) concentrations in herbage and millet residues were observed in western Niger due to feed quality variation from season to season (Figure 1). Variation in crude protein and organic matter digestibility indicated both seasonal and inter-annual fluctuations in feed quality, with the highest values in the wet season and the lowest at the end of the dry season. Nutritional quality varies among plant species, but the variation within a species class (grass, legume and non-legume) is lower than between classes, that is, grasses and forbs (Fernández-Rivera *et al*., 2005).

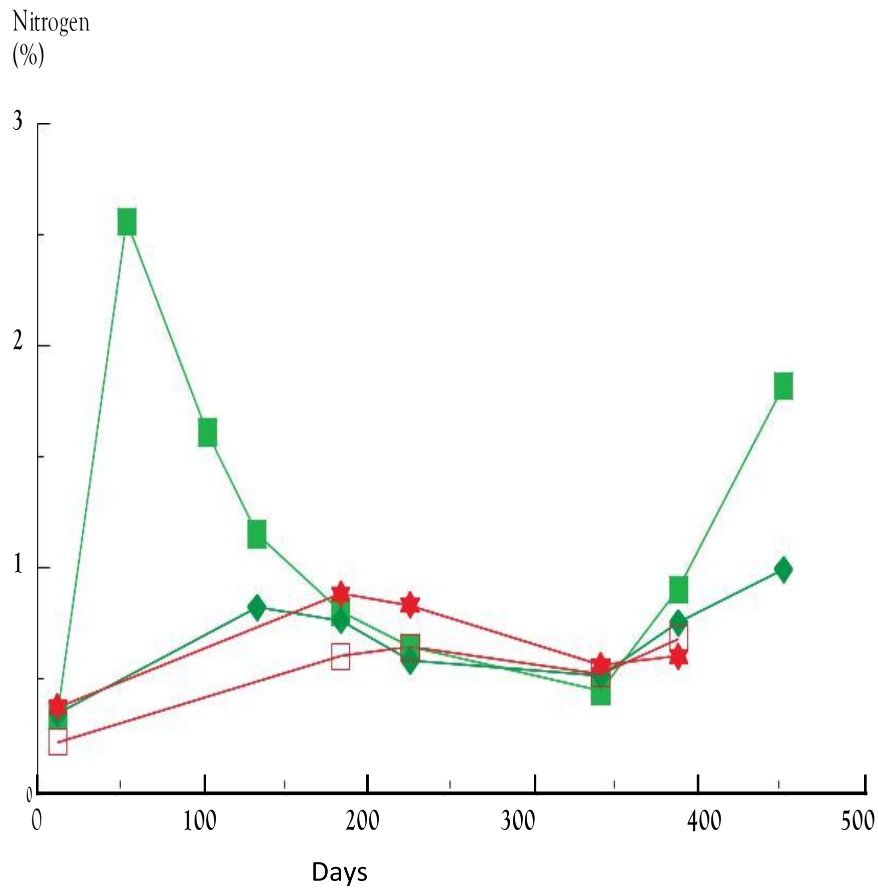


Figure 1. Seasonal changes in nitrogen concentrations in herbage and millet residues in western Niger (Source: Fernández-Rivera *et al*., 2005).

The peak values of N and P in the standing herbage corresponded with the vegetative stage (around August) after which the nutritive quality declined rapidly (Figure 1 and 2). After the rapid fall, the feed quality, especially of grasses, remained constant and excessively low for most of the dry season (Fernández-Rivera *et al*., 2005).

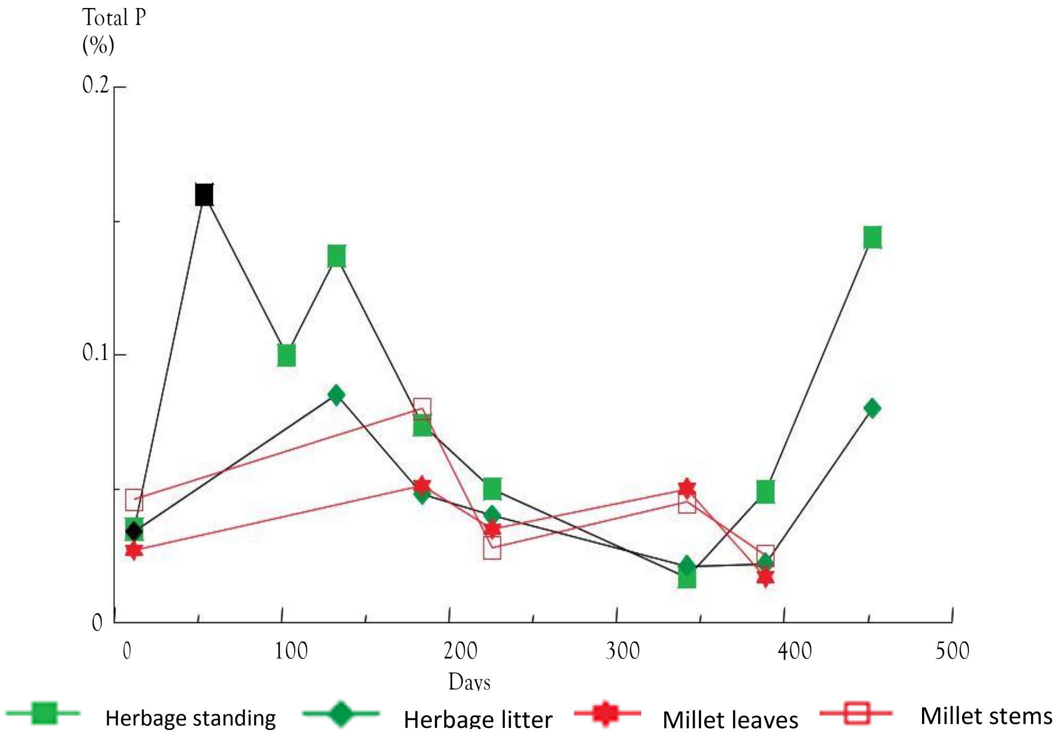


Figure 2. Seasonal changes in phosphorus concentrations in herbage and millet residues in western Niger (Source: Fernández-Rivera *et al.*, 2005).

Natural pastures mostly suffer from seasonal spells of dry periods during which they drop in quality, which is characterized by low digestibility, low in nitrogen, very low protein and energy contents in addition to high fiber content. The nutrient and/or element concentrations of feeds also vary greatly with in different seasons of a year as shown in Table 4.

Table 4. Seasonal concentrations of crude protein (%). phosphorus (ppm) and fibre (%) of plant species occurring in forage in central district of Botswana

	Summer			**Autumn**			**Winter**			**Spring**		
Grasses	Protein	Phos	Fibre	Protein	Phos	Fibre	Protein	Phos	Fibre	Protein	Phos	Fibre
Digitaria eriantha	7.73	0.063	34.11	4.39	0.036	35.71	4.06	0.036	35.86	4.61	0.047	35.80
Eragrostis lehmanniana	6.04	0.052	34.82	4.05	0.040	34.73	3.83	0.037	36.46	4.55	0.048	36.85
Eragrostis rigidior	5.67	0.057	32.98	4.06	0.043	33.36	4.12	0.044	33.02	4.02	0.049	35.65
Schmidtia papophoroides	4.98	0.073	36.21	3.72	0.041	38.26	3.55	0.035	38.71	4.27	0.044	37.30
Stipagrostis uniplumis	5.66	0.061	37.02	3.98	0.043	38.90	3.17	0.034	38.72	4.49	0.047	41.17
Panicum maxima	8.03	0.081	34.00	6.80	0.055	37.06	5.21	0.071	34.92	5.59	0.076	34.34
Urochloa trichopus	9.13	0.110	30.85	5.38	0.048	32.46	5.42	0.049	35.28	4.89	0.052	35.55
Megaloprotachne albescens	7.81	0.072	25.55	3.58	0.040	32.89	3.86	0.043	31.49	3.32	0.041	32.55
Eleusine Africana	13.67	0.209	30.21	6.07	0.068	33.41	-	-	-	-	-	-
Dactylotium aegyptium	15.16	0.225	29.89	9.34	0.087	30.23	-	-	-	-	-	-

Aristida spp	4.67	0.062	40.94	3.24	0.042	40.31	3.31	0.039	43.03	2.86	0.022	42.36
Forbs												
Amaranthus thumbergii	11.69	0.289	21.70	11.2	0.217	25.0	-	-	-	-	-	-
Cassia biescensis	13.71	0.192	23.09	8.61	0.195	29.01	-	-	-	-	-	-
Idingofera daleoides	16.41	0.095	23.81	6.92	0.044	30.10	-	-	-	-	-	-
Tribolus terrestris	13.11	0.283	25.60	11.77	0.213	26.70	-	-	-	-	-	-
Mean	9.56	0.123	30.75	6.22	0.082	33.19	4.06	0.049	36.39	4.29	0.053	36.84
Std Dev	±4.02	± 0.01	± 0.42	± 0.90	± 0	± 5.37	± 0.01	± 0.01	± .02	± 0.16	± 0.01	± 0 .78
Woody Plants												
A. fleckii	22.82	0.182	21.7	12.56	0.130	22.32	12.83	0.082	25.97	17.80	0.110	19.56
A. gerrardii	18.15	0.120	20.90	17.04	0.098	23.26	13.56	0.074	25.44	-	-	-
B. albitrunca	18.15	0.181	19.3	18.44	0.132	22.94	14.87	0.093	22.81	17.20	0.165	21.42
B. pertersiana	21.72	0.170	22.5	16.63	0.126	26.33	10.71	0.112	28.38	18.31	0.162	19.21
C. gratissmus	17.74	0.174	20.5	13.77	0.143	24.52	9.62	0.095	28.92	-	-	-
D. cinerea	19.44	0.140	20.3	14.72	0.128	25.31	10.30	0.114	27.62	-	-	-

G. flava	15.70	0.181	15.2	14.57	0.136	28.41	9.51	0.097	29.28	16.8	0.163	21.47
O. pulcra	11.96	0.113	29.3	11.65	0.098	29.97	9.11	0.067	30.81	15.40	0.185	19.55
M. sericea	17.18	0.144	28.2	16.14	0.122	28.95	-	-	-	-	-	-
T. ericea	14.13	0.108	15.7	15.64	0.079	24.97	15.60	0.039	29.11	16.30	0.133	16.83
Z. mucronata	13.22	0.123	23.5	14.81	0.076	23.75	-	-	-	-	-	-
Mean	17.29	0.148	21.6	15.08	0.110	25.52	11.79	0.07	27.59	16.97	0.150	19.67
Std Dev	± .54	± 0.01	± 0.32	± 0.70	± 0	± 4.33	± 0.01	± 0.01	± 0.22	±0 .01	± 0.01	± 0.02

(Source: Mphinyane *et al.*, 2015).

2.5. Impacts of Seasonal Feed Availability and Quality on Livestock Production

Tropical and Mediterranean climates are characterized by the existence of a season of varied duration, when rainfall is scanty or non-prevalent. Such season is termed dry season in the tropics and summer in Mediterranean climates. During rainy season pastures are available in higher quantities and show good nutritional quality whereas dry season pastures have poor nutritional quality with high fiber and low protein contents (Lamy *et al*., 2012).

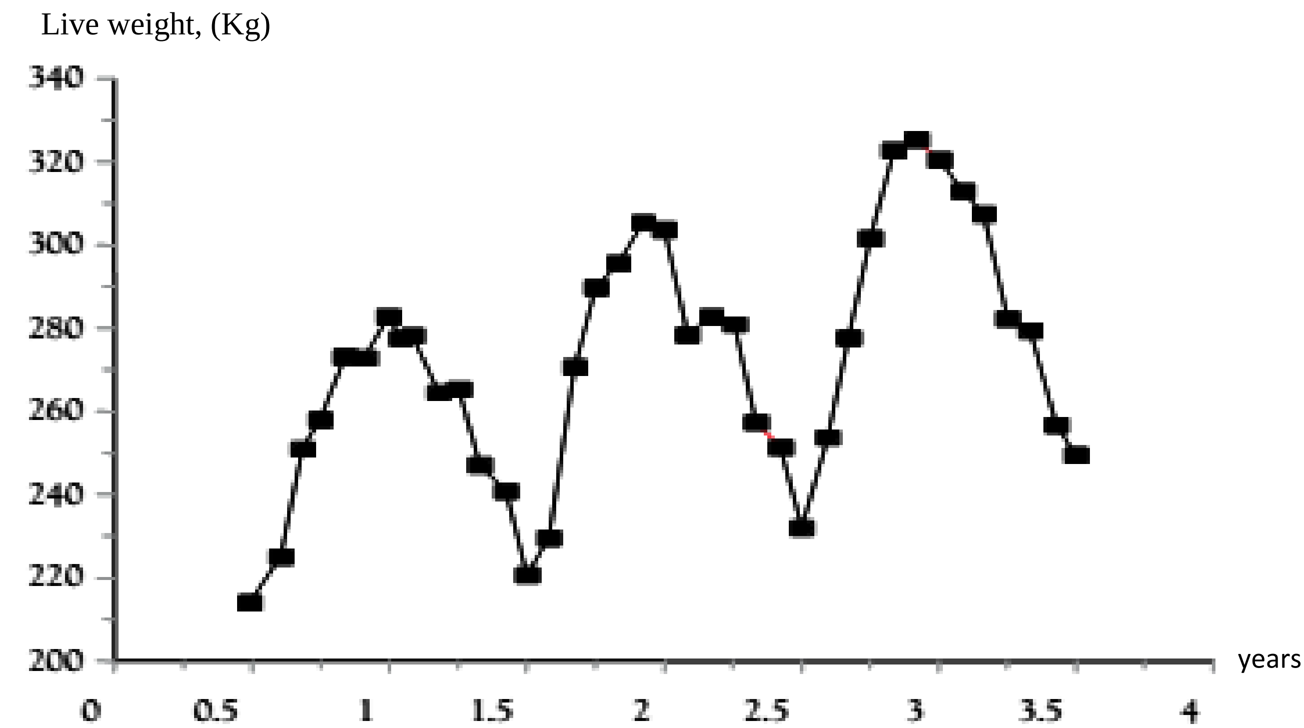
In tropical countries, lack of feed supplementation during the dry season is frequent in extensive or traditional management systems. This situation leads to a problem of seasonal weight loss of approximately 20–40% of the body weight at the onset of the dry season. This fact has been reported by several authors. Hence, pasture shortage significantly affects animal production in tropical nations such as Mali, Brazil, the Philippines, South Africa, or Guinea-Bissau. Seasonal weight loss has therefore great impact on all aspects of animal production (Lamy *et al*., 2012).

In Ethiopia among other factors, poor nutrition is a major constraint limiting livestock performance. Animals are undernourished because of fluctuating supply of nutrients, insufficient intake of available feeds or from inherent deficiencies in the available feeds (Yeshitila, 2008). Consequently, this leads to high mortality amongst livestock, longer calving intervals, and substantial weight loss, particularly during dry season usually extending from December to May in most parts of the country (EARO, 2000; Belete *et al*., 2012). Deribe *et al.* (2013) and CSA (2013) have also reported the decline of animal products such as milk, meat, and traction and at the worst the death of animals during the periods of serious feed scarcity. Feed scarcity is also indicated as a factor responsible for the lower reproductive and growth performance of animals especially during the dry season (Legesse, 2008).

Inadequate nutrition in the dry-season usually results in reduced body weight and condition scores in adult animals, retarded growth and increased mortality rates in calves. Also associated with poor nutrition is the increased susceptibility of animals to stress and disease challenges, which result in these animals performing below their expected genetic potential. All these factors result in heavy economic losses to the farmer (Belete *et al*., 2012).

During the dry season, plant growth is highly suppressed; shortage of forage availability reduces growth of grazing animals. This also affects nutrient requirements and bioavailability of minerals in grazing animals. Furthermore, in the dry season, most ruminants reared on grass alone have problems in meeting their maintenance requirements and consequently lose weight gained during the wet season (Aregheore, 2001; Kassahun, 2016).

Cattle showed a regular pattern of body weight changes consisting in gains of 80–100 kg for about 6 months (July to December) followed by a loss of 60–80 kg for 6 months (January to June) with a net weight gain of about 20 kg per year (Figure 3), whereas small ruminants showed much shorter periods of losses and relatively higher weight increases per year (Figure 4). The live weight changes followed closely the pattern of availability of forage and this was more notorious in the case of cattle (Fernández-Rivera *et al*., 2005).



(a) Cattle

Figure 3. Live weight changes of cattle due to seasonality of feeds over three years in the western Niger (Source: Fernández-Rivera *et al*., 2005).

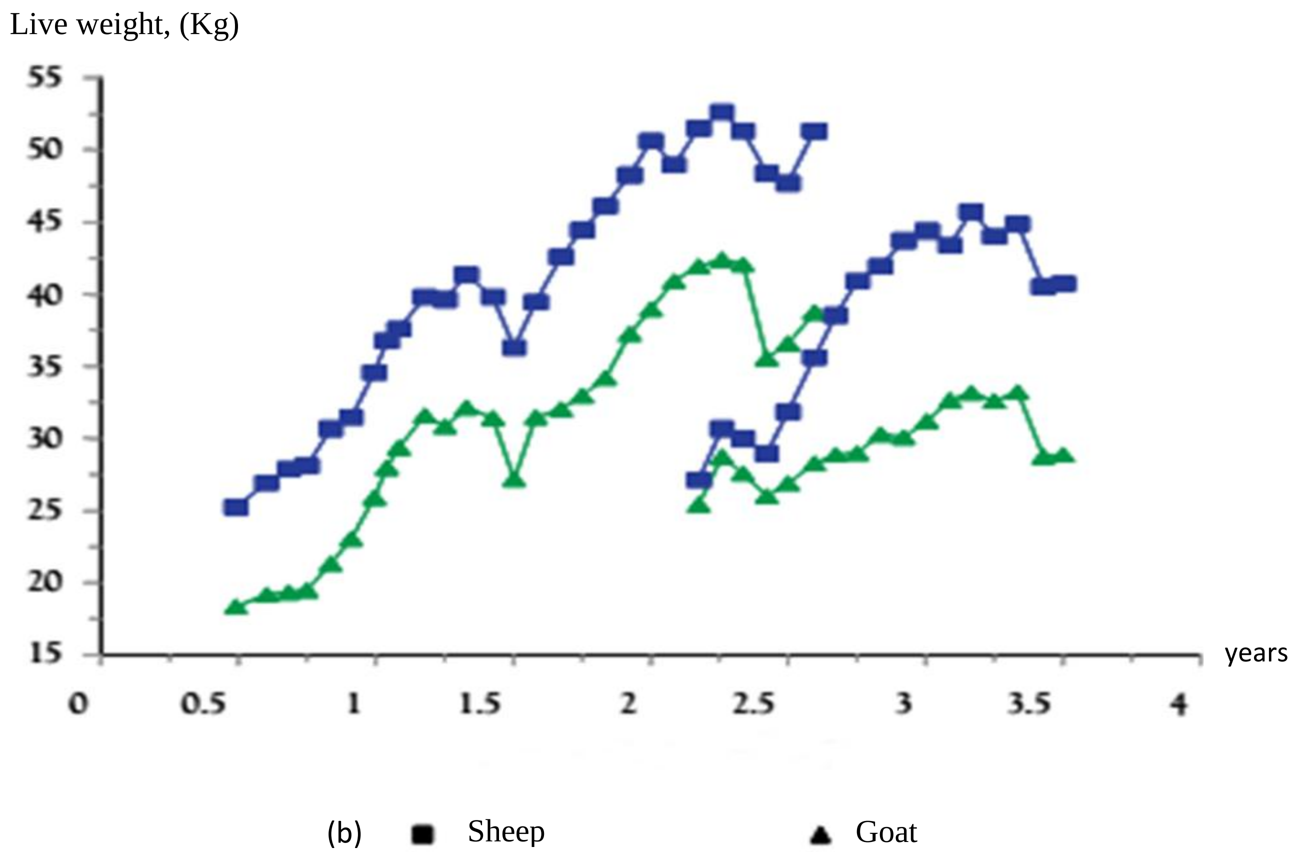


Figure 4. Live weight changes of sheep and goats due to seasonality of feeds over three years in the western Niger (Source: Fernández-Rivera *et al*., 2005).

Seasonal variations in forage intake and quality and the higher energy expenditure due to long walking distances result in low availability and imbalances of nutrients at the animal, tissue and cell levels. From the mid dry season to the early rainy season, lack of feed is the overriding factor. It leads to low availability of all nutrients, primarily those yielding energy and protein. Nutrient imbalances are likely manifested as protein deficiencies from the peak of forage biomass and crop residues early in the dry season, when fodder is still abundant and nutritional quality is decreasing. Late in the dry season insufficient levels of nitrogen and soluble carbohydrates in the herbaceous layer and the presence of anti-nutritional factors in browses impair rumen function and limit the ability of the animal to extract nutrients from the available feed (Fernández-Rivera *et al*., 2005).

The low availability and imbalances of nutrients lead to poor animal performance. Depending on the animal physiological status, nutrient deficiencies and imbalances result in growth retardation, reproductive wastage, low milk yield, increased susceptibility to disease, lower ability to perform work and lower amounts of manure. These effects on the animal negatively impact the ability of farmers to benefit fully from their herds. The ultimate consequence of poor livestock nutrition is lower income due to productivity losses and lesser sales of products; losses of assets and increased vulnerability to risk due to animal mortality; food insecurity resulting from lower farm productivity; and less sustainable farming due to a lower ability of farmers to recycle soil nutrients efficiently (Fernández-Rivera *et al*., 2005).

2.6. Mitigation of Seasonal Feed Availability and Quality Variations

The quantity, quality and continuity of feed supply throughout the year promote a favorable level of animal production in any environment. Most grass species have low dry matter digestibility and intake. To solve this problem, animal production systems resort to strategies such as transhumance in pastoral societies or to supplementation in mixed crop livestock and intensive systems. Animals that evolved in such production systems tend to have physiological adaptations that enable them to cope with seasonal weight loss (Lamy *et al*. 2012).

The causes of undernutrition in livestock, and therefore the options to improve nutrition, vary seasonally. Late in the dry season lack of feed is the overriding factor and low protein content, especially in cattle, limits the efficient use of the feed available. The problem is compounded as the rains start due to spoilage of the remaining roughage, and occasionally, due to the direct effects of rains on animals. The main option during the late dry season and early rains, before the herds leave on transhumance, consists in providing supplementary feeding with crop residues, bush hay and/or grain by-products. If the amount of roughage available aboveground is extremely low, the rate of intake is very low and the animals spend more energy walking. Under these situations an alternative is to keep the animals tethered or in camps with survival feeding. Supplementary feeding with roughage will be determined by availability of labour and cost of transport, whereas use of concentrates will be a function of availability and cost of grain by-products. As the rains continue, the forage starts to grow and the crops develop. At this stage the quality of the forage available is very high and the main constraint is herd mobility. Grazing and moving herds to watering points during this season may lead to crop damage and thus to conflicts between herders and farmers. The main option to improve nutrition and prevent conflicts in this season is the establishment or strengthening of local institutions to facilitate herd movements through corridors for herds to access range and watering points (Fernández-Rivera *et al*., 2005).

Except some trees that continue growing after the rainy season ends, all range forage and crops residues are produced during the rainy season. Attempts to increase fodder production on rangeland and/or cropland must be targeted during this season. Heavy continuous grazing during this season leads to undesirable changes in vegetation and lowers range productivity. There are opportunities for controlling the intensity and timing of grazing using short duration rotational grazing strategies by organizing herders. Increasing the quantity and quality of fodder with food–feed crops is possible through precision manuring and applying fertilizers and possibly through variety selection. It can be an option to supplement animals with higher protein requirements, such as lactating cows. Conserving crop residues and bush hay under cut-and-carry strategies may reduce spoilage and provide feed late in the dry season (Fernández-Rivera *et al*., 2005).

In the early to mid-dry season, herd management appears the most practical option to improve nutrition. Night grazing can also be practiced to improve nutrition during the early and mid-dry season. Allowing animals to graze at night increases feed intake but reduces the amounts of manure collected. As the dry season progresses, aboveground forage mass decreases. Animals require longer grazing times and spend more energy walking. Up to some point, the decrease in forage availability is compensated with longer grazing times. However, when forage availability is extremely low, such compensation is no longer possible. At this stage, if harvested crop residues or bush hay are available, it is advantageous to restrict walking by keeping animals on fields scheduled for manuring and feed these roughages or other supplements. In peri-urban areas with easy access to markets these supplements are increasingly being used to improve livestock nutrition (Fernández-Rivera *et al*., 2005).

Supplementary feeding with nitrogen, energy and minerals as well as chemical and physical methods of treatment has been used in order to improve feeding value. The commonly used chemicals include: $NaOH$, $Ca(OH)_2$, NH_4OH, CaO, UREA, O_3 and SO_2. Treatment of fibrous feeds with NaOH is too expensive, and more emphasis is being put on ammonification; and that urea is preferable to NH3 especially for developing countries. Apart from supplementation, many techniques have been developed to increase the efficiency of utilization of crop residues and by-products of agriculture. Methods available are physical processing or grinding that have given reasonable results when roughages are included in complete diets but it does not improve the ME value of the roughage to any significant extent. Biological methods are still in the early stages of development and it may be some time before methods are devised for large-scale application. The most applicable way of improving the ME value of a roughage is by chemical treatment especially for low quality roughage and crop residues (Yeshitila, 2008).

Feed conservation in suitable forms is another option to extend feed availability and quality during the dry season and thereby support better livestock production. According to Zewdie (2010), livestock feed supply in different parts of Ethiopia either totally or partially depends on conserved feeds for at least half of the year. Proper feed conservation is therefore essential to preserve the nutritional quality of the feed and to reduce direct loss of nutrients to the environment (Fekede, 2013).

In addition people use different browse species as a "stop gap" measure during the transition period from dry to wet seasons since they stay green. Browse pods are also high in nutritive value and can be used as supplements to low quality roughages (Kassahun, 2016). Browse species have considerable potential in mixed crop livestock production system, to supplement low quality feeds, fix atmospheric nitrogen, and provide fuel and shelter and to help in soil and water conservation. Moreover, the ability of most browse species to remain green for a longer period is attributed to deep root systems, which enable them to extract water and nutrients from deep in the soil profile and this contributes to the increased CP content of the foliage (Belete *et al*., 2012). Trees provide other functions important for climate adaptation, including the provision of ethno-veterinary treatments to counter increased disease threats (such treatments are often relied on in areas with poor state veterinary services, especially in pastoral systems with poor infrastructure) (Dharani *et al*., 2014). Wider use of the right fodder trees in substitution for other feed options also provides mitigation opportunities through dietary intensification, tree carbon sequestration and savings through foregone concentrate and annual crop production and use (Dawson *et al*., 2014).

2.7. Animal Preference of Plants and Plant Parts

Preference is the selection of a plant species by the animal as a feed (Hussain and Durrani, 2009). Feed preference determines the feed ingested by an animal which in turn affects its physiological condition and fitness (Scott *et al.* 2005). The concept of feed preference comprises two features of the feed, attractiveness (measured by choice tests) and palatability (measured by comparing the quantity of the different feed stuffs ingested). Diet selection in terms of both quantity and quality is primarily a function of the types and amount of feed on offer. Selective grazing, due to differences in relative plant palatability, is a problem confronting people concerned with the practices of correct range utilization. Two forms of selective grazing, namely species selective grazing and area selective grazing were identified (Masahiko *et al*., 2008; Soder *et al*., 2009).

The measurement of animal diet preferences presents numerous problems that, as yet, have not been entirely overcome. Therefore no standard method has been devised by which animal preference can be successfully measured under a variety of conditions. The causes for differences in palatability among both grasses and other life forms are as yet not clearly understood in spite of the fact that numerous attempts had been made in the past to relate preference differences to a number of factors such as forage quality (Soder *et al*., 2009), frequency of grazing and forage available in the range (Darlene et al., 2005; Kilonzo *et al*., 2005). Knowledge of the reason why herbivores select the species that they eat is necessary for an understanding of the forage needs of range animals and the underlying basis of composition interaction among them. Variations in nutrient content occur between, and within, plant species and herbivores select their food to obtain a nutritionally balanced diet. Less selective livestock such as cattle, suffer more from poor diet quality during dry season compared to selective feeders such as goats that predominantly browse throughout the year and include fewer species of grasses (Mphinyane *et al.,* 2015).

2.7.1. Factors influencing preference

Many researchers have studied the relationship between chemical composition of plants and their preference by livestock species. High positive correlation between protein content and preference by cattle and sheep has been shown. Foods high in sugars or with sugars added are preferred by cattle, pigs, calves and deer. In work with silage high preference was associated with high content of acetic, linolenic, and butyric acids. High total ether extract indicates high preference. Increased fats resulted in greater preference. Grasses highest in phosphate and potash were also the most acceptable to livestock. As proteins, sugars, fats, and preferred components of ether extract increase in percentage composition, lignin and crude fiber decrease. Therefore negative correlations of lignin and crude fiber with increased preference were shown in most of the studies done in different parts of the world. Tannins showed no correlation with preference but tannic acid made hays more acceptable in a study with cattle. A high negative relationship between tannin and preference by cattle for lespedeza varieties has also been reported. The variety with highest tannin also had the highest percentage of crude protein. Several compounds, including tannin, coumarins, and nitrates, are believed to decrease forage preferences. In analyzing manure affected and unaffected plants, the manure affected plants were always higher in protein, calcium, potassium, iron, fat, nitrates, and vitamins. The normal or unaffected plants were always higher in silica, aluminum, phosphorus, tannin, chloride, and sugars. When sugar was added to manure-affected plants, they became palatable and were readily eaten. Sugar *per se* may not be the cause, as the same results were achieved when saccharine and sodium cyclohexyl sulfamate were added. The spraying of molasses on dry mature grass herbage has been used to promote grazing of plant materials with low palatability. Many conflicting results have been reported in studies conducted to determine what chemical components influence on forage preference. The extremes are shown by the positive correlations mentioned above in contrast to the conclusion that there seems to be no consistent correlation between chemical composition of forage and its preference (Heady, 1964).

Perhaps, more significant than the amount of any chemical compound is the combination of different components. Although protein shows the best correlation of all chemical ingredients with preference of forages by livestock, several investigators believe that total nutritive value of the plant is a better indicator of palatability. Good reason exists for this conclusion. Results which relate chemical composition to preference usually give a list of compounds that increase as preference increases and another list of compounds which decrease. Definitive work to show the effects of each compound with the others held constant has not been successful under grazing conditions. In effect, preference has been correlated with groups of compounds rather than with single items in most studies. With partial regression analysis the effects of one factor could be determined independently of the others. Within any plant the actual amount of chemical compounds varies with plant parts. Leaves are higher in ether extract and crude protein than stems, and lower in lignin, cellulose, and crude fiber. Fruits and seeds vary in chemical composition among species but commonly are high in crude protein, fats, and soluble carbohydrates. Fruits and leaves can be grazed without stems but stems can hardly be taken without leaves. Advancing growth stage has frequently been mentioned as a factor correlated with decreasing preference. As grasses and broad-leaved herbs mature, they decrease in crude protein and increase in crude fiber, lignin, cellulose, and other carbohydrates. These are actual changes in the plant as a whole and are further affected by changes in leaf-stem-fruit ratios. Plants also change in succulence and harshness of the foliage. Anatomical studies have shown that position and extent of lignification is associated with curing qualities (Shaheen *et al*., 2014).

Preference changes with growth stage as plants in mixed vegetation do not mature at the same rate. Whether the response is to taste or to some other stimulus such as touch is not known and insufficient evidence is available to evaluate the palatability aspects in these relationships. Workers in grazing management have attempted to manipulate feed values and, perhaps incidentally, palatability in two ways. One is with mineral soil amendments which speed early growth, delay maturity, and favor some species over others. For example, nitrogen fertilization often increases size of cells without proportionate increase in cell-wall material so the plants are more succulent and less harsh. Thus fertilized range areas are preferred by livestock and deer is a widespread observation. The second is by management system which keeps the forage species from becoming tall and coarse by periodic heavy use and mowing. Clipping studies have shown that changes in the relative amounts of chemical compounds occur after a plant is clipped. It is assumed that similar changes would occur as a result of repeated and periodic grazing and that the relative amounts of certain chemical compounds influence palatability (Heady, 1964; Amjad *et al*., 2014).

2.7.2. Methods used to determine preference

Because correct utilization is an important aspect of rangeland management, numerous methods have been devised to measure what and how much herbage has been removed from the grazing area. These techniques are used to determine preference which is usually expressed as the relative use made of different species. Preference may be expressed in terms of the proportionate time an animal spends grazing on different species of plants. Cafeteria plots of several species in pure stands are used to study preference, which is measured in terms of percentage of time animals graze in each plot and the amount of herbage removed. Giving penned animals a choice of two or three foods is a similar technique. Other techniques that give information on animal preference include analysis of stomach contents, fecal material, collections from esophageal fistulas and from stomach fistulas. Fistulas have been used for many years in nutritional studies but only few promising results in examining food preference (Heady, 1964).

Preference has been expressed in different ways. General terms such as excellent, good, fair, and poor and as many as ten numbered classes are common. Data have been presented in frequency indexes based on number of stems or plants or plots grazed. Weight of clippings taken before and after grazing or inside and outside enclosures give indications of differential use, hence preference. The proportions of time animals were eating various foods and number of animals eating each food at certain time intervals is other expressions of preference. The proportion of species and plant parts in materials collected from fistulas as ratios to the feed offered measures whether the species are selected or avoided. In general the methods used to measure preference are those employed primarily for other purposes such as determining grazing capacity, effects of grazing on vegetation, forage production, food intake, animal nutrition, and range utilization (Heady, 1964).

In fact these techniques are not completely satisfactory for the purposes employed. For example, all the methods of determining forage use are based on differences between grazed and ungrazed conditions and on computing the eaten portion from the herbage remaining. Accurate measurement of what the freely grazing animal has eaten is most difficult, especially when the forages are mixed. Analysis of stomach contents requires fistula operations or sacrifice of animals, and the results are biased in favor of slowly digestible materials. Esophageal fistulas seem to be the most promising aid to determining what is eaten. This technique does not give quantity consumed, nor have inherent variability and bias been studied. Several points stand out concerning methods of determining preference. Techniques should be perfected, results should be expressed in a way that shows relative use in relation to relative availability, and studies which concentrate on preference are needed. The latter should include controlled experimental manipulations and measurements throughout the stimulus response system of food selection and acceptance (Heady, 1964).

2.8. Palatability of Plants and Plant Parts

In accordance with the definition given by Greenhalgh and Reid (1971) as well as Church (1979), palatability is the dietary characteristics or conditions which stimulate a selective response by the animal, palatability being considered as an inherent characteristic of the feed (Hodgson, 1979). For Matthews (1983), the palatability of a feed is interchangeable with preference for the feed. It is determined by the taste, smell, appearance, temperature and texture of the feed. However, Forbes (1986) claims that palatability cannot be considered solely as a quality of the feed since it depends on the experience and metabolic status of the animal in question; palatability of a feed is not absolute and depends on the state of hunger of the animal.

Palatability of the feed is the corollary of the appetite of the animal, which is the stimulation to eat aroused by the feed. Eating rate, especially at the beginning of the meal, is a good criterion of the animal's appetite, and palatability of the feed is defined as all the physical (plant bearing, spines) and chemical (odour, taste) characteristics of the feed that act on appetite. Mertens (1994) concurs with this last definition but does not mention physical characteristics of the plant; thus, it is not clear if the physical characteristics that determine ease of prehension and ease of mastication are components of palatability or not. At pasture, ease of harvesting has a major effect on diet selection. For animals fed indoors, it is well known that the same hay in long, chopped or ground form is not eaten at the same rate and in the same amount. As it is established that physical characteristics such as particle size and water content contribute to the sensory response invoked by the feed are considered as features of palatability (Baumont, 1996; Khan and Hussain, 2012).

2.8.1. Evaluating palatability

Palatability is obviously not a quantitative measure unless feed intake is measured per unit time. An ideal measure of palatability will not be influenced by the consequences of previous ingestion of feeds, nor by the postingestive consequences of intake. Several methods are used to evaluate palatability. They differ according to what intake or behavioural parameters are recorded and whether only one or more than one feed is offered. However, none of these methods can avoid the effects of prior learning of feed characteristics (Baumont, 1996).

2.8.1.1. Intake measurements

Differences in voluntary intake cannot be attributed only to palatability as they result from the sensory response and the digestive, metabolic and hormonal events following meals. Recording intake during the first minutes, following exposure to the feed limits confusion of palatability with postingestive factors. A simple exponential model accurately fits intake rate during meals both in monogastric animals and ruminants. This enables to calculate initial eating rate at the beginning of the meal (Baumont, 1996).

2.8.1.2. Behavioral measurements

Behavioral measurements allow the evaluation of the motivation of the animal for the feed rather than the result of this motivation, which is intake. Two different types of behavior can be measured: behavior associated with eating freely-accessible feeds and behavior that will gain access to elected feeds. Under grazing conditions eating time is much easier to measure than intake. Grazing time has often been recorded at pasture and the differences in grazing times interpreted as differences in intake. The time spent grazing on different sward types is considered to reflect the motivation for the different swards. Thus, time spent grazing is often used to evaluate preferences at pasture. Monitoring grazing time allows an analysis of the temporal pattern of preference at pasture. However, time spent grazing varies not only with the palatability of plants but also with the sward structure (height, density) (Baumont, 1996).

3. MATERIALS AND METHODS

3.1. Description of the Study Area

The study was conducted in four *woredas* of Wolayta zone in Southern Nations Nationalities and Peoples Regional State, Ethiopia (Figure 6) for one year from November 2016 to October, 2017. Wolayta zone is located 390 km southwest of Addis Ababa following the tarmac road that passes through Shashamane to Arba Minch. Alternatively, it is located 330 km southwest of Addis Ababa following the tarmac road that passes through Butajira-Halaba to Arba Minch. Wolayta Sodo is the town of the Wolayta zone. It is located between 6.40- 7.10 N and 37.40- 38.20 E latitude and longitude, respectively. Wolayta zone has a total area of 4,541km^2 and is constitutes of 12 *woredas* and 3 registered towns. It is approximately 2000 meters above sea level and its altitude ranges from 700-2900 meters above sea level (WZFEDD, 2012).

According to Central Statistical Agency report of 2010, total number of population of Wolayta zone is about 1,581,650. Out of this, males are 781,068 (49.4%); while females comprise about 800,582 (50.6%). About 1,364,943 (86.3%) people live in rural area while only 216,707 (13.7%) people live in urban area. Population density of the area is estimated at 385 people per square kilometer (CSA, 2010). Wolayta zone is divided into three agro-ecological zones: 35% *Kolla* (lowland <1500 masl, 56% *Woina-Dega* (mid-altitude 1500-2300 masl) and 9% *Dega* (highland > 2300 masl) with the most of the area lies within the mid altitude zone (Berhanu, 2012; WZFEDD, 2012).

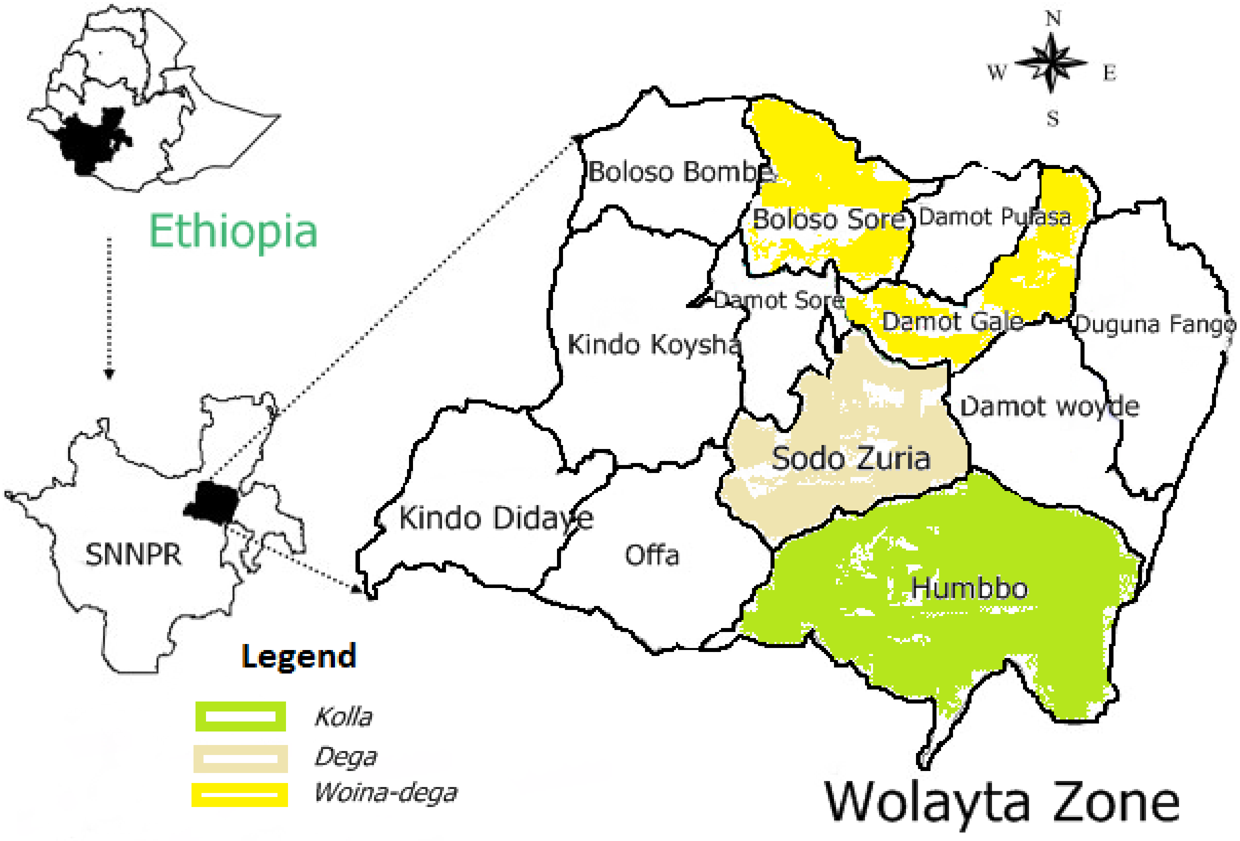


Figure 5. Map of Wolayta zone

Wolayta zone has a bi-modal rainfall pattern that usually extends from March to October IN WHICH the first rainy period occurs from March to May, while the second rainy period covers July to October, with its peak in July and August. The average annual rainfall over 43 years is 1,014 mm (Gian Luca Bagnara, 2017). Mean monthly temperature vary from 26^{0}C in January to 11^{0}C in August (Ayele, 2008; WZFEDD, 2012).

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, 2008). Primary occupation of Wolayta zone is mixed crop-livestock farming. 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. In addition, farmers own cattle as wealth indicators. 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 for livestock production (Berhanu, 2012; WZFEDD, 2012).

3.2. Sampling Techniques

Multi-stage sampling procedures were used to collect series of data. In the first stage, Wolayta zone was selected purposively by 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. 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 woredas were selected from *woina-dega* agro-ecology as most of the area lies within mid altitude (*Woina-dega*)) were randomly selected. From the selected 4 *woredas*, a total of 8 *kebeles*, two from each were taken randomly (Figure 7). Subsequently, a total of 176 farmers that owned any of the livestock species from the 8 *kebeles* (22 farmers from each *kebele*) were interviewed. The total number of households sampled for the study was calculated based on the formula given by Cochran (1977). A precision level of 5% and 95% confidence interval was used to calculate the sample size using the formula $n = (Z^2pq)/d^2$, 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). In addition, 40 households (5 from each *kebele*) were selected purposively based on their educational background for monitoring seasonal availability and differential palatability of plants.

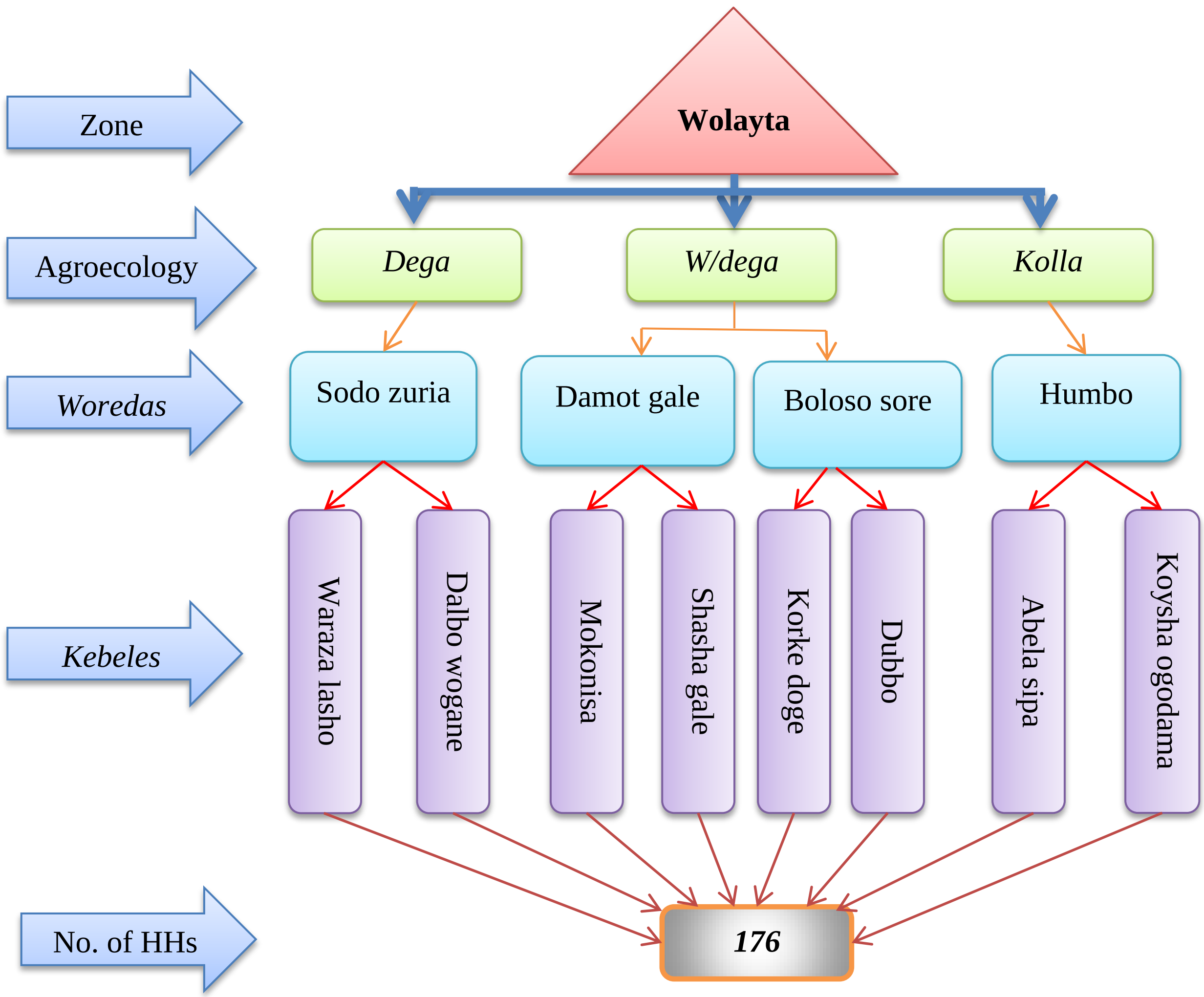


Figure 6. Schematic diagram of selection procedures of study site and sample households

3.3. Data Types

Both quantitative and qualitative data types were used in this study. In order to generate these data types, both secondary and primary data sources were used. Primary data included information on demographic and socio-economic issues, crop, livestock and livestock feed production from respondents, visual observations of the existing situation, palatability, seasonality and preferences of feeds by monitoring, and other important information from experts of *woreda* and zonal offices. Secondary sources included reports from zonal and *woreda* offices, journals, books, CSA and internet browsing, among others.

3.4. Data Collection Procedures

The data were collected through discussions with individual households, groups (6-8 households per *kebele*) and key informants, observations, monitoring and formal surveys. A preliminary assessment was conducted to collect basic information about the zone in order to select representative *woredas*. In addition, visits to already proposed study *woredas*, observation of livestock feeds and feeding systems were also made to collect data. Survey questionnaire were prepared and pre-tested on 16 households (2 from each *kebele*) 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) were hired to collect data from selected livestock farmers. Detailed descriptions of the data collection methods used were presented below.

3.4.1. Palatability of plants and animal preferences

3.4.1.1. Identification of palatable plant species

To identify palatable plant species, all the plant species available on the area were recorded on the basis of different research papers, published and unpublished sources, as well as using guide books such as '*Useful trees and shrubs of Ethiopia*' by Azene *et al*. (1993) and local names of the plants were matched to their scientific names using the information gathered from local communities who are familiar with the plant species. To identify different grass and browse species whose scientific names were not properly identified, specimen were prepared in duplicate, pressed between newspapers, dried and sent to the herbarium of Addis Ababa University following the guide provided in the Flora of Ethiopia (Hedberg and Edwards, 1989).

3.4.1.2. Differential palatability of plant species

Differential palatability of plants was recorded by daily observing the individual grazing animals for one year (from November 2016 to October, 2017). The special questionnaire prepared for this purpose (Appendix I) was administered to households selected for monitoring palatability of plants. The observations were taken fortnightly for 2-3 hours in the morning hours at the onset of grazing and then in the afternoon between 4-5 P.M. Each household was randomly assigned to a single animal species in order to ease data recording process. The field observations were further related with the information gathered from local herders/elders (key informants) and questionnaire findings. Plants were then classified into following palatability classes (Hussain and Durrani, 2009).

1. Non palatable (NP): Not grazed by animals at any stage; possibly toxic or harmful.
2. Highly palatable (HP): Species, which were preferred the most by livestock.
3. Mostly palatable (MP): Species with average preference by the livestock.
4. Less palatable (LP): Species with less preference.
5. Rarely palatable (RP): Species rarely grazed under compulsion when no other forage was available.

3.4.1.3. Differential palatability of plant parts and animal preference

The palatable species were further classified on the basis of animal preferences (all animal species available) and parts consumed (leaves, whole plant, fruits, twigs and roots).

3.4.2. Seasonal availability of palatable plant species

Every month for one year (from November 2016 to October, 2017) the available palatable plant species with the foliage such as grasses, herbs, shrubs and tree species were recorded by the questionnaire prepared for this purpose (Appendix II). The dormant plants with no foliage were considered non-available (Hussain and Durrani, 2009). The results obtained by monthly monitoring were related with that of questionnaire findings.

3.4.3. Quantity estimation of available feed resources

3.4.3.1. Dry matter yield of natural pasture

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

3.4.3.2. Crop residue, fallow land and aftermath grazing

The quantity of available crop residues (DM basis) was estimated from the total crop yields of the households, which was obtained from questionnaire, according to conversion factors. The conversion factors are 1.5 for barley, wheat, teff, 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 has been determined by multiplying the available land by the conversion factors of 1.8 for fallow land and 0.5 for aftermath grazing (FAO, 1987).

3.4.3.3. Trees and shrubs

There are two methods of estimating DM yield from fodder trees and shrubs (Petmak, 1983). The estimation by measuring stem diameter using measuring tape and applying the allometric equation of log W = 2.24 log DT-1.50, where W = leaf yield in kilograms of dry weight and DT is trunk diameter (cm) at 130 cm height. Similarly, trunk diameter (DT) can be obtained by DT = 0.636 C; where C = circumference in centimeter (cm). For the leaf DM yield of a shrub the following allometric equation can be used: log W = 2.62 log DS -2.46 where DS is the stem diameter in cm at 30 cm height. In quantifying tree feed resources from common property resources (e.g. open forest areas) at individual household level, similar approaches, as communal grazing area mentioned earlier, was used (Petmak, 1983). Alternatively, the dry matter from browsing trees and shrubs of leaf biomass can also be estimated at 1.2 ton ha^{-1} (FAO, 1987). For this study, the later estimation method (1.2 ton of DM ha^{-1}) was utilized.

3.4.3.4. Estimating available concentrates

The quantity (DM basis) of non-conventional concentrates (supplements) used in animal feeding per household was obtained by interviewing the farmers during the questionnaire based survey.

3.4.4. Quality estimation of available feed resources

3.4.4.1. Determination of chemical composition of feed resources

Review of available literature was used to describe the nutritive value of various feed resources. The Ethiopian feed resources database (http://www. vslp.org/ETH Feed/default.asp) and Sub-Saharan Africa feed resources database (http://www.vslp.org/ssafeed/), EIAR handbook

(Seyoum *et al*. 2007; Yisehak *et al*. 2010; Yisehak *et al*. 2013) and other published or unpublished sources were used to describe the nutritive value of feed resources commonly grown in the study area. The chemical composition of palatable plant species not obtained from previous works was subjected to laboratory analysis.

3.4.4.2. Analysis of chemical composition of palatable plant species

The chemical composition of some palatable plant species not obtained from previous records was subjected to laboratory analysis. Leaves and twigs of six fodder tree and shrub species (FTS) were collected during the dry season, a critical time when these plants serve as the alternative feed source. Leaf and twig samples of the plants were plucked from the fodder trees and shrubs by hand. The leaf and twig samples were collected from three agro-ecologies (*Dega*, *Woina-dega*, and *Kolla*). From each agro-ecology, samples were collected from at least three randomly selected fodder trees and shrubs and bulked to have one leaf sample for each FTS and taken to NVI (national veterinary institute) nutrition laboratory for chemical analysis. Feed samples were air-dried before being transported to the laboratory, then dried at 65 °C for 72 hours, milled to pass a 1 mm sieve and finally stored in air tight plastic containers until analysis. Feed samples were analyzed for dry matter (DM), crude protein (CP) and ash contents according to Association of Official Analytical Chemists (AOAC) (2000). Nitrogen was determined using the micro-Kjeldahl method (AOAC, 2000). The CP content was calculated by multiplying nitrogen content by a factor 6.25 (N x 6.25). Neutral detergent fiber (NDF) was determined using Van Soest *et al*. (1991) whereas, acid detergent fiber (ADF) and acid detergent lignin (ADL) were determined according to Van Soest and Robertson (1985).

3.4.5. Estimation of annual dry matter requirements for livestock

Data of livestock population in the sampled households were obtained from the interview of household heads during the survey. The number of livestock population was converted in to tropical livestock unit (TLU) using the conversion factors of camel (1), cattle (0.7), sheep (0.1), goat (0.1), mules (0.7), horses (0.8), donkeys (0.5), and poultry (0.01) (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).

3.5. Statistical Analysis

Means, standard deviations and percentages were used to describe variables observed among households stratified into three agro ecologies. To compare the differences in terms of feed type, feed source, net feed supply, net demand and feed balance, a one-way analysis of variance (ANOVA) was used. All data were analyzed using R software version 3.3.3. Mean comparisons of the three agro-ecologies were carried out using Tukey HSD test when there was a significant difference. Non-numerical (bionomial) data were analyzed using cross tabulation. 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 of was:

$$Y_{ij} = \mu + L_i + e_{ij}$$

Where,

Y_{ij} = is the response variable;
μ = is the overall mean;
L_i = is the effect of i^{th} location (agro-ecology), i = 1… 3;
e_{ij} = is the random error

4. RESULTS

4.1. Demographic and Socioeconomic Characteristics of the Households

A household characteristic of the sampled households is presented in Table 5. A total of 176 household heads were interviewed for this particular survey from which, 90.9% and 9.1% were male and female headed households respectively. The average age of the household heads was 45.3 years and average household size of the study site was 6.8. The household size varied significantly ($P<0.05$) across the agro-ecologies. It was higher in *Kolla* (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 statistically significant difference ($P<0.05$) across the agro-ecologies. From the total sampled household heads, 22.7% were illiterate, 47.7% followed primary education, 23.9% followed secondary education and 5.7% followed post-secondary education.

Table 5. Demographic and socioeconomic characteristics of the sampled households

Parameters	Agro-ecology, mean			Overall	SEM	P-value
	Dega (n=44)	*Woina-dega (n=88)*	*Kolla (n=44)*	mean (N=176)		
Household size (No.)	6.18[a]	6.77[abc]	7.61[c]	6.84	0.15	**
Age of HH heads (years)	45.34	45.25	45.38	45.30	1.00	NS
Land ownership (ha)	0.86[a]	0.89[b]	1.21[bc]	0.98	0.08	***
Livestock ownership in TLU	3.52[a]	3.59[a]	2.96[b]	3.42	0.08	**
• Cattle	3.05[a]	2.87[a]	2.27[b]	2.76	0.07	***
• Sheep	0.22[a]	0.18[a]	0.61[b]	0.16	0.01	***
• Goats	0.05[a]	0.05[a]	0.29[b]	0.11	0.01	***
• Equines	0.16	0.39	0.27	0.30	0.02	NS
• Chicken	0.03[b]	0.09[a]	0.06[c]	0.07	0.00	***
	Agro-ecology, frequencies			Total		P-value
Level of Education of HH heads						
• Illiterate	10[a]	13[ab]	17[b]	40 (22.7%)		**
• Primary	18	43	23	84 (47.7%)		NS

• Secondary	16[a]	23[a]	3[b]	42 (23.9%)	**
• Post-secondary	0[b]	9[a]	1[ab]	10 (5.7%)	*
Sex of HH heads					
• Male	40	82	38	160 (90.9%)	NS
• Female	4	6	6	16 (9.1%)	NS

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

4.1.1. Land Use Pattern and Feed DM Production

Landholdings per households showed statistically significant difference (P<0.05) across the agro-ecologies. Average landholding for the sampled households was 0.98 ± 0.081 ha (Table 5). Crops produced in the study area included maize, *teff*, wheat, barley, sorghum, bean and pea. In addition, sweet potato, Irish potato, cassava, yam, taro and *enset* were also common root crops in the area. Crops like *teff*, wheat and barley were mostly produced in some parts of *Woina-dega* and all *Dega kebeles* of the *woreda*. However, all root crops in addition to maize, sorghum and bean were produced in all agro-ecologies. The largest land size was allocated for maize (113.63 ha) followed by others crops like by *teff* (37.28 ha) and bean (28.25 ha). From the root crops, sweet potato production covered the largest area (40.13 ha) followed by Irish potato (22.25 ha) and cassava (20.43 ha) (Table 6).

Table 6. Land use pattern and feed DM produced from crop production in tone

Crops	Conversion factor	Total area (ha)	Total DM (ton)
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	64.06
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
Irish 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	
Banana	NA	7.35	
Total		404.84	517.35

** Irrigation areas produced twice within a year; NA, not available*

The sampled households owned on average (0.14 ± 0.17 ha) permanent grazing land and (0.8 ± 0.14 ha) fallow land. The ownership of communal grazing land and other sources of pasture for animals with total amount of DM obtained from each sources were summarized in (Table 7).

Table 7. Total amount of DM from natural pasture, fallow land and aftermath grazing in (ton)

Feed sources	Conversion factor	Total area (ha)	Total DM (ton)
Fallow land	1.8	47.33	85.19
Aftermath grazing	0.5	21.9	10.95
Permanent grazing land	2	54.06	108.12
Communal grazing land*	2	3472	45.72
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_

4.1.2. Livestock Holding and Composition

This study focused on the individual as well as the total livestock holdings of the study areas based on the sampled households. Farmers in the study site kept a mix of cattle, sheep, goat, donkeys 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 was significantly different (P<0.05) across all the three agro-ecologies. Yet, average cattle holding was significantly higher (P<0.05) in *Dega* agro-ecology (3.05 ± 0.19), followed by *Woina-dega* agro-ecology (2.87 ± 0.12) and *Kolla* agro-ecology (2.27 ± 0.27) (Table 5). The total livestock population of sampled households in terms of TLU was 602.24; cattle making the largest share (Table 8).

Table 8. Total livestock population of the sampled households in TLU

Tropical Livestock Unit (TLU)			
Livestock type	Conversion factor	Total population	TLU
Cattle	0.7	696	487.2
Sheep	0.1	289	28.9
Goat	0.1	199	19.9
Mule	0.7	4	2.8
Donkeys	0.6	85	51.0
Poultry	0.01	1244	12.44
Total			602.24

4.2. Differential Palatability of Plants

In Wolayta zone, 145 plants were identified as palatable by all livestock species (Appendix III). Among the palatable species, 48 (33.1%) were trees, 27 (18.6%) were shrubs and the remaining 70 (48.3%) were herbs. Of the 145 recorded species, 82 (56.6%) were highly palatable (Hp), 25 (17.2%) were mostly palatable (Mp), 24 (16.6%) were less palatable (Lp), and 14 (9.6%) were rarely palatable (Rp) (Figure 8). Most of the less palatable species (15 species, 62.5%) and rarely palatable (8 species, 57.1%) were from multipurpose trees. Some of them included *Vernonia* species, *Rhus glutinosa*, *Nuxia congesta* and *Schrebera alata* from less palatable species, whereas *Eucalyptus globulus*, *Combretum molle*, *Rhus natalensis* and *Rytigynia neglecta* were from rarely palatable species.

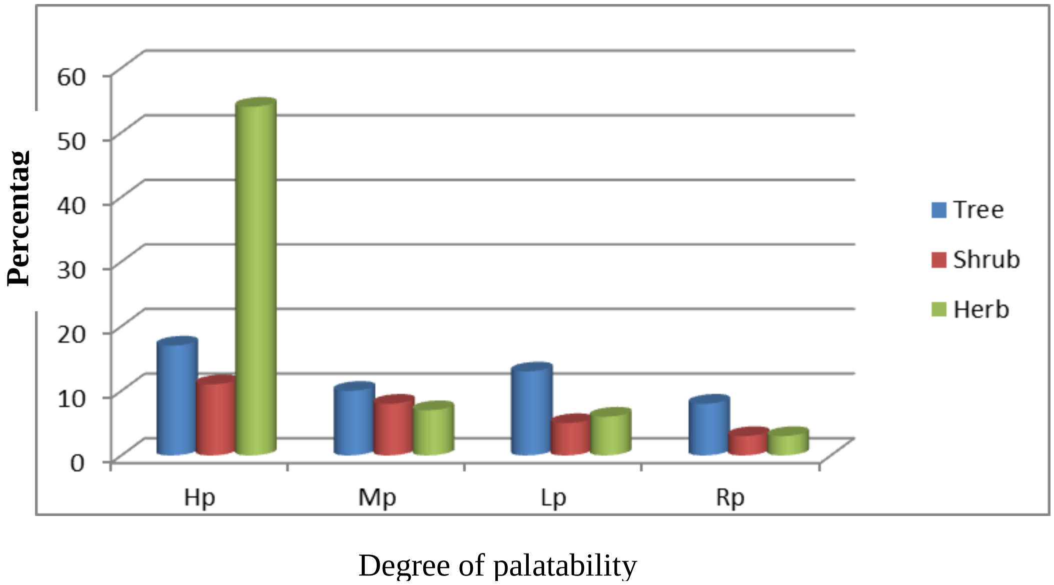


Figure 7. Differential palatability of plants

4.3. Preferences of Plants by Grazing Animals

The preference of cattle, sheep, goats and donkeys for plant species is presented in (Figure 9). Goats had a preference to the most forage plants (139 species, 95.8%), cattle (121 species, 83.4%), sheep (106 species, 73.1%) and donkeys (67 species, 46.2%). Goats preferred herbs (66 species, 47.5%), trees (46 species, 33.1%) and shrubs (27 species, 19.4%). Cattle preferred mostly herbs (67 species, 54.0%), trees (34 species, 28.1%) and shrubs (20 species, 16.5%). Sheep preferred herbs (64 species, 60.4 %), trees (24 species, 22.6 %) and shrubs (18 species, 17.0 %). The donkeys also preferred herbs (59 species, 88.0 %), trees (4 species, 6.0 %) and shrubs (4 species, 6.0 %).

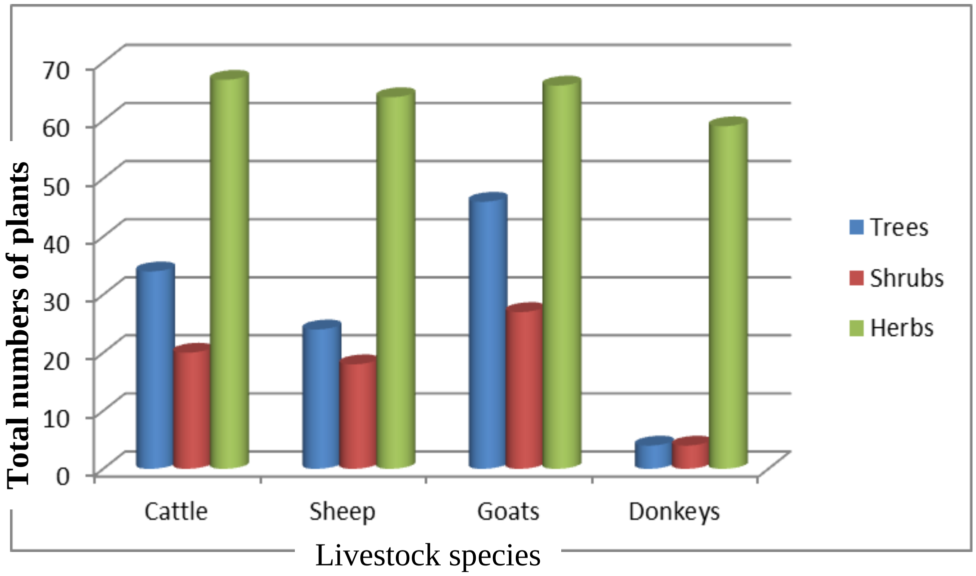


Figure 8. Preference of plant species by livestock species

4.4. Differential Palatability of Plant Parts

It was observed that most of the animals preferred the leaf part of plants (78 species, 53.8 %), shoots/whole plants (53 species, 36.5 %), fruits and/or flowers (53 species, 36.5 %), twigs (41 species, 28.3 %) and roots (6 species, 4.1 %) (Figure 10). Root crops produced in the area like *Manihot esculenta*, *Ensete ventricosum*, *Colocasia esculenta* and *Dioscorea alata* were consumed by humans, thus animals consumed parts not used by humans such as leaves, peels, flowers and twigs.

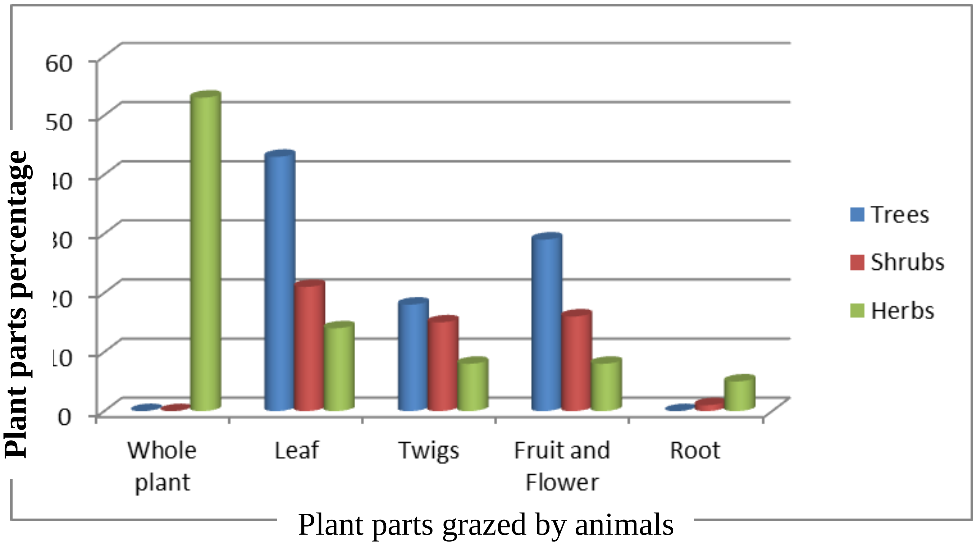


Figure 9. Differential palatability of plant parts

4.5. Seasonal Availability of Palatable Plant Species

From the total 145 identified palatable plants species (Appendix III), the largest number was recorded in March (133 species, 91.7%), in which the short rainy season started in the zone. In other months, the numbers decreased until the smallest palatable plant species were recorded in January and February (87 species, 60%). When there are many palatable species, animals selected the best and ignored others, however, when the number of palatable species decreased, less palatable plants were also consumed by the animals. Herbs were the most palatable species highly available at the start of short rainy season in March (64 species, 48.1%) but disappeared after some months (17 species, 19.5%) in January (Figure 11). The evergreen perennial plant species such as *Vernonia amygdalina*, *Dovyilas abssynica*, *Ehertia cymosa*, *Vangueria apiculata* and *Persea americana* were found throughout all growing seasons. Thus people in the study site used the leaves and twigs of these trees and shrubs to feed animals at times of feed shortage.

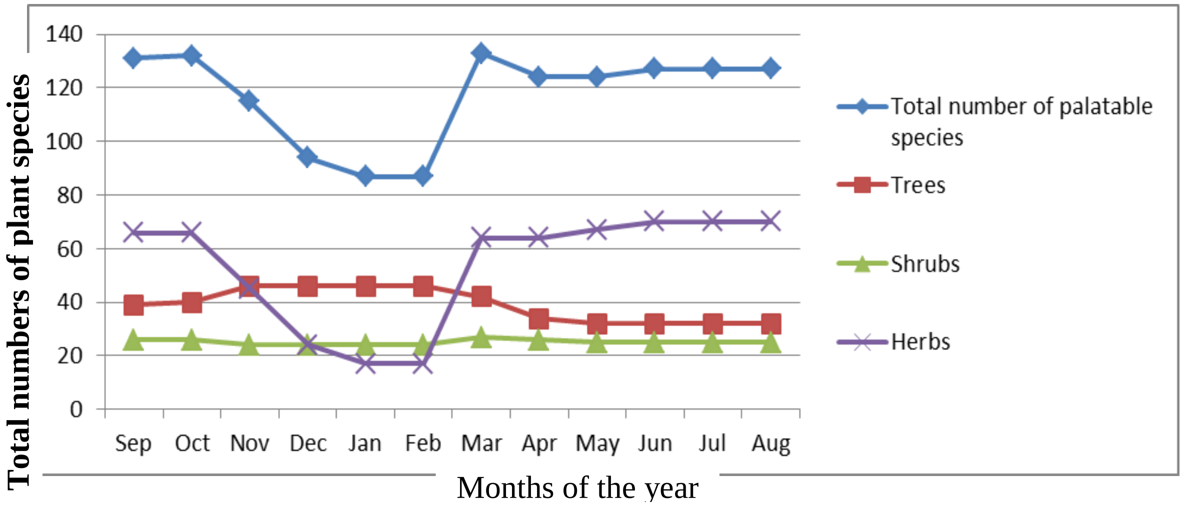


Figure 10. Seasonal availability of palatable plant species

4.6. Quantity Estimation of Available Feed Resources

4.6.1. Dry matter yield of natural pasture, fallow land and aftermath grazing

The total amount of DM produced from natural pasture (private and communal grazing areas), fallow land, aftermath grazing, river and road side grazing of the sampled households was 356.62 ton/year (Table 7). Feed supple from permanent land, fallow land and river side grazing did not show statistical difference (P>0.05) throughout the agro-ecologies, however all other sources of pasture for animals were statistically different (P<0.05) in all agro-ecologies (Table 9).

Table 9. Dry matter yield from natural pasture, fallow land and aftermath grazing according to agro-ecology

Feed supply by source	Agro-ecology, mean *Dega* (n=44)	*Woina-dega* (n=88)	*Kolla* (n=44)	Overall Mean (N=176)	SEM	P-Value
Permanent grazing land (t)	0.39	0.55	0.45	0.48	0.032	NS
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

Aftermath grazing (t)	0.04[a]	0.05[ab]	0.09[b]	0.06	0.006	*
Fallow land (t)	0.38	0.55	0.44	0.48	0.031	NS

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

4.6.2. Dry Matter Yield of Crop residues

The total amount of DM produced from all crop residue produced by the sampled household was 517.35 ton/year (Table 6). Supply of feeds from most crop residues showed statistically significant difference (P<0.05) throughout all agro-ecologies as shown in (Table 10).

Table 10. Dry matter yield from crop residues and their supply according to agro-ecology

Feed supply by source	Agro-ecology, mean *Dega* (n=44)	*Woina-dega* (n=88)	*Kolla* (n=44)	Overall Mean (N=176)	SEM	P-Value
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	***
Irish 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	***

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

4.6.3. Dry Matter Yield from Trees and Shrubs

In the study site, 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 per year.

4.6.4. Estimating non-conventional feed sources

In the study site, 166 (94.3%) respondents used *enset* plant parts as concentrate supplement to their animals. *Enset* plants have been contributing a lot as supplement for animals, though the production and productivity is in question due to drought, land shortage and poor productivity of small and fragmented landholdings as it was observed during the field visits and raised during group discussion. Only 17 (9.6%) respondents used very small amount of mineral-rich soil locally called (*Aduwa*), whereas, all respondents used kitchen wastes, residues of fruits and vegetables, coffee leaf prepared in liquid form (*Hayta tukiya*) and residues of local drinks as concentrate supplement for their animals. In addition, small amount of different locally available leaves of plants were cooked (*manache maatta*) and given as concentrate source to the milking cows in order to improve the quality and yield of milk and milk products. Leaves of plants were collected, cooked in the pot (used for milk churning (*manaachiya*)), and given for the cows. Thus, it also improves the odor, taste and texture of milk and milk products as it is cooked in the pot and fed to the animals (Table 11).

Table 11. Different non-conventional feed sources used by sample households

Non-conventional feeds	Frequency (N=176)	Percentages
Enset parts	166	94.3
Kitchen wastes, fruit and vegetable residues	176	100
Aduwa (mineral rich soil)	17	9.6
Manaache maataa	76	100
Hayta tukiya (coffee leaf)	147	83.5
Purchase of concentrates	66	37.3

4.7. Chemical Composition of Available Feed Resources

Chemical composition, *invitro* dry matter digestibility and mineral profile of 76 plant species used for livestock feeding in the study area were collected from different sources (Appendix IV). The values reported were average values of the data obtained from different sources.

The results of laboratory analysis for chemical compositions of preferred trees and shrub species (Table 12) showed that the DM content of *P. thonningii*, *M.esculenta*, *G. occidentalis*, *P. americana*, *T.indica*, *R. vulgaris* were 96.35, 95.63, 95.71, 96.07, 97.00 and 96.74% respectively. The CP content of the trees and shrubs considered varied from 20.15 *(M.esculenta)* to 10.03 *(P. americana).* The concentration of calcium in *P.americana* (3.82) was higher compared to *M.esculenta* (3.31) and it was very small in *P.thonningii* (2.08). The NDF content of *T.indica (67.83) was the highest compared to others, but M.esculenta* contained the highest ADF (37.4) and ADL (14.5).

Table 12. The chemical composition of preferred trees and shrubs

	Chemical composition (%DM) of different trees and shrubs and their local names					
Parameters	*P.thonningii* *(Qaaliqaala)*	*M.esculenta* *(Mitta boyiya)*	*G.occidentalis* *(Xawayiya)*	*P.americana* *(Abkadosiya)*	*T.indica* *(Koriya)*	*R.vulgaris* *(Mucakkuwa)*
DM %	96.35	95.63	95.71	96.07	97.00	96.74
OM	94.69	90.05	89.38	93.53	92.54	94.49
CP	17.33	20.15	19.13	10.03	18.11	14.03
Ash	5.31	9.95	10.62	6.47	7.46	5.51
CF	31.32	21.30	17.69	16.26	28.88	30.66
Ca	2.08	3.31	3.31	3.82	2.23	2.24
NDF	60.89	47.02	54.25	59.31	67.83	65.36
ADF	29.17	37.40	25.78	27.12	34.71	30.03
ADL	10.11	14.50	9.29	10.46	12.14	10.47

DM dry matter; OM organic matter; CP crude protein; CF crude fiber; NDF neutral detergent fiber; ADF acid detergent fiber; ADL acid detergent lignin

4.8. Livestock Feed Balance

Total available DM obtained from all sources was compared to the annual DM requirements of livestock population of the sampled households. Overall livestock-feed balance of the sampled households is summarized in Table 13.

Table 13. Feed balance estimates from all feed sources

Feed supply		**Area (ha)**	**DM (tone)**
Natural pasture, fallow land and aftermath 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 (tone)			
Total HH	176 (2)		
No of TLU/ HH	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 (3*4) 5		
Feed balance	**-495.77 (1-5)**		
Proportion of feed gap (%)	36.10		

Thus, the survey result showed that, the available feed sources fulfilled only 63.9% of the annual DM requirement for TLU. The balance between DM supply and requirement was not similar in all agro-ecologies. The DM gap was significantly higher (P<0.05) in *Woina-dega* followed by *Dega* agro-ecology (Table 14).

Table 14. Average yearly differences in the balance between DM supply and requirements

Feed supply	Agro-ecology, mean			Overall		
	Dega	*Woina-dega*	*Kolla*	Mean	SEM	P
Available, tones	4.39	5.09	5.37	4.98	0.168	NS
Required, tones	8.04[ab]	8.20[a]	6.77[b]	7.80	0.195	**
Balance, tones	-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

The total available feed addressed only 63.9% of the annual DM requirement which was able to support existing stock for 7.7 months. Due to the negative feed balance, many animals died in the study site according to reports from the respondents. For some animals who survived, it resulted in reduced milk production, body weight loss, abortion and weakness as reported by some respondents and further discussed with the groups and confirmed at field visits. To fill the feed gap and reduce the impacts of feed shortage for their animals, farmers in the study site used different strategies. Among the strategies, mixed cropping of many plants within same plot of land, production of high yielding improved grasses used as feed for animals and cash crop/grass, production of improved food crops used for human consumption and animal feeding, using tree and shrubs leaves as dry time supplement and purchase of feed were some to mention (Table 15).

Table 15. Consequences of feed shortages and coping strategies used by sampled households for feed shortage

Consequences and coping strategies	Parameters	Frequency	Percent
Coping strategies for feed shortage used by the sampled HH	Mixed cropping of many plants	101	57.3
	Leaves of trees and shrubs	143	81.2
	Purchase feed	119	67.6
	Improved forage production	72	40.9

Consequences of feed shortage on livestock production of sampled HH	Feed and food crop production	89	50.5
	Feed conservation	80	45.2
	Weight loss	40	22.7
	Milk yield reduction	34	19.3
	Increased mortality	45	25.5
	Abortion	38	21.6
	Weakness	11	6.3
	Others	8	4.6

Crops produced in the mixed cropping system included maize, banana, pigeon pea, and cassava (Figure 12). Thus such type of cropping helps to make livestock production bearable through improved feeding as farmers in the area own small and fragmented lands.

Figure 11. Mixed cropping of cassava-banana-pigeon pea

In some parts of the area, maize was also constantly intercropped with pegion pea (Figure. 13). 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.

Figure 12. Mixed cropping of maize - pigeon pea

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 sar* (*Brachiaria brizantha)*. Feed shortage was challenging for production and productivity of livestock in the study, as 67.6% of the respondents reported to have purchased feed in the year 2016/17 and all sampled households reported that livestock feeding was a big problem in terms of quality and quantity in addition to the information gathered during field visits and group discussions (Table 15). Different governmental and 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, but the current negative balance between supply and demand of feed in the study area shows that livestock feeding still requires owed attention in the research sites from different responsible bodies.

5. DISCUSSION

5.1. Household Characteristics

Wolayta zone has always been characterized by densely populated and intensively cultivated mid-altitude area of Ethiopia. Average household size of the sampled households was 6.8, which is comparable to 6.56 reported by Gecho (2017) and 6.74 reported by Tsedeke and Endrias (2011) for similar area. Education is another important variable with regard to its association to other demographic behaviors. The education status of the households heads in current study site showed statistically significant difference ($P<0.05$) across all agro-ecologies. It further showed that the majority of sampled households attended formal education. In fact, educational level of farmers is assumed to increase the ability to understand process and use agriculture related information and adopt technologies in a better way. Generally, in the study area, the education level of sampled households was better relatively compared to the findings of Bashe *et al*. (2018) and the national literacy level (39%) (CSA, 2007). Average age of the household heads was 45.3.

5.2. Landholdings and Land Use Systems

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, landholding per households was small in the study area. Average landholdings of the sampled households was 0.98 ha which is much greater than 0.7 ha reported by Bashe *et al*. (2018) and 0.62 ha reported by Gian Luca Bagnara (2017), however, less than 1.41 ha which was reported by Ayele (2008) for the same area. Crops mostly produced in the study area included maize, *teff*, wheat, barley, sorghum, bean and pea. In addition, root crops like sweet potato, potato, cassava, yam, taro and *enset* were also commonly produced by the sampled households. Land allocation for crops showed a reduced trend from year to year due to increased human population and the consequent reduction in landholdings per household. Land allocation for feed production had also been diminishing on size due to population growth which had resulted in the use of grazing lands for crop production. In line with this, the report by Qoricho (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.

5.3. Livestock Holding and Composition

Farmers in the study site keep a mix of cattle, sheep, goats, equines and chicken. Most of the households in the study site owned local animal breeds. Average livestock ownership in terms of Tropical Livestock Unit (TLU) was significantly different ($P<0.05$) across all the three agro-ecologies which agreed with the findings of Gian Luca Bagnara (2017). Average ownership of livestock showed reduced trend from 3.65 reported by Gecho *et al*. (2014), to 1.94 reported by Almaz *et al*. (2015) and 1.94 reported by Gian Luca Bagnara (2017) which could be related to unavailability of feeds that support the existing stock throughout the year or low attention given to the sector from different responsible bodies. Average cattle holding also showed statistically significant difference ($P<0.05$) across all the three agro-ecologies which was higher in *Dega* agro-ecology (3.05 ± 0.19), followed by *Woina-dega* agro-ecology (2.87 ± 0.12) and *Kolla* agro-ecology (2.27 ± 0.27). Cattle constitute the largest share of the households TLU holdings which was in line with the findings of Fekede (2013) who concluded that cattle are both numerically and functionally the dominant livestock species in Ethiopia.

5.4. Differential Palatability of Plants

Most of the less and rarely palatable species were from trees and shrubs. These species were less and rarely palatable and mostly rejected by the livestock, which were available throughout the year as overgrazing has decreased the number of palatable species which agreed with the findings of Hussain and Durrani (2007, 2008) and Shaheen *et al*. (2014) who concluded that overgrazing reduces palatable cover and species diversity.

5.5. Preferences of Plants by Grazing Animals

Animal species differ markedly in their food habits; with each species showing innate preferences for certain plants, parts of plants, or plants in particular growth stages (Hussain and Durrani, 2009). Goats had a preference to the most forage plants (139 species, 95.8%) followed by cattle (121 species, 83.4%) similar to the report by Kasahun (2016) which explains goats are active and inquisitive in their foraging behavior. Grazing animals exhibit variation in preference from one location to another, from one season to another, over a period of few days, within the same day and among individuals (Hussain and Durrani, 2009). The study area is densely populated and land ownership is small which has resulted in over use of existing palatable species and in shifting of animals' food habit to some non-palatable or less palatable species which was in concomitant with the report by Amjad *et al*. (2014). Most plants are poisonous only when eaten in large amounts at particular stage but might provide nutritive forage when consumed in small amounts or mixed with other forage (Hussain and Durrani, 2009). Wet season feeds of animals were primarily herbaceous in the study area. These results concur with those revealed by Hu *et al*. (2014) and Mphinyane *et al.* (2015) who concluded that differences between the mean wet and dry season's biomass of annual grasses were primarily due to early cessation of growth and ultimate death of plants, which, coupled with grazing pressure, led to significant reduction in the average biomass of individual annual grasses.

5.6. Differential Palatability of Plant Parts

Most animals in this study preferred the leaf part of plants unlike the findings of Amjad *et al*. (2014) who reported that whole plants were preferred mostly by the animals. The rejection or preference of species/parts of plants by an animal is closely related to the availability of the plant in the pasture. Goats preferred herbs (66 species, 47.5%), trees (46 species, 33.1%) and shrubs (27 species, 19.4%) which indicated that they consumed a wide diversity of foliage found in the area. Goats particularly prefer browsing to grazing and are attracted to trees and shrubs as shown in figure 14 which was also reported by Kasahun (2016).

Figure 13. Goats prefer browsing than grazing in the study area

It is possible that a plant or part of plant was rejected under certain conditions but preferred under other circumstances. Annual forbs/grasses besides their importance in nutritional contributions also reduced grazing pressure on palatable perennial species as animals shifted from browsing on trees and shrubs to grasses and herbs when they began to grow starting from March, when short rainy season started. It was found out that low quality or non-palatable plants/plant parts replaced/dominated good quality forage plants under poor management/drier periods when no other materials were available to graze/browse. Therefore, the findings of this study agreed with others like Khan and Hussain (2012) who stated that most of the forage species are present in March to April and fodder availability is high in this time and Marqueus *et al*. (2004) stated that in the absence of annuals, the shrubs provide fresh fodder for animals.

5.7. Seasonal Availability of Palatable Plant Species

Season was the main factor affecting herbage biomass availability and quality (Mphinyane *et al.*, 2015). The highest numbers of palatable plant species were recorded at March, in which short rainy season started in the zone. In other months the numbers were decreased until the smallest palatable plant species were recorded in January and February. It was found out that when climate was suitable (summer), the numbers of palatable species were increased, that was in concomitant with Hussain and Durrani (2009) who stated that seasonal availability of fodder species depend on phonological stages and climate. Seasonal variability in weather and climate change contributes to the high fluctuation of forage quality and quantity between seasons and years (Sultan *et al*. 2008). Mphinyane *et al.* (2015) also stated that forage quality decreased from wet to dry season with greater declines in grasses than browse. In dry seasons, dried grasses, shrubs and trees leaves were the only sole fodder source to the livestock, which agreed with the findings of (Khan and Hussain, 2012). Indigenous tree and shrub species in the study area have increased feed resource base for the season of feed gap to supplement poor quality roughages which was also reported by (Takele *et al*. 2014). Browse therefore, constituted a necessary supplement to herbage during the dry seasons, as dry season grasses are extremely deficient in most nutrients needed to meet livestock maintenance which was also reported by Mphinyane *et al.* (2015). The evergreen perennial plant species such as *Vernonia amygdalina, Dovyilas abssynica*, *Ehertia cymosa*, *Vangueria apiculata* and *Persea americana* were found throughout all growing seasons which agreed with the findings of Alemayehu (2006).

5.8. Quantity Estimation of Available Feed Resource

The largest proportion of feed came from crop production which agrees with the findings of Kassa *et al*. (2003) who concluded that crop residues were the primary source of feed for animals in Harar highlands of eastern Ethiopia. Natural pasture was the second most important feed source for animals in the study site. This is disagreed with the findings of Adugna (1990) and Zereu and Lijalem (2016) who concluded that natural pasture was the main source of feed for Wolayta zone, yet population pressure forced the farmers to grazing land for crop production which has resulted in reduction of natural grazing land. Some small amount of feed was obtained from trees and shrubs 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 study area also collected herbaceous wild plants, mostly legumes, as feed for lactating cows as reported by Adugna (1990). The use of concentrate feeds is very limited in the area as some small amount of kitchen wastes, coffee leaf prepared in liquid form, mineral salts, fruits and vegetable rejects and purchased concentrates were used. The degrees by which local residues were used by the sampled households were lacking a clear system of quantifying the dry matter percentages of each residue. In addition, crops like *enset* and banana contributed a lot to the dry matter production by the sampled households but these crops lacks conversion factor.

5.9. Chemical composition of Available Feed Resource

Feeding leaves and twigs of indigenous trees and shrubs for livestock, particularly during the dry season is common practice in Wolayta zone (Deribe, 2015). The importance of a species considered as forage depends largely on its chemical composition and individual growth in the plant community (Le Houérou, 1980). The dry matter (DM) content of all leaves and twigs of trees and shrubs considered was above 90%, which agrees with the findings of Sisay (2006) and Andualem *et al*. (2015). The CP content of all plants considered was above the required level of 7 % CP for animals in the tropics (Kearl, 1982; Van Soest, 1994; Mlay *et al.*, 2006). Feeds with the CP level less than 7.5 % inhibits voluntary feed intake and the activity of microbial action declines, resulting in lower digestibility of roughages (Van Soest, 1994). The highest and lowest CP content was obtained from *M.esculenta* and *P.americana* respectively. Crude ash or mineral matter concentration was highest in *G.occidentalis* whereas *P.thonningii* contains the highest crude fiber among others. These browse trees and shrubs rich in protein are potential sources of crude protein which can facilitate the growth of rumen microbes that play a significant role in digestion of feeds as reported by Ammar *et al.* (2000); Njidda and Ikhimioya (2010). They were also commonly harvested and supplemented to lactating cows, ewes and/or does, kids and lambs which were in concurrence with the findings of Deribe (2015).

5.10. Livestock Feed Balance

The total feed available in the study area 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 Amsalu and Addisu (2014) for Gumara-Rib watershed; Amahara region, Funte *et al*. (2010) in southern Ethiopia, Tessema *et al*. (2003) in Belesa district of Amhara region, Bedasa (2012) in the highlands of the Blue Nile basin, Kechero and Jansson, (2014) in Jimma; south western Ethiopia, Yeshitila (2008) in Halaba; southern Ethiopia, Tolera, (1990) in Wolayta; southern Ethiopia, and Kassa *et al*. (2003) in Harar highlands, eastern 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).

The sampled households used different strategies to cope with feed shortage and reduce its impact on their animals. Among the strategies, mixed cropping of many plants within same plot of land, production of high yielding improved grasses, production of improved feed crops used for human consumption and animal feeding, using tree and shrubs leaves as dry time supplement and purchase of feed were used. The negative balance of feed intermingled with poor quality and seasonal availability has resulted in animal death which agreed with the findings of Belete *et al*. (2012), reduced milk production and body weight loss which was in concomitant with the findings of Legesse (2008), and abortion and weakness which agreed with the findings of Deribe *et al.* (2013).

6. CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

Wolayta zone is highly populated area with very small and fragmented landholdings. Even though livestock production is an integral part of the economy of Wolayta zone, due to different factors in addition to having small and fragmented plots of land, livestock production is at risk. Based on current study, the following major conclusions can be drawn:

- The majority of interviewed households were male headed households.
- The average household size (6.8), average livestock ownership (3.42) and average land holdings on hectare (0.98) of the studied area, respectively
- Decreased trend of land allocation for crop production was observed in all agro-ecologies due to increased human population and the consequent reduction in landholdings per households.
- The largest land was allocated for maize followed by *teff* and peas. From the root crops, sweet potato production covered the largest area followed by Irish potato and cassava.
- Land allocation for feed production had also been diminishing on size due to population growth which has resulted in use of grazing lands for crop production.
- 145 plants were identified as palatable by all livestock species. Among the palatable species, 33.1% and 18.6% were trees and shrubs respectively and the remaining 48.3% were herbs.
- Of the 145 recorded species, 56.6% were highly palatable, 17.2% were mostly palatable, 16.6% were less palatable, and 9.6% were rarely palatable.
- Goats preferred most of the plants, 95.8%; cattle, 83.4%; sheep, 73.1% and donkeys, 46.2%.
- Most of the animals preferred the leaf part of plants 53.8 %, shoots/whole plants 36.5 %, fruits and/or flowers 36.5 %, twigs, 28.3 and roots 4.1 %.
- From the total 145 identified palatable plants species, the largest number was recorded at March (91.7%), in which the short rainy season started in the zone.
- In other months the numbers of palatable plant species were decreased until the smallest recorded in January and February (60%).

- The total amount of DM obtained from natural pasture (private and communal grazing areas), fallow land and aftermath grazing was 356.62 ton/year.
- The total amount of DM produced from all crops produced by the sampled household was 517.35 ton/year.
- About 2.8 ha of land was covered by trees and shrubs used for livestock feeding in the sample households, producing 3.36 ton of DM per year.
- The supplementation of nonconventional feed resources was very limited as some of sampled households used *enset* and *enset* parts and some others used kitchen wastes, coffee leaf, mineral soils and vegetable rejects as supplementary feeding.
- The CP content of the trees and shrubs considered varied from 20.15 *(M.esculenta)* to 10.03 *(P. americana).*
- The total feed available addressed only 63.9% of the annual DM requirement which would be able to support existing stock for 7.7 months.
- To fill the feed gaps, farmers used different strategies like mixed cropping of many plants species within the same (small) plot of land and using these plants/crops for food and feed production, production of improved grass species, using trees and shrubs leaves as dry season supplement and purchase of feeds.
- In addition to feeding animals, some improved crops and/or grasses commonly growing in the area like pigeon pea (*Cajanus cajan*) and desho grass (*Brachiaria brizantha*) were used as food for the family and income sources.
- Feed shortage, poor quality and seasonal availability of feeds in the study area has resulted in death of some animals, reduced milk production, body weight loss, abortion and weakness as reported by the sampled households.

6.2. Recommendations

The contribution of livestock to the economy of the country generally and to the study area specifically is being constrained by different factors. Based on current study findings, some points were considered as very important to give due attentions for improving livestock production of the study area. The following are some of them:

- Enhancement of soil fertility through different strategies as the size of land allocated for crop and animal feed production is diminishing from time to time.

- Supporting the mixed cultivation systems commonly being practiced in the area with other innovative and highly productive production systems
- Motivating the households to plant different leguminous trees and shrubs that can be used as sheds for the animals and income source for the households in addition to supplementary feeding at dry seasons as they were highly used but very small land is covered by this important feed source.
- Working in collaboration with different stakeholders that are working on livestock sector to promote utilization of concentrate feeds, improved forages and pastures and conservation of produced feeds to optimize feed production can support the existing livestock population throughout the year.

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8. APPENDIXES

Appendix I: Monthly monitoring of feed availability

Name of the *kebele* -------------------------- Name of the household head -------------------------------

Name of enumerator ---

Feed name	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jull	Aug	Sep	Oct

Appendix II: Daily monitoring of feed palatability

Name of the *kebele* ---------------------------- Name of the household head -----------------------------

Name of enumerator ------------------------------- Type of the animal ------------------------------------

Name of the month -------------------------------

Plants name	Week 1							Week 2							Week 3							Week 4						
	m	t	w	t	f	s	s	m	t	w	t	f	s	s	m	t	w	t	f	s	s	m	t	w	t	f	s	s

Appendix III: Palatable plants identified in and around Wolayta, southern Ethiopia

S/n	Wolaytigna name	Scientific name	Habit	Palatability class						Plant part				Grazing animals				Season of availability
				Np	Hp	Mp	Lp	Rp	whol	leaf	twigs	Fruit	Root	Cattle	Sheep	Goat	Equine	
1	Abokadosiya	*Persea americana*	T	-	-	+	-	-	-	+	+	+	-	+	+	+	-	Year round
2	Ambbiya	*Terminalia schimperiana*	T	-	-	-	-	+	-	-	+	-	-	-	-	+	-	Sep-March
3	Badanaa	*Ballanite aegyptica*	T	-	+	-	-	-	-	+	-	+	-	-	+	+	-	Year round
4	Boota Zaagiya	*Millettia ferruginea*	T	-	-	-	-	+	-	+	-	-	-	-	-	+	-	Year round
5	Borttuwaa	*Erythrina abyssinica*	T	-	-	+	-	-	-	+	+	-	-	+	+	+	-	Year round
6	Ciqottiya	*Clausena anisata*	T	-	-	-	+	-	-	+	-	+	-	+	-	+	-	Sep-March
7	Dambbiya	*Ficus thonningii*	T	-	-	-	+	-	-	+	+	-	-	+	+	+	-	Sep-March
8	Ettaa	*Ficus sycomorus*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	+	Sep-March
9	Garaa	*Vernonia amygdalina*	T	-	-	-	+	-	-	+	-	-	-	+	-	-	-	Year round
10	Gergeccuwa	*Maesa lanceolata*	T	-	-	-	+	-	-	+	-	-	-	+	-	+	-	Nov-March
11	Gershshuwa	*Maytenus serrata*	T	-	-	-	+	-	-	+	-	-	-	+	-	+	-	Nov-Feb
12	Gumariya	*Grewia ferruginea*	T	-	-	+	-	-	-	+	+	+	-	+	+	+	-	Sep-Feb
13	Guugantta	*Acacia lahai*	T	-	+	-	-	-	-	+	+	+	-	-	+	+	-	Year round
14	Hagilaa	*Dovyilas abssynica*	T	-	+	-	-	-	-	+	-	+	-	-	-	+	-	Year round
15	Halakuwa	*Moringa stenoptalla*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	-	Year round
16	Higisha meruwaa	*Clutia lanceolata*	T	-	-	-	-	+	-	+	-	-	-	+	+	+	-	Sep-Feb
17	Ittiriwanjjiya	*Ehertia Cymosa*	T	-	+	-	-	-	-	+	-	-	-	+	+	+	+	Year round
18	Jiijuwaa	*Vangueria apiculata*	T	-	-	-	+	-	-	+	-	-	-	+	-	+	-	Year round
19	Kana miqiya	*Pavetta oliveriana*	T	-	-	+	-	-	-	+	-	-	-	+	-	+	-	Nov-Feb
20	Kazamuriya	*Casimiroa edulis*	T	-	-	-	+	-	-	-	-	+	-	+	-	+	-	Year round
21	Koriya	*Tamarindus indica*	T	-	-	+	-	-	-	+	+	+	-	+	+	+	-	Year round
22	Laadiya	*Carissa edulis*	T	-	-	+	-	-	-	+	-	+	-	+	-	+	-	Year round
23	Loomiya	*Citrus sinensis*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	+	Year round
24	Maaruwaa	*Ficus elastica*	T	-	-	-	-	+	-	+	-	+	-	-	-	+	-	Year round
25	Mangguwa	*Mangifera indica*	T	-	-	+	-	-	-	-	-	+	-	+	+	+	-	Year round
26	Miimiya	*Melia azandirachta*	T	-	-	-	+	-	-	-	-	+	-	-	-	+	-	Year round
27	Miqiya	*Rytigynia neglecta*	T	-	-	-	-	+	-	+	-	-	-	+	-	-	-	Nov-April

28	Moqotaa	*Cordia africana*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	-	Year round
29	Mucakuwaa	*Rhus vulgaris*	T	-	+	-	-	-	-	+	-	+	-	+	+	+	-	Year round
30	Ochchaa	*Syzygium guineense*	T	-	-	-	+	-	-	+	-	+	-	-	-	+	-	March-Aug
31	Odooruwaa	*Acacia polyacantha*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	-	Year round
32	Ongapiriya	*Rhus natalensis*	T	-	-	-	-	+	-	-	-	+	-	-	-	+	-	Year round
33	Poolanttuwa	*Acacia seyal*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	-	Year round
34	Qaliqala	*Piliostigma thonningii*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	-	Year round
35	Qaraa	*Schrebera alata*	T	-	-	-	+	-	-	+	-	-	-	-	-	+	-	Oct-Feb
36	Shinkkaa	*Buddleja polystachya*	T	-	-	+	-	-	-	+	-	-	-	+	-	+	-	Sep-March
37	Sobbuwaa	*Combretum molle*	T	-	-	-	-	+	-	+	-	-	-	-	-	+	-	Nov-March
38	Uguugiya	*Strychnos innocua*	T	-	+	-	-	-	-	+	+	+	-	+	-	+	-	Year round
39	Wogaraa	*Olea europaea*	T	-	-	+	-	-	-	+	-	+	-	-	+	+	-	Year round
40	Wolaa	*Ficu vasta*	T	-	+	-	-	-	-	+	-	+	-	+	+	+	+	Year round
41	Wolayta loomiya	*Citrus aurantifolia*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	-	Year round
42	Wora shinkkaa	*Nuxia congesta*	T	-	-	-	+	-	-	+	-	-	-	-	-	+	-	Sep-march
43	Woshilechaa	*Sclerocarya Caffra*	T	-	+	-	-	-	-	+	-	+	-	+	+	+	-	March-Aug
44	Xaamuwa	*Rhus glutinosa*	T	-	-	-	+	-	-	+	-	-	-	+	-	+	-	Sep-Feb
45	Xuxuwa	*Maytenus sp.*	T	-	+	-	-	-	-	+	+	+	-	+	+	+	-	Year round
46	Yemeenuwa	*Vernonia sp.*	T	-	-	-	+	-	-	+	-	-	-	+	-	+	-	Nov-April
47	Zaafiya	*Eucalyptus globulus*	T	-	-	-	-	+	-	+	+	-	-	-	-	+	-	Year round
48	Zaytooniya	*Psidium gauava*	T	-	-	+	-	-	-	+	-	+	-	+	+	+	-	Year round
	Total			**0**	**17**	**10**	**13**	**8**	**0**	**43**	**18**	**29**	**0**	**34**	**24**	**46**	**4**	
49	Akure atara	*Cajanus cajan*	S	-	+	-	-	-	-	+	+	+	-	+	+	+	+	March-Oct
50	Alkashaa	*Agave satalina*	S	-	-	-	-	+	-	-	-	+	-	+	-	+	-	Year round
51	Asttiya	*Ximenia americana*	S	-	+	-	-	-	-	+	-	+	-	-	+	+	-	Year round
52	Ataraa	*Pisum sativum*	S	-	+	-	-	-	-	+	+	+	-	+	+	+	+	March-Oct
53	Bawiya	*Tapinanthus globiferus*	S	-	+	-	-	-	-	+	+	-	-	+	+	+	-	Year round
54	Bulo santta	*Solanum marginatum*	S	-	+	-	-	-	-	+	+	+	-	+	+	+	+	Year round
55	Buluwa	*Solanum incanum*	S	-	-	-	+	-	-	+	+	+	-	+	-	+	-	Year round
56	Caatiya/jimmaa	*Catha edulis*	S	-	-	+	-	-	-	+	+	-	-	+	+	+	-	Year round

57	Doomayiya	*Balanites rotundifolia*	S	-	-	+	-	-	-	-	+	+	-	-	+	+	-	Year round
58	Geeshuwa	*Rhamnus prinoides*	S	-	+	-	-	-	-	+	+	-	-	+	+	+	-	Year round
59	Kana hamakka	*Vernonia adoensis*	S	-	-	-	+	-	-	+	-	-	-	+	-	+	-	Nov-April
60	Kooshimiya	*Dovyalis abyssinica*	S	-	-	-	+	-	-	-	-	+	-	-	+	+	-	Year round
61	Koosuwa	*Hagenia abyssinica*	S	-	-	+	-	-	-	+	-	-	-	+	+	+	-	Year round
62	Kosorootiya	*Lippia adoensis*	S	-	+	-	-	-	-	+	+	-	-	+	+	+	-	Year round
63	Maaxuwa	*Euphorbia tirucalli*	S	-	-	-	-	+	-	-	+	-	-	-	-	+	-	Year round
64	Miqiya	*Rytigynia neglecta*	S	-	-	+	-	-	-	+	-	-	-	+	-	+	-	Year round
65	Mita boyiya	*Manihot esculenta*	S	-	+	-	-	-	-	+	+	-	+	+	+	+	+	Year round
66	Monoqiya	*Annona senegalensis*	S	-	-	+	-	-	-	+	-	+	-	+	+	+	-	Year round
67	Muulahuwa	*Dovyalis abyssinica*	S	-	-	+	-	-	-	+	+	+	-	+	+	+	-	Year round
68	Ohaa	*Acanthus sennii*	S	-	-	-	-	+	-	-	-	+	-	-	-	+	-	Year round
69	Puutuwa	*Gossypium hirsutum*	S	-	+	-	-	-	-	+	+	+	-	+	+	+	+	Year round
70	Qobbuwa	*Ricinus communis*	S	-	-	+	-	-	-	+	-	+	-	+	-	+	-	Year round
71	Shoosha inxxarssaa	*Corchorus trilocularis*	S	-	-	-	+	-	-	+	-	-	-	+	-	+	-	March-Oct
72	Shuwaa	*Celtis africana*	S	-	-	+	-	-	-	+	-	-	-	+	-	+	-	Sep-March
73	Xawayiya	*Grewia occidentalis*	S	-	+	-	-	-	-	+	+	+	-	+	+	+	-	Year round
74	Xunduqiya	*Acacia brevispica*	S	-	+	-	-	-	-	+	+	+	-	-	+	+	-	Year round
75	Zambaba	*Borassum aethiopum*	S	-	-	-	+	-	-	-	-	+	-	-	+	+	-	Year round
	Total			**0**	**11**	**8**	**5**	**3**	**0**	**21**	**15**	**16**	**1**	**20**	**18**	**27**	**4**	
76	Aa"inaa	*Amaranthus albus*	H	-	-	+	-	-	+	-	-	-	-	+	+	+	+	March-Aug
77	Abishiya	*Trigonella foenum-graecum*	H	-	+	-	-	-	-	+	+	+	-	+	+	+	+	March-Oct
78	Adil"e ciishaa	*Bidens macroptera*	H	-	-	+	-	-	-	+	+	-	-	+	+	+	-	March-Oct
79	Azil"o	*oxalis-crass (all spp)*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Aug
80	Badalaa	*Zea mays*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
81	Banggaa	*Hordeum vulgare*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov

82	Baqeelaa	*Vicia faba*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
83	Boota shuquwa	*Cuminum cyminum*	H	-	+	-	-	-	-	+	+	-	-	+	+	+	+	March-Nov
84	Boyiya	*Dioscorea alata*	H	-	-	-	-	+	-	+	-	-	+	-	-	+	-	March-Oct
85	Boynaa	*Coccinia abyssinica*	H	-	-	+	-	-	-	-	-	-	+	+	-	-	-	March-Nov
86	Ceecaa	*Cyprus papyrus*	H	-	-	-	-	+	-	+	-	-	-	+	-	-	-	Year round
87	Cumadhiya	*Amaranthas retroflexus*	H	-	-	+	-	-	+	-	-	-	-	+	+	+	+	March-Aug
88	Cuquniya	*Artemisia Abyssinica*	H	-	+	-	-	-	-	+	+	-	-	+	+	+	+	March-Nov
89	Dal"isha	*Commelina benghalensis*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
90	Danqala santta	*Brassica carinata*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
91	Dashuwaa	*Brachiaria brizantha*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	Year round
92	Deebuwa	*Coriandrum sativum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	-	March-Oct
93	Donuwa/shukaria	*Ipomoea batatas*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	May-Feb
94	Duppaa	*Pennisetum schimperi*	H	-	-	-	+	-	+	-	-	-	-	+	+	-	+	Year round
95	Ecere agunttaa	*Oxygonum sinuatum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
96	Ecere turaa	*Stephania abyssinica*	H	-	-	-	+	-	-	+	-	-	-	+	+	+	-	Year round
97	Elephant grassiya	*Pennisetum purpureum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	Year round
98	Eqqaa	*Vigna unguiculata*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
99	Gaashiya	*Eragrostis tef*		-	+	-	-	-	+	-	-	-	-	+	+	+	+	May-Feb
100	Gagabisaa	*Amaranthus caudatus*	H	-	+	-	-	-	-	+	+	+	-	+	+	+	+	March-Oct
101	Girolliya	*Sporobolus pyramidalis*	H	-	-	+	-	-	+	-	-	-	-	+	+	+	+	Year round
102	Gisttiya	*Triticum aestivum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	May-Feb
103	Godare uuttaa	*Aloe vera*	H	-	-	-	+	-	-	-	-	+	-	-	+	+	-	Year round
104	Hanxxaqaluwa	*Bidens_pilosa*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
105	Hariya maata/wontiqama	*Tagetes minula*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
106	Hixiixiya	*Galinsoga parviflora*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
107	Kaarootiya	*Daucus carota*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	May-Nov

108	Kafo xugunttaa	*Lablab purpureum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
109	katikala	*Ferula communis*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
110	Keppuwa	*Ocimum lamifolium*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
111	Kookiya	*Passiflora edulis*	H	-	-	-	+	-	+	-	-	-	-	+	+	+	-	March-Dec
112	Lelehiya	*Cucurbita maxima*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Dec
113	Lokomaa	*Phaseolus vulgaris*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	May-Nov
114	Maaxe santta	*Brassica oleracea*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
115	Machaaraa	*Datura stramonium*	H	-	-	-	-	+	-	-	-	+	-	-	-	+	-	March-Oct
116	Malduwa	*Sorghum bicolor*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	May-Nov
117	Mixmixxaa	*Capsicum minimum*	H	-	+	-	-	-	-	+	+	+	-	+	+	+	+	March-Nov
118	Mudhdhaa	*crassula argentea*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
119	Muuziya	*Musa paradisiaca*	H	-	-	+	-	-	-	+	+	+	-	+	+	+	+	Year round
120	Naana	*Mentha piperita*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
121	Naatiraa	*Artemisia afra*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
122	Ocholoniya	*Arachis hypogaea*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Oct
123	Orkkondduwaa	*Phaseolus lunatus*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
124	Papaya	*Carica papaya*	H	-	+	-	-	-	-	+	-	+	-	+	+	+	+	Year round
125	Paranjja lelehiya	*Cucurbita pepo*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
126	Qaariya/barbariya	*Capsicum abyssinicum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
127	Qaccaa	*Sehima nervosa*	H	-	-	-	+	-	-	+	-	-	-	+	+	+	+	Year round
128	Qaysiriya	*Beta vulgaris*	H	-	+	-	-	-	+	-	-	-	+	+	+	+	+	March-Nov
129	Qolxxuwa	*Arisaema flavum*	H	-	-	-	+	-	-	+	-	-	+	+	-	+	-	March-Oct
130	Qosxxaa	*Spinacia oleracea*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
131	Quxuquliya	*Solanum sarrachoides*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
132	Salaaxaa	*Eruca sativa*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
133	Shonkooruwa	*Saccharum officinarum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	Year round
134	Sunburaa	*Cicer arietinum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Dec
135	Surraa	*Cynodon dactylon*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Dec
136	Suufiya	*Carthamus tinctorius*	H	-	+	-	-	-	-	+	+	+	-	+	+	+	+	March-Nov
137	Talbba	*Linum usitatissimum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov
138	Timatimiya	*Lysopersicon*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Nov

		esculentum																
139	Turaa	*Neonotonia wightii*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Dec
140	Uuttaa	*Ensete ventricosum*	H	-	+	-	-	-	+	-	-	-	+	+	+	+	+	Year round
141	Woshuwa	*Panicum spps*	H	-	-	+	-	-	+	-	-	-	-	+	-	-	-	March-Dec
142	Xalotiya	*Ruta chalepensis*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	Year round
143	Xattaa	*Cyperus alternifolias*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Aug
144	Xiqil gomaniya	*Brassica oleracea*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	Year round
145	Zardduwa	*Lolium temulentum*	H	-	+	-	-	-	+	-	-	-	-	+	+	+	+	March-Dec
	Total			**0**	**54**	**7**	**6**	**3**	**53**	**14**	**8**	**8**	**5**	**67**	**64**	**66**	**59**	

T = tree S = shrub H = herb

Appendix IV: Summary of chemical composition, *invitro* dry matter digestibility and mineral profile of palatable plant species found in the study area

		%DM											Kcal /g	ppm				
Scientific name	**Parts sampled**	**%DM**	**OM**	**CP**	**NDF**	**ADF**	**ADL**	***IVDMD***	**Mg**	**Ca**	**K**	**P**	**ME**	**Na**	**Mn**	**Cu**	**Fe**	**Zn**
Acacia brevispica	Leaf	92.15	93.15	22.04	41.89	29.29	12.03	58.63	0.23	0.47	1.91	0.2	2.14	300	33	13.5	148.3	27
Acacia polyacantha	Leaf	90.69	91.3	24.86	49.81	30.56	15.76	-	0.3	2.7	10.33	0.27	-	-	-	-	-	-
Acacia seyal	Leaf	91.64	91.24	16.91	28.48	19.09	5.29	75.79	0.29	2.43	0.79	0.15	2.7	200	41.2	9.7	283.1	21.5
Acacia spp	Leaf	94.23	92.73	23.34	65.53	43.26	11.76	*32.15*	-	-	-	-	-	-	-	-	-	-
Amaranthus graecizans	Leaf	72.2	78.0	28.5	-	8.5	-	-	-	-	-	-	-	-	7.2	0.65	19.3	2.3
Andropogon gayanus	Aerial	93.32	89.67	6.18	70.74	39.23	5.05	58.16	0.15	0.32	1.10	4.00	2.03	62.9	103.1	8.20	347.3	22.30

Arachis hypogaea	Leaf	91.72	87.41	16.3	38.44	18.7	2.75	74.17	0.58	0.95	1.59	0.07	2.5	84.1	105.9	25.87	825.2	37.99
	Stem	91.33	86.16	10.09	43.83	58.25	-	63.94	-	-	-	-	2.14	-	-	-	-	-
Balanites aegyptiaca	Leaf	92.88	89.71	18.49	33.93	24.57	13.18	63.71	0.07	0.79	1.41	0.26	2.28	900	36.7	18.7	98.8	22.5
Brachiaria brizantha	Aerial	90.75	93.81	5.56	73.76	39.29	4.74	51.28	0.15	0.4	1.43	0.23	1.93	121.3	-	-	-	-
Buddleja polystachya	Leaf		92.43	18.62	55.11	37.72	17.65	42.18	-	1.47		0.18	-	-	-	-	-	-
Cajanus cajan	Aerial	91.39	93.47	25.68	53.97	35.59	16.92	48.62	-	-	-	0.25	1.83	-	-	-	-	-
Carissa edulis	Leaf	91.78	93.09	8.63	42.93	31.46	15.3	-	0.4	1.33	1.36	0.15	-	296.8	211.7	12.9	1347.9	48.3
Cenchrus ciliaris	Aerial	92.34	85.63	9.90	67.08	38.99	5.47	60.98	0.21	0.28	2.07	0.22	2.02	300	62.3	9.00	618.1	49.2
Cicer arietinum	Aerial	91.78	89.6	6.5	63.83	47.17	9.94	-	-	-	-	-	-	-	-	-	-	-
Clausena anisata	Leaf	90.34	89.22	-	-	-	-	-	0.33	1.7	3.48	-	-	47.93	115	12.4	366.5	24.8
Clutia abyssinica	Leaf	91.37	91.12	18.5	16.86	16.98	4.08	-	-	-	-	-	-	-	-	-	-	-
Coffee arabica	Leaf	93.6	90.44	12.5	50.82	46.08	21.01	57.03	-	-	-	-	2.04	-	-	-	-	-
Colocasia esculenta	Root	32.36	96.08	6.62	-	-	-	-	-	-	-	-	-	37.61	-	0.76	10.57	14.27
	Tuber	92.7	96.38	12.6	48.8	6.81	0.2	-	-	-	-	-	-	-	-	-	-	-
Combretum molle	Leaf	95.91	92.69	8.89	48.47	33.35	23.4	21.16	-	-	-	-	-	-	-	-	-	-
Commelina benghalensis	Aerial	90.79	81.49	7.38	52.48	33.7	6.08	-	0.44	1.92	1.46	0.09	-	300	396	10.3	1651.0	43.2
Corchorus trilocularis	Leaf	83.9	84.6	20.4	-	11.1	-	-	-	-	-	-	-	-	-	0.68	18.6	2.9
Cordia africana	Leaf	88.74	84.55	19.19	40.61	69.22	39.65	-	0.61	3.89	1.64	0.25	-	919.9	-	-	147.38	14.4
Cynodon dactylon	Aerial	92.24	87.15	8.45	68.54	37.18	5.05	52.13	0.14	0.25	1.87	0.36	1.91	146.6	88.8	9.44	489	30.31
Cyperus amabilis	Aerial	88.91	81.98	24.63	46.79	31.29	4.09	76.02	0.35	0.62	4.45	0.62	2.38	755.1	74.57	8.44	667.08	33.52
Cyprus papyrus	Aerial	94.8	86.5	10.6	67.6	43.5	4.9	-	-	-	-	-	-	-	-	-	-	-
Dioscorea alata	Root	88.3	96.83	5.54	-	-	-	-	-	-	-	-	-	-	-	-	34.42	0.78

Dovyalis abyssinica	Leaf	95.35	91.61	11.34	40.67	33.56	9.10	-	-	-	-	-	-	-	-	-	-	-
Ehertia cymosa	Leaf	94.25	86.17	15.67	42.75	39.95	10.92	-	-	-	-	-	-	-	-	-	-	-
Ensete	Leaf	91.38	83.92	13.65	63.56	37.87	7.71	-	0.29	0.98	5.37	0.21	-	29.29	642.7	9.22	151.49	24.69
ventricosum	Stem	91.94	86.21	-	64.86	53.53	1.14	-	0.39	2.11	3.85	0.17	-	108.4	226.1	6.85	156.52	21.86
Eragrostis tef	Aerial	91.72	92.23	4.18	76.44	44.65	5.44	53.17	0.17	0.36	1.33	0.15	1.94	107.4	142.6	11	176.7	28.12
	Straw	92.19	92.52	3.58	81.19	44.41	5.24	-	0.12	0.3	1.18	0.11	-	77.68	84.88	16.02	272.7	64.17
Erythrina abyssinica	Leaf	90.88	87.91	19.42	58.17	42.83	11.66	-	0.28	1.93	1.91	0.31	-	-	-	-	-	-
Ficus sycomorus	Leaf	92.66	88.51	12.42	61.01	-	-	-	-	-	-	-	-	-	-	-	-	-
	Fruit	95.56	90.3	10.81	66.71	-	-	-	-	-	-	-	-	-	-	-	-	-
Ficus thonningii	Leaf	94.04	93.12	11.13	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gossypium hirsutum	Husk	92.41	97.08	5.97	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grewia bicolor	Leaf	91.31	90.61	14.73	57.25	47.22	19.4	-	0.34	1.36	1.62	0.13	-	450	92.3	12.75	290.1	27.6
Grewia ferruginea	Leaf	95.0	91.0	15.0	33.0	27.5	5.5	64.5	-	-	-	-	-	-	-	-	-	-
Grewia tembensis	Leaf	92.32	88.39	16.37	-	24.64	4.92	-	0.28	1.77	2.18	0.14	-	350	134.2	21.33	385.3	28.15
Grewia villosa	Leaf	91.67	89.54	18.88	-	-	-	-	0.45	2.16	1.81	0.14		348.9	148.2	16.36	276	60.55
Hagenia abyssinica	Leaf	94.78	92.08	18.12	28.28	23.78		62.83	-	-	-	-	-	-	-	-	-	-
Hordeum vulgare	Aerial	85.74	90.82	7.5	53.75	34.28	4.39	63.19	-	-	-	-	2.25	-	-	-	-	-
Ipomoea batatas	Aerial	90.34	86.83	15.88	43.09	33.78	13.93	90.43	0.54	1.23	2.59	0.22	2.93	257	337.3	18.44	625	34.28
	Root	91.86	89.72	6.16	36.65	31.9		65.36	0.35	1.07	2.78	0.18	2.29	63.58	179.8	14.95	590.2	20.33
Lablab	Aerial	90.98	89.2	15.76	47.5	39.46	7.65	-	0.29	1.57	2.38	0.47	-	52.9	38.9	17.3	496.7	33.1
purpureum	Seed	87.79	94.75	26.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Linum	Stem	92.51	93.25	5.16	64.63	52.64	13.95	48.83	-	-	-	-	1.82	-	-	-	-	-

usitatissimum																		
Maesa lanceolata	Leaf	95.1	92.85	17.06	61.33	-	-	-	-	-	-	-	-	-	-	-	-	-
	Fruit	96.5	92.55	9.79	62.00	-	-	-	-	-	-	-	-	-	-	-	-	-
Manihot esculenta	Root	85.03	96.45	3.38	16.96	8.76	2.26	-	-	-	-	-	-	-	-	-	-	-
	Peelings	90.55	90.12	-	-	-	-	-	0.28	2.29	2.26		-	23.08	671.5	9.94	535.17	45.39
Maytenus arbutifolia	Leaf	89.1	87.1	20.5	32.0	24.9	7.16	-	-	-	-	-	-	-	-	-	-	-
Millettia ferruginea	Leaf	91.7	86.13	22.21	-	53.86	34.11	-	-	-	0.83	0.17	-	-	-	-	-	-
Moringa oleifera	Leaf	90.03	84.88	27.72	20.24	-	-	-	1.15	3.04	-	0.41	-	-	-	-	-	-
Musa acuminate	Leaf	93.27	75.96	-	-	-	-	-	-	-	-	0.54	-	-	-	-	-	-
Neonotonia wightii	Aerial	91.02	89.61	20.66	41.15	-	-	66.05	0.29	0.75	2.28	-	2.32	29.61	149.5	16.45	2950.2	18.89
Olea Africana	Leaf	94	91.96	10.75	38.61	32.64	16.98	-	0.17	0.78	1.21	0.44	-	122.4	27.87	15.95	362.58	45.31
Panicum spps	Aerial	92.46	87.92	7.78	69.2	38.55	5.64	63.79	-	-	-	0.32	2.1	-	-	-	-	-
Pennisetum purpureum	Aerial	91.9	80.04	9.95	61.7	34.53	3.5	64.98	0.22	0.55	3.89	0.33	2	98.3	42.45	22.95	255.3	29.75
Phaseolus vulgaris	Aerial	91.81	90.46	6.78	64.2	54.5	9.29	49.63	0.18	0.89	2.46	0.14	1.78	858.3	41.99	20.61	987.55	23.92
	Stem	92.59	92.11	7.62	57.18	44.59	8.29	54.13	-	-	-	-	1.99	-	-	-	-	-
Piliostigma thonningii	Leaf	92.73	89.59	19.81	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pisum sativum	Seed	89.01	96.39	29.5	-	-	-	-	-	-	1.5	0.65	-	-	-	-	-	-
	Aerial	89.4	93.08	6.77	75.47	61.85	11.47	-	-	-	2.86	0.11	-	-	-	-	-	-
Rhus glutinosa	Leaf	96.86	90.71	16.04	49.31	-	-	-	-	-	-	-	-	-	-	-	-	-
	Fruit	92.43	94.43	11.21	68.9	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhus natalensis	Leaf	92.1	89.79	9.25	-	-	-	-	0.41	0.95	2.57	0.1	-	200	87.7	9	173.1	20.2
Ricinus communis	Leaf	94.9	91.36	24.34	27.94	26.77		6.93	-	-	-	-	-	-	-	-	-	-

Saccharum officinarum	Aerial	75.76	81.16	3.28	-	-	-	-	0.22	1.06	3.44	0.08	-	741.1	21.4	17.2	359.3	26
	Tops	92.7	86.32	10.13	66.4	39.82	5.44	-	0.12	0.44	3.25	0.2	-	37.32	46.06	6.36	82.31	12.73
Schrebera alata	Aerial	90.43	92.23	-	-	-	-	-	0.35	-	2.58	-	-	-	-	93.11	285.08	9.07
Sehima nervosa	Leaf	80.45	87.63	3.0	77.2	-	-	-	-	-	-	-	-	-	-	-	-	-
Sorghum bicolor	Leaf	89.39	85.57	13.06	54.76	-	-	-	-	-	-	-	-	-	-	-	-	-
Sporobolus pyramidalis	Leaf	84.42	79.82	3.06	71.57	-	-	-	-	-	-	-	-	-	-	-	-	-
Syzygium guineense	Leaf	94.48	90.82	12.85	33.78	26.95		64.77	-	-	-	-	-	-	-	-	-	-
Terminalia schimperiana	Leaf	92.84	93.75	14.99	50.46	23.81	15.5	29.45	-	-	-	-	-	-	-	-	-	-
Trigonella foenum-graecum	Stem	91.79	86.69	9.74	44.34	37	6.26	-	-	-	-	-	-	-	-	-	-	-
Triticum aestivum	Aerial	92.23	90.78	4.41	74.39	49.56	6.96	53.61	0.09	0.32	1.13	0.11	2.01	182.5	49.69	15.92	212.9	17.1
	Straw	91.38	90.34	6.1	81.1	51.89	6.52	-	-	-	-	0.11	-	-	-	-	-	-
Vernonia amygdalina	Leaf	91.9	87.3	18.64	27.29	35.85	14.12	-	0.31	1.38	2.82	0.23	-	95.71	102.2	14.99	441.4	49.99
Vernonia sp.	Leaf	92.3	88.6	22.29	42.23	36.83	9.49	-	0.45	1.63	2.59	0.35	-	868.7	80.38	22.35	564.3	248.1
Vicia faba	Aerial	92.68	89.97	-	67.39	56.45	11.53	-	-	-	-	-	-	-	-	-	-	-
Vigna unguiculata	Aerial	90.9	84.45	21.67	37.65	19.28	4.23	73.31	-	-	-	-	2.37	-	-	-	-	-
Ximenia caffra	Fruit	61.2	95.0	21.6	-	10.4	-	-	-	-	-	-	-	-	-	-	-	-
Zea mays	Leaf	91.29	86.1	7.03	56.54	30.61	2.13	70.19	0.49	0.63	2.03	0.08	2.36	203.2	76.22	17.16	240.87	26.18
	Stem	91.24	93.38	4.44	72.73	49.98	5.87	47.7	0.28	0.21	1.63	0.02	1.76	169.9	16.08	8.85	63.58	58.83
	Stover	91.15	92.52	4.59	70.69	47.35	5.63	58.02	0.22	0.13	1.69	0.12	2.1	561.5	41.38	13.41	249.3	43.9
	Grain	91.5	98.26	9.48	32.71	4.59	0.81	77.05	-	0.06	-	0.31	2.94	-	-	-	-	-