ANALYSIS OF *ENSET (Ensete ventricosum*) BASED CATTLE PRODUCTION SYSTEM; AVAILABILITY AND QUALITY OF COMMON FEED RESOURCES IN GURAGE ZONE, SOUTHERN ETHIOPIA

PhD Dissertation

By

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Addis Ababa University, College of Veterinary Medicine and Agriculture

Department of Animal Production Studies

PhD Program in Animal Production

March, 2019

Bishoftu, Ethiopia

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A PhD 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 Dirsha Demam Wonchesa titled: **Analysis of Enset (*Ensete ventricosum*) Based Cattle Production System; Availability and Quality of Common Feed Resources in Gurage Zone, Southern Ethiopia** and recommend that it be accepted as fulfilling the partial requirement for the degree of Doctor of Philosophy in Animal Production.

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STATEMENT OF AUTHOR

First, I declare that this dissertation is my bonafide work and that all sources of material used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for a PhD degree at Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University/College library to be made available to borrowers under 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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BIOGRAPHICAL SKETCH

The author, Dirsha Demam Wonchesa, was born on December 02, 1967 in Agena Kebele of Ezia Woreda (District), Gurage Zone, Ethiopia. He attended his elementary education at Koter Gedra Elementary School and his junior secondary education in Gummer Junior Secondary School. His Secondary High School was attended at Emdibir Comprehensive Secondary School in Emdibir town.

He joined the then Alemaya University of Agriculture in 1985 and graduated with Bachelor of Science Degree in Animal Science in 1989. Soon after graduation, he joined the then Relief and Rehabilitation Commission (RRC) and served as Head, Animal Production Section at Metu, Gambela, Asosa and Nekemte regional offices up to April 1994. Then after, he was transferred to the Ministry of Agriculture and served as Zonal Animal Production Expert and National Livestock Resource Development Project (NLRDP) Coordinator and Head of District Agriculture and Rural Development Office in Gurage Zone Administration until January 2003.

From February 2003 on, he was transferred to the Bureau of Agriculture and Rural Development of SNNPR and served as a Manager of Gubre Poultry Farm. In October 2007, he joined the School of Graduate Studies of Haramaya University, Department of Animal Sciences majoring in Animal Production and graduated in July 2009 with Master of Science Degree in Animal Production. After graduation, he rejoined Gubre Poultry Farm as a Manager. On 1st of June 2012, he joined Wolkite University as a Researcher/Lecturer and he assumed the position of Dean of Student Services on July 25, 2012, wherein he served until November 2016. In December 2016, he joined Addis Ababa University, College of Veterinary Medicine and Agriculture to pursue PhD study in the field of Animal Production.

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DEDICATION

I dedicate this thesis manuscript to my beloved wife w/o Tsehay Kebede and my mother w/o Bizunesh Murare for nursing me with love and for their sacrifice in the success of my life.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACTESA	Alliance for Commodity Trade in Eastern and Southern Africa
ADF	Acid detergent fiber
ADL	Acid detergent lignin
AFC	Age at First Calving
AFS	Age at First Service
AI	Artificial Insemination
ANHMRC	Australia's National Health and Medical Research Council
AOAC	Association of Official Analytical Chemists
BoARD	Bureau of Agriculture and Rural Development
CE	Cereal Equivalent
CI	Calving Interval
COMESA	Common Market for Eastern and Southern Africa
CP	Crude Protein
CSA	Central Statistics Agency
DA	Development Agent
DAEI	Daily Average Energy Intake
DANRD	Department of Agriculture and Natural Resource Development
DCP	Digestible Crude Protein
DM	Dry Matter
DO	Days Open.
DOFED	Department of Finance and Economic Development
EARO	Ethiopian Agricultural Research Organization
EHNRI	Ethiopian Health and Nutrition Research Institute
ENI	Ethiopian Nutrition Institute
ESAP	Ethiopian Society of Animal Production
ESSP	Ethiopian Support Strategy Program
FGD	Focus Group Discussion
FMD	Foot and Mouth Disease
GDP	Gross Domestic Product

LIST OF ABBREVIATIONS AND ACRONYMS (*Continued*)

HFBM	Household Food Balance Model
HH	Household
ILCA	International Livestock Centre for Africa
ILRI	International Livestock Research Institute
IVDMD	*In Vitro* Dry Matter Digestibility
LL	Lactation Length
LSD	Lump Skin Disease
MAFF	Ministry of Agriculture, Fisheries and Food
ME	Metabolizable Energy
MoARD	Ministry of Agriculture and Rural Development
MoFED	Ministry of Finance and Economic Development
MY	Milk Yield
N	Nitrogen
NAIC	National Artificial Insemination Center
NDF	Neutral Detergent Fiber
NRC	National Research Council
OM	Organic Matter
PA	Peasant Association
SD	Standard Deviation
SE	Standard Error
SNNPR	Southern Nations, Nationalities and Peoples' Region
SPSS	Statistical Software for Social Sciences
TDCP	Total Digestible Crude Protein
TDM	Total Dry Matter
TLU	Tropical Livestock Unit
TME	Total Metabolizable Energy
UNIDO	United Nations Industrial Development Organization

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ANALYSIS OF *ENSET (Ensete ventricosum*) BASED CATTLE PRODUCTION SYSTEM; AVAILABILITY AND QUALITY OF COMMON FEED RESOURCES IN GURAGE ZONE, SOUTHERN ETHIOPIA

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ABSTRACT: *The study was conducted in four districts of Gurage zone, Sothern Nations Nationalities and People's Region to identify the major constraints of* dairy cattle production, *to determine the quantity and quality of available feed resources, to determine the livestock feed balance, to identify the interdependence between that exists between cattle and enset and to assess the role of cattle in enset based agriculture in relation to food security status of farming families. Households of 360 were selected using proportional sample size determination (Cochran, 1909; Thrustfield, 2013) and individually interviewed with personal observation and focus group discussion. The overall average family size of 7.71±.18 persons, herd size of 4.87±0.12 heads of cattle (3.35 TLU) and land holding of 1.75±0.05 hectare per household were obtained in this study. Around 88.05% of the farmers in the study areas were keeping cattle primarily for the production of milk and manure while 11.95% held cattle mainly for milk production and traction. Mating systems used by households predominately (83.6%) covered by the natural mating. Some (15.3%) of households reported to use AI and natural mating. About 95.55% of cattle were local breed. The overall average lactation yield of indigenous dairy cows was 1.53kg with lactation length of 7.23 months. The overall average age at first service and age at first calving for local heifers, respectively, was 53.44 and 62.44 months. The overall average days open of 211.44 and calving interval of 481.44 days was reported for local dairy cows. Farmers of 82.78% were relied on river water source for their cattle. Extensive-dairying is the dominant system where farmers majorly depend on enset leaf and leaf midribs (51.05% DM) to feed their cattle. Feeding systems of Grazing & cut and carry; Tethering, grazing and cut & carry as well as Tethering & cut and carry were practiced by farmers of 34.7%, 31.4% and 33.9%, respectively. Households of 77.5% gave feeding priority to the lactating cows and calves. The prevalent diseases of the study areas include: Anthrax, Blackleg, FMD, Bovine Pasteurollosis, LSD, Mastitis, Pneumonia, Metritis and parasites and their infestation depends majorly on seasons of the year. The DM produced from leaf and leaf midribs of enset, crop residues and natural grasses in tons, respectively, were 506.4; 312.33 and 141.62 in dega whereas it was 662.96; 472.83 and 207.33 in weinadega. The DCP produced from enset leaf and leaf midribs, crop residues and natural pasture, respectively, were 51,819.91 kg; 8,401.16 kg and 10,335.43 kg in dega while it was 55,217.94 kg; 13,799.32 kg and 11,490.23 kg in weinadega. The ME produced in dega was 4,420,872; 2,296,269.8 and 1,188,191.8 MJ whereas it was 6,013,047.2; 3,430,459.7 and 1,689,739.5 MJ in weinadega from enset parts, crop residues and natural pasture, respectively. The amount of DM, DCP and ME produced by individual household per year in weinadega agroecology were significantly higher ($p<0.05$) than the amount produced in dega agroecology. The annual feed supply in the study areas met only 76.81% DM and 69.9% DCP of the maintenance requirement of livestock in TLU but the available ME was 1.67% surplus. Conversely, the annual feed supply met only 64.98% DM, 66.24% DCP and 85.66% ME of the* *maintenance requirement of livestock in dega agroecology, whereas in weinadega, agroecology about 88.31% DM and 73.46% DCP of the maintenance requirement were met but the estimate of ME was 17.22% above the requirement. Livestock in the study areas of Gurage zone are in serious feed deficit which needs a special attention. There is a strong linkage between enset and cattle production in enset-cattle based mixed production system of Gurage zone through generations which has a strong bond in determining the livelihoods and food security of the rural farming families. Similarly, in the existing situation of fragmented land holding which doesn't give opportunity of producing feed enough for cattle, it is paramount important to practice enset cultivation without which sustainability in cattle feeding cannot be obtained. Leaf and leaf midribs of enset represented the greatest share of 50.77% TDM, 70.86% TDCP and 54.81% of TME available for cattle feeding and it is imperative in safeguarding the life of animals especially during drought and unusual periods of the year. On the other hand, cattle manure is the only source of organic matter and nutrient input and is crucial for improvement in quantity and quality of enset products. The sampled manure had a total nitrogen of 2.68% and C: N ratio of 11:1 in dega and 2.24% with C: N ratio of 12:1 in weinadega. The organic matter obtained from manure sample in dega and weinadega, respectively, was 51.89% and 44.82%. The gm of N, P and K kg^{-1}DM of manure, respectively, were 26.8, 16.5 and 1.6 for dega and 22.4, 12.6 and1.2 for weinadega. Feed shortage, low performance of indigenous cattle, inefficient AI service, water scarcity and animal diseases were the major challenges of dairy production. To achieve better result from dairying in particular and from livestock in general, efficient storage and utilization of crop residues, improved forage development, upgrading technical and managerial efficiencies of crossbreeding, supplementing livestock with concentrates of protein sources for both agroecologies and energy for dega agroecology, provision of animal health extension services focusing on preventive measures and developing different water harvesting structures based on agroecologies must be implemented. In food security realization programs, everyone should take his/her own accountability and responsibility through provision of strong and continuous extension services and area specific research works. The development planners including political leaders should pay attention on bringing improvement in production and productivity, understand the life securing abilities and do not undermine the economic and famine buffering potentials of these two resources. By considering multi-socio-economic use of enset crop, on the other hand, special attention should also be given to hasten the production of enset throughout Ethiopia.*

1. INTRODUCTION

Throughout their history Ethiopians have constantly relied on livestock to survive Livestock in Ethiopia are extremely important as they serve a wide variety of functions in society from social to subsistence purposes (Kimball, 2011; Dereje *et al*. 2014). An estimation indicated that about 60-70% of livelihoods of the Ethiopian population is contributed by livestock (Halderman, 2004). They can contribute in a myriad of different forms from traditional security systems to cash to transportation for many Ethiopians. As the oldest form of assets in Ethiopia, livestock have and still today serve as a significant indicator of wealth. The immense scope of dependence on livestock is not without reason; Ethiopia's population is growing at a tremendous rate of 2.56% (CSA, 2009). Ethiopia is believed to have the largest livestock population in Africa. An estimate indicates that the country is a home for about 57.83 million cattle, 28.04 million sheep, 28.61 million goats, 2.08 million horses, 7.88 million donkeys, 0.406 million mules, 1.23 million camels and 60.51 million poultry. From the total cattle population, 98.59% are local breeds and the remaining 1.22% are hybrid and 0.19% exotic breeds (CSA, 2016).

The agricultural sector contributes 52% to the gross domestic product (GDP) and 90% to the foreign exchange earnings (CSA, 2008). Cattle produce a total of 3.2 billion liters of milk annually (FAO, 2005; FAO, 2009; CSA, 2009). About six million oxen provide the draught power required for the cultivation of crop land. Livestock are therefore closely linked to the economic, social and cultural lives of millions of resource-poor farmers for whom animal ownership ensures varying degrees of sustainable farming and economic stability (Befekadu and Birhanu, 2000). Ethiopia has a huge potential to be one of the key countries in dairy production for various reasons that include a large population of milk cows in the country which is estimated at 11.33 million milk cows (CSA, 2016), a conducive and relatively disease free agro-ecology, particularly the mixed crop-livestock systems in the highlands that can support crossbred and pure dairy breeds of cows (Ahmed *et al.*, 2003), a huge potential for production of high quality feeds under rain-fed and irrigated conditions, existence of a relatively large human population with a long tradition of consumption of milk and milk products and hence a potentially large domestic market, existence of a large and relatively cheap labor force and opportunities for export to neighboring countries and beyond (Holloway *et al.*, 2000).

Although the dairy sub-sector has a significant contribution to the Ethiopian economy, production per animal is extremely low. According to CSA (2016), the average lactation period of cow at country level was estimated to be about six months, and average milk yield is about 1.37 liters/cow per day. The per capita milk consumption was only about 16 kg/year, which is much lower than African and world per capita averages of 27 kg/year and 100 kg/year, respectively (FAOSTAT, 2009). Based on MOA (2012), on the other hand, some improvement has been reported in per capita consumption of milk and it was estimated to be 19.2 kg. From the overall Ethiopian milk production, the rural dairy system, which includes pastoral, agro-pastoral and mixed crop livestock system, contributes 98%, while the peri-urban and urban including the commercial dairy farms produce only 2% of the total milk production of the country. Indigenous cattle stock produce 97% of the milk and the remaining 3% from improved exotic crosses and pure grade cattle. Most of the milk produced in the rural dairy system is retained for home consumption and it is non-market oriented **(**Getachew, 2003). More importantly, the total milk production from about 11.33 million milking cows is much lower and is estimated at 1.37 liters per cow per day (CSA, 2016).

Feed supply from natural pasture fluctuates following seasonal dynamics of rainfall (Alemayehu, 1998; Solomon *et al*., 2008b). Poor grazing management contributed to shortage of feed resources as a result of replacement of productive and nutritious flora by unpalatable species (Ahmed, 2006). Quality of native pasture is very low especially in the dry season due to their low content of digestible energy and protein and high amount of fiber. This is much worse for crop residues owing to their lower content of essential nutrients (protein, energy, minerals and vitamins) and lower digestibility and intake (Chenost and Sansoucy, 1991; Zinash *et al*., 1995). Moreover, progressive decline of average farm sizes in response to rising human populations, encroachment of cropping land onto previous grazing areas and expansion of degraded lands which can no longer support either annual crops or pastures contributed to shortage of feed resources (Anderson, 1987; Alemayehu, 2005).

Interventions to improve livestock production and productivity, identifying possible constraints and opportunities in smallholder agriculture are an indispensable pathway towards economic growth and development for developing countries relying on the agricultural sector. In Ethiopia, livestock production system in different agro-ecological zones is not studied fully and farmers' needs and production constraints have not been identified exhaustively. Improvement in livestock productivity can be achieved through identification of production constraints and introduction of new technologies or by refining existing practices in the system (EARO, 2001; Berhanu *et al*., 2009).

Southern region occupy most of south and southwestern part of Ethiopia, the region sharing up to one-fifth of the country's population and most characterized by production of *enset* (*E. ventricosum)*. The product of *enset* is eaten in various forms: boiled corm (*Amicho*), or a fermented product in the form of bread (*kocho*), or the best-quality product from mature *enset* (*bulla*) in the form of pancakes, porridge or dumplings. As a perennial and maturing at around 5 to 7 years, *enset* acts as a food store which can be used at any time of the year; it is a relatively drought-tolerant plant, the leaves along its midribs provide fodder for livestock. It also provides fiber for industrial purpose; used as construction material and as traditional source of medicines (Mulugeta, 1996; Brandt *et al*, 1997). In the high altitudes (2300-3100 masl) where mean temperature drops to 10-15^{o}C, on the other hand, *enset* takes 8-10 years and sometimes up to16 years (Tesfaye, 2005).

Enset (*E. ventricosum)* is considered as a security food crop, as it relatively can withstand drought, heavy rain and seasonal flooding which ordinarily devastate other food crops, especially cereals (Million *et al.*, 2003). Once *enset* plant is established in the field, it can be utilized as a source of food all year round so long as it exits with reasonable size, by which nature it saved many lives during recurrent drought in the country (Mulugeta, 1996). A crop assessment data provided by Southern Nations Nationalities and People's

Region (SNNPR) Bureau of Agriculture (1994) and as reported by Shank and Entiro (1996), 300,000 hectares of land was occupied by *enset* plant and 4,653,076mt (2,299,000 mt-CE) of *Kocho* and 355,439mt (202,600 mt-CE) of *bulla* was produced giving a total of 15.51mt (7.66 mt-CE) *kocho* and 1.19mt (0.68mt-CE) *bulla* per hectare. Similar report prevailed that above 1,745,028 quintals or 174,502,800 kilogram of fiber locally called *Kacha* was produced which is imperatively important for the production of sacks used in the sugar and coffee processing industries. According to FAO (1987) and SNNPR, Bureau of Agriculture and Rural Development (2009), *enset* provides about 8 metric tons of dry matter feed per hectare of land per year for livestock feeding particularly for cattle.

Southern Nations, in general and Gurage Zone in particular is characterized by mixed crop-livestock farming system. *Enset* has been practiced for millennia (William, 1966) and involved as one of the major established farm components of the diverse farming systems and it has a major component in the livelihoods of the farming community. *Enset* culture has got a great role due to its high agronomic yield per hectare, serving as a major source of food, income and livestock forage. Based on annual reports of Department of Agriculture and Natural Resource Development of Gurage Zone (DANRD, 2016), *enset* occupies 102,850 hectare of land and the amount of *kocho* produced accounts for about 4,352,573.2mt. Popularity and demand of *enset* products are increasing in urban area too. “Previously *enset* regarded as a 'peasant's crop', *kocho* is now a required dish in many restaurants throughout the country, including Addis Ababa, where it is combined with a spicy mincemeat known as *Kitfo”* (George, 2007).

Concerning with the importance of *enset* in Gurage zone, William (1966) reported that, “The Gurage have a vital interest in *enset* (locally called ‘*asset*’). They depend on it for many of the necessities of life. The uses of *asset* seem endless and all parts of the plant are consumed in one way or another and this increases considerably the importance of *asset* in Gurage culture”. Households of Gurage Zone have paid every endeavour to enhance and improve the production and productivity of *enset* through their own cultural management practices. However, the Local Governments and the respective Offices of

Agriculture and Rural Development of Gurage Zone did not give considerable attention towards *enset* production either due to undermining or not understanding enset's potential of contribution to livelihoods and food security of farm households. Based on the perception of the households, there is an idea and practices of replacing the *enset* farm by annual crops due to emphasis given by the political leaders to increase annual crop production through crop extension program.

On the other hand, *enset* and cattle production have prudent interaction in Gurage zone, particularly in the altitudes where *enset* serves as a source of fodder for cattle and cattle provide manure to fertilize *enset* fields, as a result farmers in this area have tried to make sustainable *enset* and cattle production. *Enset* and cattle production have been interdependent through generations and have strong bond with the livelihoods of the rural farming families of the zone. In the absence of cattle in this system, the sustainability of *enset* production will definitely and negatively be affected. Identifying the existing situations in relation to production and productivity constraints and opportunities in the area is crucial for further interventions. Hence, assessment of the production system in selected *Woredas* of the Zone is imperative to identify and prioritize the constraints and opportunities that helps to understand the production system and to design appropriate technologies compatible with the system of production.

Therefore, this study was initiated with the general objective of investigating the trends of cattle and *enset* interdependence among smallholder farming families whose food security has been based on these two resources through generations with the following specific objectives:

1. To characterize dairy cattle production practices in Gurage zone, Southern Ethiopia;
2. To identify available livestock feed resources and determine chemical compositions of the major feeds in the study area;
3. To determine livestock feed balance in the study area;
4. To identify the interdependence that exists between cattle and *enset* production and
5. To assess the role of cattle in *enset* based agriculture for household food security.

2. LITERATURE REVIEW

2.1. Economic Importance of Livestock Species in Ethiopia

Naturally endowed with different agroecological zones and suitable environmental conditions, Ethiopia is a home for many livestock species and suitable for livestock production. The livestock subsector has an enormous contribution to Ethiopia's national economy and livelihoods of many Ethiopians and still promising to rally round the economic development of the country (Metaferia *et al*., 2011).

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. The subsector contributes about 16.5% of the national Gross Domestic Product (GDP) and 36% of the agricultural GDP. The livestock subsector currently support and sustain livelihoods for 80% of all rural population. The GDP of livestock related activities valued at birr 59 billion (Metaferia *et al.,* 2011). It also contributes 15% of export earnings and 30% of agricultural employment (Behnke, 2010).

Despite high livestock population and existing favorable environmental conditions, the current livestock output of the country is below its potential. This is associated with a number of complex and inter-related factors such as inadequate feed, water scarcity, poor livestock health management, low productivity of local breeding stock, inefficiency of livestock development services with respect to credit, extension, marketing, and infrastructure (Jabbar *et al.,* 2007; Negassa *et al*., 2011; Dawit *et al.,* 2013).

An estimation indicated that about 60-70% of livelihoods of the Ethiopian population is contributed by livestock. They can contribute in a myriad of different forms from traditional security systems to cash and transportation for many Ethiopians. As the oldest form of assets in Ethiopia, cattle and other types of livestock have traditionally and still today serve as a significant indicator of wealth. Even today, Ethiopia is generally recognized to have the largest population of livestock of any other African nation (Halderman, 2004). However, the sub sector's contribution is well below its potential due to various reasons such as feed shortage and disease (Berhanu *et al.,* 2009), less efforts in introducing the appropriate package of improved livestock technologies such as cross breeding, improved feed management practices and inadequate healthcare services which enhance the current livestock production and productivity (Getahun, 2012).

During the period from 2001 to 2007, based on FAO data, cattle milk production is growing at an average rate of 2.6%, which is equivalent to the Ethiopia's population growth rate (2007 census). The recommended per capita milk consumption according to FAO (2009) is 200 liters per annum. The average per capita consumption of milk in Sub-Saharan African is 25kg, Ethiopia's per capita milk consumption is estimated to be about 19.2 kg, whereas our neighbor Kenya is consuming about 90kg and global average is 190 kg.

Given the long tradition of using milk and milk products by the Ethiopian society, there is no doubt that increasing smallholder dairy cattle production and productivity would bring about a prominent impact on improving the welfare of women, children and the citizens of the country at large. It also constitutes a significant proportion of the value of total food products in the country (CSA, 2008). However, production and consumption of milk and milk products are not balanced because of the ever increasing demand and traditional production system constrained by different factors of production (Asrat *et al.,* 2013).

Cattle are kept for multiple purposes and the emphasis on use varies with the production system. In both crop-livestock and agro-pastoral systems, animal traction ranked first, followed by milk and reproduction. Manure production is also considered as a secondary important by-product by most crop-livestock and agro-pastoral farmers. However, in pastoralist systems, reproduction (breeding) requirements received higher ranks and for female animals breeding outranked the importance of milk production (Workneh and Rowlands, 2004). By the year 2020, the rural and urban human population distribution of

84.7% and 15.3% is projected to reach 80.1% and 19.9% (CSA, 1996) indicating the shift towards urbanization. Thus, the demand for milk products is expected to increase substantially with the projected growth in human population, increased urbanization and expected growth in per capita incomes (Mohammed *et al.*, 2004).

In the highlands of Ethiopia, smallholders rear cattle primarily for the supply of oxen power for crop production. Milk production, cash source, manure and fuel are considered as secondary. Cattle play vital role in smallholder farms for crop cultivation and transportation (Alemu, 1998). Dairy products can make a unique contribution to human nutrition to the poor in developing countries by providing nutrients in bio-available form such as vitamin A, carbohydrates, protein and calcium (Ahmed *et al*., 2003). The value of output from cattle increased by a factor of 3.75 from Ethiopian birr 9.97 billion to 37.38 billion between 1999/2000 and 2008/09 (MoFED 2010). Data collected from the Ethiopian Custom and Revenue Authority also showed that import of dairy products in Ethiopia increased from 1.3 million kg in 2004 to 1.77 million kg in 2009 and spent Ethiopian birr 42.1 million and 100.57 million, respectively to satisfy the domestic demand for milk and milk products (FAO, 2009).

With annual human population growth rate of 2.56%, the existing Ethiopia's human population will increase to about 149.3 million by the year 2040 (FAO, 2005). The rural to urban ratio will also continue to change and is expected to increase in favor of urban population in the coming 25 years. Demand for milk products especially in urban areas is mostly met with imported products. Import has increased from about $3.1 million in the year 2001 to the level of $9.3 million in the year 2008, which is about 300% growth from what has been in 2001. In terms of quantity it has increased from 1,716 tons (2001) to 2,087 tons (2007) with steady increases every year (UNIDO, 2009).

2.2. Socioeconomic Role of Cattle

Cattle are an important component of nearly all farming systems in Ethiopia and provide draught power, milk, meat, manure, hides and serve as a capital asset against risk. In addition, cattle are important source of cash income and play an important role in ensuring food security and alleviating poverty (Ehui *et al*., 2002). In both crop-livestock and agro-pastoral systems traction ranked highest, followed by milk and reproduction/breeding. Manure production is also considered important by most crop/livestock and agro-pastoralist farmers, but as secondary rather than a primary purpose (Alemayehu, 2004). In contrast to crop-livestock and agro-pastoral systems, reproduction/breeding requirements received higher ranks in pastoralist systems and female cattle requirements for breeding outranked for the importance of milk production (Workneh and Rowlands, 2004). In the semi-arid lowlands, cattle are the most important species as they supply milk for the subsistence pastoral families (Asfaw, 1997).

Cattle production performs several functions primarily as source of household incomes, food and animal drought power for crop producers in Ethiopia. Cattle production is also an anchor for economic diversification and sustainable rural development, although most of the agricultural policies are biased towards crops for food-security purposes. Because of the low potential for crop production, including absence of or limited irrigation technologies in Ethiopia and most countries in COMESA, cattle remains a major source of income and food for the majority of rural people in the traditional and agro-pastoral/pastoral farming systems. In this respect, cattle ownership, in terms of both quantity and quality, is an important asset because of its multiple social, economic and cultural uses (ACTESA, 2011).

About 76 million poor animal producers are found in Common Market for Eastern and Southern Africa (COMESA), suggesting this sector is still subsistence oriented. In order to tap into the emerging opportunities in the Far East and Europe, there is a need to upgrade the sector to commercial production and intensification. Commercially oriented animal production systems are more likely to respond to demand and price signals thus allocating scarce resources more efficiently. Commercial orientation is also likely to have more sustainable and ripple effects on increasing incomes and employment opportunities, improving nutrition and food security and overall poverty reduction in the sub region (ACTESA, 2011). Study made by Staal *et al*. (2008) showed that food-secured households were associated with high livestock, especially cattle asset ownership, indicating that increased cash incomes primarily came from these animals, through the sale of live cattle, milk, meat, hides and skins.

Gryseels (1988b), also indicated that the income accumulated from sale of cattle and their products and by-products was wisely used to finance the purchase of household commodities such as grains, salt, coffee, tea, cooking oil, sugar, as well as meeting health expenses. Moreover, cattle are a legal tender among livestock keepers and therefore, are used as payment for dowry, to settle disputes and as gifts to relatives. For lack of investment opportunities and banking facilities in the remote parts of most countries in COMESA, cattle remains the only investment “bank on the hoof" and source of wealth, prestige and social security among the smallholder farmers and agro-pastoralists/pastoralists. Prosperity is measured according to the number of cattle that one has. The more animals one has the more prosperous one becomes and the more respect and recognition one commands in the society (ACTESA, 2011).

2.3. Dairy Cattle Production Systems in Ethiopia

Based on degree of integration of livestock with crop production, level of input and intensity of production and agroecology, dairy production systems in Ethiopia has been classified in to four major production systems of smallholder crop-livestock mixed system, pastoral and agro- pastoral, urban and peri-urban and intensive dairy farming (Azage and Alemu, 1998). Smallholder farmers and pastoralists produce 98% of the country's total milk production (CSA, 2008). The majority of milking cows are local breeds which have low production performance. The average lactation yield is 524 liters over a lactation period of 239 days. About 238 liters are used for human consumption, while the remaining 286 liters are suckled by the calf (FAOSTAT, 2007). The average age at first calving is 53 months and average calving interval is 25 months. Cows produce three to four calves before leaving the herd at 11-13 years of age. Cows are kept to provide milk primarily for household consumption and reproduce for production of draught oxen and replacement heifers. Surplus milk is sold, usually by women, who use the regular cash income to buy household necessities or to save for festival occasions (Zewdu, 2004).

2.3.1. Pastoral system

Even though information on both absolute numbers and distribution vary, it is estimated that about 30% of livestock population of Ethiopia which are entirely indigenous breeds are found in the pastoral areas. In this farming system, the entire feed requirement of cattle is come from grazing of native grassland. The pastoralist livestock production system supports an estimated 10% of the human population and covers 50-60% of the total area mostly lying at altitudes ranging from below 1500 masl. Pastoralism is the major system of milk production in the lowlands. Cows, camels and goats are the major dairy animals used for milk production by pastoralists. However, availability of milk is dictated by the shortage and erratic nature of the rainfall and fluctuations in availability of feed (Ketema and Tsehay, 2004). Pastoralists rely on milk for food and also use animals to generate wealth. Animals in this system are consequently important in the social value system that promotes flexibility in resource use (Kedija *et al*., 2008).

2.3.2. Highland smallholder crop-livestock system

The Ethiopian highlands possess a huge potential for dairy development. These areas occupy the central part of Ethiopia and cover about 50-40% of the country's land area. In these areas agricultural production system is predominantly subsistence smallholder mixed farming, with crop and livestock husbandry typically practiced within the same management unit. In this farming system, the entire feed requirement for cattle is derived from native pasture and the balance comes from crop residues and stubble grazing. Crop farming is mainly practiced using oxen/draught power and oxen are given due attention next to lactating cows particularly with regard to better feeding. Traditional grazing on natural pasture is used as the main source of feed for the livestock followed by crop residues such as maize stover, wheat, barley and *teff* straw, (Tolera, 2009; Funte *et al*., 2010 and Dereje *et al*., 2014).

The cows are the main source of milk. Milk production is an integral part of the production system of small scale, non-commercial subsistence farms which represent about 83.9% of the human population and are responsible for the major part of 98% of the total milk produced and 75% of commercial liquid milk production (Tsehay, 2001; Getachew, 2003). Indigenous cattle are the typical animals maintained within this system. The system is largely a system of extensive husbandry; that is, the stock are for the most part expected to feed for themselves, making the best of natural pasture and crop residues. Such a system does not entail investment in the improvement of stock or of the grazing lands. Milking cows in the traditional sector have an average lactation length of 190 days and an average milk yield of 1.9 liters per day. Cash expenses for purchased inputs are minimal, supplementary feeding is not practiced and drugs and vaccinations use is much lower, those medicines required for the handling of indigenous stock are typically provided on a highly subsidized basis by the Veterinary Department of the Regional Agricultural Bureaus and sometimes through project finance (MoARD, 2008).

2.3.3. Urban and peri-urban smallholder dairy system

The introduction of crossbred dairy heifers into the mixed farming system in the development of an integrated agricultural production has proved successful in the highland regions of Ethiopia. This system of dairy production is mainly located in the potential highland areas of the country where farmers in the peri-urban and some rural areas not distant away urban centers practice market oriented milk production. They tend to be developed mainly in the Addis Ababa milk shed area and some other urban centers where market for fresh milk is readily available and adequate (Getachew, 2003). The animals used in this system are capable of producing 1,120 to 2,005 liters over 209 day lactation. The dairy farms in this system rely mainly on purchased feeds. They are market oriented and will respond to improved technical, input supply and marketing services (Azage, 2004).

2.3.4. Specialized intensive commercial dairy system

Specialized intensive dairy production is on a commercial basis and is concentrated in the central highland plateau. The system comprised of small and medium sized dairy farms and is based on the use of purebred exotic or high grade and crossbred dairy cows and the feed sources are based on purchase. They are mostly operating in the urban and peri-urban areas and around major cities and towns with high demand for milk having population of more than 10,000 (Sintayehu *et al.*, 2008). The system is labor and inputs intensive as compared to the other systems. Based on the above classification and characterization of the systems, the milk production systems represent a gradually increasing management level and investment in improved dairy cattle management. The higher levels of investments are found near the main urban markets where the higher milk prices are obtained (Sintayehu *et al.*, 2008).

2.4. Milk Processing and Marketing in Ethiopia

Studies indicate that butter making is an ancient practice that dates back as far as 2000 BC to the Egyptian civilization. Butter making may have begun at a similar time in Ethiopia. The traditional Ethiopian practice is to accumulate the milk for two to three days until it sours. A clay pot is then used to churn the sour milk. Butter is used for cash generation, cooking Ethiopian dishes, used in medicinal and cosmetic purposes (e.g. application to the braided hair of women). In almost all societies of Ethiopia, female household members are responsible for butter making. The contribution of dairy products to the gross value of livestock production is not known, but in peri-urban areas about 20% of average income is estimated to be derived from dairy products (Winrock, 1992). In the central highlands of Ethiopia smallholder milk processing is based on sour milk. The milk for processing can be either from a single milk cow or an accumulation from a large number of cows. The equipment commonly used is clay pot and a stick with three to six finger-like projections at one end (locally called 'Mesbekia' in Amharic and '*Erba*' in Oromiffa). Some households use only one of the materials, while others use them in combination (Zelalem and Inger, 2000).

2.5. Landholding and Land Use System

The land size allotted to individual farmers by Peasant Association (PA) as per the land reform declaration of 1975, depended on family size, fertility of the land, the number of PA members and the total land area available within the PA (Getachew *et al.*, 1993). Most farms in Ethiopia are fragmented and smallholder mixed crop-livestock systems are interdependent. Increasing human population coupled with diminishing land resources and increasing urbanization are creating a growing number of landless people who cannot produce their own subsistence (Kebreab *et al*., 2005*).*

Yitaye *et al.* (2007) reported that in the highland areas of Amhara region, where integrated farming is found, farmers owning on the average 3.3ha of land. The same report described that in urban areas where 75% of the farmers do not have access to land, dairying is the main agricultural activity. As reported by Yeshitila (2008), in Southern Ethiopia at Alaba district, the average land size owned by a farmer is about 2.5ha. The land and livestock holdings showed a direct linear relationship where farmers with large land holdings have higher number of large ruminant (cattle) holdings and when land holdings became smaller there is a trend of keeping more numbers of small ruminants than cattle.

2.6. Cattle Holding

Cattle ownership varies depending on the type of production system, wealth status and the overall farm production objectives. The average cattle herd size per household for smallholder farmers in the Highlands reported were 7.1 cattle in north west Shewa zones (Agajie *et al.*, 2002), 17.9 cattle around Debrebirhan (Ahmed, 2006) and 4 cattle at Akaki and Lemu, Central Ethiopia (Bayush *et al*., 2008). In the mixed crop livestock production system of Central Rift Valley around Ziway the average cattle herd size reported per household were 15.5 cattle (Lemma *et al.*, 2005) and 19.4 cattle (Zewdie, 2010). Dawit *et al*. (2013) revealed an average cattle size of 8.27 at Adami Tullu Jiddo

Kombolcha district in Oromiya Region and Yoseph *et al.* (2003) reported an average herd size of 26.5 in urban and peri-urban production systems.

2.7. Factors Influencing Dairy Production in Ethiopia

2.7.1. Cattle genotype

It was reported by Azage *et al*. (2013) that the number of crossbred cows is very low and is mainly concentrated in and around major urban and peri-urban centers. About 98.59% of the cattle population in Ethiopia are indigenous that are adapted to feed and water shortages, disease challenges and harsh climates (CSA, 2016). The use of AI has failed in many situations in developing countries because of lack of infrastructure and the costs involved, such as transportation and liquid nitrogen for storage of semen and because the breeding program has not been designed to be sustainable (Philipsson *et al*., 2011). Similarly, Minale and Yilkal (2015), in their study reported that the owner of the cattle had a problem of getting AI services through which they can upgrade the genetic makeup of their low producing dairy animals.

2.7.2. Knowledge of dairy cattle management

Level of management achievable in Ethiopia is unfavorable to higher exotic inheritance levels than 50%. Milk production, lactation length and calving interval decreased or remained constant in higher cross inheritance from 50% crossbred whereas gross country milk production increased (Addisu, 2013). Sintayehu *et al*. (2008) on their study reported that the major constraints for dairy development in the Southern Ethiopia included availability and costs of feeds, shortage of farm land, discouraging marketing systems, lack of improved dairy animals, poor extension and animal health services and knowledge gap on improved dairy production, processing and marketing. Report made by Minale and Yilkal (2015), in Southern Ethiopia at Chencha and Kucha districts also indicated that most of the owners of cattle having higher exotic blood levels than 50%, do not have awareness about the modern level of dairy cattle management in relation to feeding and housing, particularly of feeding which is attributed to high level of animal performances in terms of both growth rate and milk yield.

2.7.3. Market access

Market involves locations, sales, sellers, buyers and transactions (Debrah and Berhanu, 1991). Challenges and problems for dairying vary from one production system to another and/or from one location to another. The structure and performance of dairying and its products marketing both for domestic consumption and export is generally perceived poor in Ethiopia. Lack of market oriented production and inadequate market information (internal and external), lack of adequate information on livestock resources, inadequate permanent trade routes and other facilities like feeds, water, holding grounds, lack or non-provision of transport, ineffectiveness and inadequate infrastructural and institutional set ups, prevalence of diseases and illegal trade are generally mentioned as some of the major reasons for the poor performance of this sector (Belachew and Jemberu, 2003). The primary selling outlet of milk is direct sell to consumers and price of dairy commodities are determined by different factors such as season, access to market from towns, fasting and non-fasting days, festivals/holidays, level of supply to purchasing ability of the urban dwellers, quality and sources of dairy products (Sintayehu *et al*., 2008 and Zewdie, 2010).

2.7.4. Feed resources

The primary constraints to increased milk production under all dairy production systems are inadequate feed resources, poor pasture development and the ever increasing feed prices. Farmers tend to keep cattle at stocking rates that far exceed the carrying capacity of their grazing lands. This has resulted in degraded pastures and eroded soils. Stock numbers are not normally reduced in the dry season leading to grazing lands becoming progressively overgrazed. In the dominating crop/livestock production system, producers supplement their dairy cows with crop residues and farm by-products from their farms. In some cases, during the dry season, these feedstuffs can be the only feeds available to the animals. Moreover, the improvement of the utilization of these feedstuffs through physical and/or chemical processing methods to increase the availability of nutrients is only practiced on a limited number of farms (Minale and Yilkal, 2015).

Feed availability and quality, especially during the dry season is an important constraint in dairy production development enterprise and it determines to a large extent the production performance of the dairy subsector in Ethiopia. In most cases, it can be confirmed that the development potential of dairy production is negatively influenced by the persistent shortage of fodder in most of the dairy producing areas. *Teff*, wheat, barley and oat straws are important feed resources in areas where they are produced and supplementation is commonly restricted to work-oxen and lactating cows. The major roughage feed resources for dairy animals across different production systems included natural grasslands, crop residues, non-conventional feed resources (e.g. leaf and stem of *enset*, banana and sugarcane, crop thinning) and crop aftermath (with the exception of urban dairy producers). The contribution of these feed resources, however, depends up on the agroecology, the types of crop produced, accessibility and production system (Azage *et al*., 2013).

The production of improved pasture and forages is insignificant and the contribution of agro industrial by products is also minimal and restricted to some urban and peri urban farms (Alemayehu, 2005). The cattle are fed almost entirely on natural pasture, fallow land, crop residues and crop aftermath (Alemayehu, 2004). Feed, usually based on fodder and grass, are either not available in sufficient quantities due to fluctuating weather conditions or when available are of poor nutritional quality. These constraints result in low milk yields, high mortality of young stock, longer parturition intervals, and low animal weights (McIntire *et al*., 1992)

2.8. Nutrient Requirement of Cattle

Cattle require nutrients for maintenance, growth, production and reproduction. Nutrients required for these functions are expressed in terms of energy, protein, minerals (particularly calcium and phosphorous) and vitamins. Energy, protein, and digestibility of feeds are central in determining nutritional adequacy and feeding levels for different classes of stock (Streeter, 2006). Energy is usually the most important feed component needed to produce milk. The energy needed depends on the composition of the milk (fat and protein content). The value of feed is clearly related to the amount of energy it can supply, since energy is usually the chief limiting nutrient in milk production.

According to McDonald *et al.* (1988), energy requirement of cattle is most commonly expressed in the simplest way possibly as the absolute quantities of energy gained or lost by animals. Energy for maintenance can be defined as the amount of feed energy required for essential metabolic processes and physical activities, which results in no net loss or gain from or to the tissues of the animal (NRC, 1996). Demand for energy depends on breed, live weight, sex and physiological state (pregnancy, lactation) of the cattle (Church and Pond, 1982). The amount of feed needed to meet maintenance requirements will vary with the type and quality of feed available (McDonald *et al.*, 1988). Proteins are the main constituents of an animal body and are continuously needed in the feedstuff. The protein content of herbage falls with the phosphorous so that protein deficiency and frequently also a deficiency of available energy, are worsening factors in the malnutrition of dairy animal in phosphorous deficient areas (Eric, 1981).

Calcium (Ca) and phosphorus (P) are closely correlated for building the skeletal structure. Approximately 90% of the calcium and 70% of the phosphorus can be found in skeleton and teeth. Phosphorus in addition to its function in bone building, is required in the utilization of energy and in the cell structure. They are also the ones most often added to ruminant diets. Animals usually require 1.5 parts of Ca for every part of P. Phosphorous deficiency can be regarded as the most prevalent and serious mineral limitation to cattle production (McDowell, 1985). However, to meet the dietary requirements of cattle, P supplementation should be seriously considered. The dietary P concentration needed to meet dietary requirements varies widely with feed intake, breed, body weight, growth rate and physiological state (Chantiratikul *et al.*, 2009). Kearl (1982) recommended P requirements for tropical beef cattle ranging from 1.7-3.5g/kg feed. Assessment on the quantity and quality of available feed resources in relation with livestock requirement has not been yet well addressed in most livestock production areas.

2.9. Measurements of Reproductive and Productive Performance of a Cow

Reproductive performance of a cow is measured by several traits such as age at first service, age at first calving, calving interval, days open and number of services per conception (Dematawewa and Berger, 1998). On the other hand, productive performance of cow is measured by daily and lactation milk yield. However, both productive and reproductive performances are influenced more by genotype and environmental factors such as nutrition, management and climate.

2.9.1. Age at first service

It is the age at which heifers attain body weight, body condition and sexual maturity for accepting service for the first time. It is the period between birth and first conception. It influences both productive as well as reproductive life of female cow directly through its effect on her life time calf crop, milk production and indirectly through its influence on the cost invested for upbringing. It is influenced by genotype, nutrition and other environmental factors. Age at first service reported in Ethiopia include about 53 months for highland Zebu (Mukassa-Mugrewa *et al.*, 1991), 55 months for Horro cattle (Mulugeta *et al.*, 1991) and 34.4 months for Ogaden cattle (Getinet, 2005).

2.9.2. Age at first calving

Age at first calving determines the beginning of the cow's productive life and influences her lifetime productivity (Ojango and Pollott, 2001). Age at first calving has a significant influence on the total cost of raising dairy replacements with older calving heifers being more expensive to raise than younger ones (Tozer and Heinrichs, 2001). Estimated age at first calving for Ethiopian cattle ranges from 35-62 months (Kiwuwa *et al.*, 1983). Mulugeta and Belayeneh (2013), on their research work reported that the overall estimated average age at first calving was found to be 40.9 months of which 47.16 months for local cows, and 37.95 months for cross bred cows. Similarly, Niraj *et al*., (2014) reported 39.4 months of estimated age at first caving for local cows under smallholder condition in Mekelle town.

There are different factors that delay age at first calving. The time taken by an animal to attain puberty and sexual maturity depends mainly on the quality and quantity of feed available, which affects growth rate and hence age at first calving. There has been substantial evidence that dietary supplementation of heifers during their growth will reduce the interval from birth to first calving, because heifers that grow faster will cycle earlier and exhibit behavioral estrus. Breed difference among cattle had also significant effect on age at first calving (Mukassa-Mugrewa, 1989; Mulugeta; Belayeneh, 2013).

2.9.3. Days open

An increase in the number of days between calving and conception (days open), which influences profitability of the dairy industry due to increased breeding cost, increased risk of culling and replacement costs and reduced milk production (De Varies and Risco, 2005). Days open affects lifetime production and generation interval and should not exceed 80 to 85 days, if a calving interval of 12 months is to be achieved. Nutritional deficiencies coupled with heavy internal and external parasite load under extensive management systems and allowing calves to suckle their dams may all interfere with ovarian function, thereby prolonging the days open (Hafez, 1993; Gebreegziabher *et al.*, 2005). Cows that are over conditioned at calving or those that lose excess body weight are more likely to have a prolonged interval to first estrus, which could result in longer days open (James, 2006). Niraj *et al*. (2014) reported the 185.82 days open (DO) for local cows under smallholder condition in Mekelle town.

2.9.4. Calving interval

Calving interval is a function of calving-to-conception interval or days open, which is considered to be the most important component in determining the length of calving interval and gestation length, which is more or less constant. Gestation length varies slightly due to breed, calf sex, calf size, dam age, year and month of calving (Mukassa-Mugrewa *et al*., 1991; Mulugeta and Belayeneh, 2013). Estimates of calving interval in zebu cattle ranged from 12.2 to 26.6 months (Mukassa-Mugrewa, 1989). The overall mean of calving interval for local and crossbred dairy cows in north Shewa zone of Amhara Region found to be 24.94 months for local cows and 22 months for crossbred cows which indicated that calving interval in crossbred cows was shorter than local cows (Mulugeta and Belayeneh, 2013). The report of Niraj *et al*., (2014), on the other hand, indicated a calving interval (CI) of 431.08 days (14.37 months) for local breed cows in Mekelle town under smallholder condition. Nutritional conditions that vary seasonally and yearly have major effects on calving interval. Increased calving interval is undesirable, particularly in a production system in which there is a high demand for pregnant or lactating heifer. This can occur when a higher yielding animal produces fewer replacements due to negative phenotypic correlation between calving interval and milk production (Hailemariam and Kassamersha, 1994).

2.9.5. Milk yield and lactation length

Milk production is affected by genetic and environmental factors. Among the environmental factors, the quantity and quality of available feed resources are the major ones. Inadequate level of nutrition has been found to be the most important factor in influencing length of post-partum anestrus in cows grazing tropical pasture lands (Topps and Oliver, 1993). According to a report by Tawah *et al*. (1995) lactation performance of pure breed Arsi and crosses with Friesian kept at Assela station in the Arsi region of Ethiopia was not affected by pre-partum supplementation with concentrate mixes, however, it was significantly and positively affected by postpartum concentrate supplementation. The estimated daily milk yield and lactation length for crossbred cows, respectively, include: 7.3kg/day/cow and 342 days for Holstein Friesian-Boran crosses in the Highlands of Ethiopia (Demeke *et al*. 2000), 8.9kg/day/cow and 296 days for crossbred cows in urban and peri-urban areas of Addis Ababa (Yoseph *et al.*, 2003), 7.8kg/day/cow and 336 days for crossbred cows in urban and peri-urban areas of northwestern highlands (Yitaye, 2008) and 4.73kg/day/cow and 334 days for crossbred dairy cows in north Shewa zone of Amhara Region (Mulugeta and Belayeneh, 2013).

On the other hand, the estimated daily milk yield and lactation length for local zebu cows, respectively, reported include: 1.0kg/day/cow and 285 days for Arsi zebu breed (Lemma *et al.*, 2005), 2.1kg/day/cow and 264 days for Sheko breed in Bench Maji zone (Stein *et al*., 2006), 2.2kg/day/cow and 249 days for Boran breed in Borana zone (Adugna and Aster, 2007), 1.2kg/day/cow and 219 days for local zebu breed at Meiso district (Kedija, 2007), 1.67kg/day/cow and 274 days for local zebu breed in Chacha town of north shewa zone of Amhara Region (Mulugeta and Belayeneh, 2013) and 1.88kg/day/cow and 247days for local zebu breed at Mekelle town of Tigray Region (Niraj *et al*., 2014).

In most dairy farms, a lactation length of 305 days is commonly accepted as a standard. However, such a standard lactation length might not work for smallholder dairy cows where the lactation length is extended considerably in most cases (Msangi *et al*., 2005). The profitability of short or extended lactation length depends on various factors, including the lactation length persistency. Borman *et al*. (2004), demonstrated that extended lactations are suitable for some dairy enterprises and that the suitability depends particularly on cow milk potential, the ability to grow pasture or feed supplements economically, management expertise, environmental constraints, herd size and labor availability. Meadows *et al*. (2005) on their study, however, reported that additional days in which cows are not pregnant beyond the optimal time of post calving are costly.

2.10. Importance of *Enset* for Sustainable Livelihoods

There are four different farming systems in Ethiopia namely: Pastoralism, crop-farming complex, shifting cultivation, and *Enset*-planting complex of the south and southwestern Ethiopia. Of these, the *enset* farming system is believed to be indigenous to Ethiopia and mainly practiced in the highlands of south and southwest parts of the country. Given the restricted geographic distribution of domesticated *enset*, the degree of complexity and variability in present-day *enset* agricultural systems, agronomists and bio geographers have long considered the Ethiopian highlands to be center of origin for the *enset* agriculture (Brandt *et al.*, 1997). Although evidence is lacking to locate the exact place of origin, Smeds (1955) speculated that the highlands along western edge of the Rift Valley, particularly the present Gurage, Wolayta, and Kembata regions, could be the original centers of *enset* cultivation. Anthropologists, archeologists, historians and other scholars have also developed theories and models that argue about the domestication of *enset* in Ethiopia to have begun as early as 10,000 years ago (Brandt *et al* , 1996). It has been estimated that production of *enset* crop contributes 20% of the national carbohydrate and is the staple food of 18% of the population of the country certainly in the Southern Region of Ethiopia (Shank and Entiro, 1996).

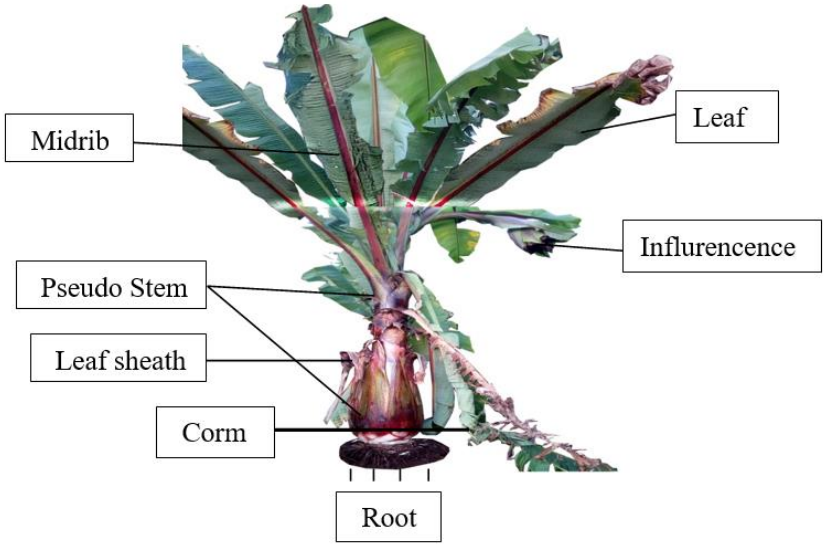
Within the *enset* agricultural systems, four major *enset* sub-systems have been recognized mainly based on the extent to which people depend upon the plant as staple crop (Westphal, 1975). One of such subsystem is where *enset* is the staple food and main crop (e.g., the Gurage and Sidama people). Another *enset* subsystem such as Gamo, Hadiya, Wolayta, and Ari people which depend upon *enset* as a co-staple crop with cereals and tuber crops. The Oromo farmers of southwestern Ethiopia exemplify the third *enset* subsystem where they rely upon cereals as the most important crops, with *enset* and root crops of secondary importance. In this subsystem, *enset* is grown largely for security reasons (e.g., if in case cereal crops fail) and eaten in the form of *kocho* and *Amicho*. The fourth *enset* subsystem is where root crops are of prime dietary importance, cereals are of secondary and *enset* is of minor importance. The Sheko in southwestern Ethiopia practice hoe based shifting cultivations, in which yams and taro are the most important crops, while *enset* and cereals are of minor importance (Westphal, 1975).

2.11. Morphology of *Enset* Crop

Enset is a banana like crop. Both *enset* and banana have an underground corm, a bundle of leaf sheaths that form the pseudo stem and large leaves. The leaves of *enset* are more erect, broad, and longer than those of banana. Banana plants normally form suckers or clusters of plants at the base but *enset* does not. The stem of *enset* has three parts. The upper-most portion is the pseudo stem, which is made of a system of tightly clasping leaf bases or leaf sheaths. Depending on the variety and agroecological condition of its cultivation, the pseudo stem height ranges from 2 to 5 m (Taye, 1984). Leaves are born on the pseudo stem almost from the same point and on short petioles and are about 5 meters long. The underground portion of the plant consists of a corm, which is 0.70 to 1.8 m long with a circumference of 1.5 to 2.5 meters at maturity. *Enset* has a fibrous rooting system that grows out from the corm.

2.12. Taxonomy of *Enset (E.ventricosum)* (Welw.) Cheesman

Enset belongs to the order Zingiberales, the family Musaceae and the genus *Ensete*. Banana and *enset* belong to the same family Musaceae but banana belongs to the genus Musa. Although further research still needs to be done on the taxonomy and distribution of *enset* species, existing data reveal that the genus *Ensete* contains about eight distinct species distributed over much of Asia and Africa (Baker and Simmonds, 1953). Among these, *enset (E. ventricosum)* (Welw.) Cheesman is generally adapted to moist areas through central and eastern Africa. Taye *et al*. (1967) reported that among the species occurring in tropical Africa, *E. ventricosum* is widely cultivated only in Ethiopia for food and fiber production. With considerable variations, farmers of the Gurage grow wide variety of *enset* clones. No enset garden was encountered with less than a clone composition of two in the study area. Without inclusion of synonyms, 73 locally recognized *enset* clones were recorded in surveyed localities of Gurage areas on farmers' farms. Each clone is perceived by the farmers of Gurage as distinct and is given a separate name (Fetta, 2007).



(Source: picture from own survey 2018)

Figure 1: Parts of Enset plant

2.13. Ecology of *Enset*

Domesticated *enset (E. ventricosum)* is cultivated at altitudes ranging from 1,500 to 3,100 meters above sea level (masl). However, it grows best at elevations between 2,000 and 2,750 masl. Most *enset* growing areas receive annual rainfall of about 1,100 to 1,500 millimeters (Westphal, 1975). The range of temperature in *enset* growing areas is between 10^{O}C and 21^{O}C (Asnaketch, 1997). Temperature plays a significant role in growth rate of *enset*. Accordingly, at altitudinal ranges of 1500-2300 meters (*Weinadega*/midaltitude) with annual temperature of 15-20^{O}C, *enset* grows fast and reaches full maturity in 5 to 7 years. On the other hand, in high altitudes of 2300-3100 meters (*Dega*/highland), where the temperature drops to 10-15^{O}C, it takes 8-10 years and sometimes up to 16 years (Tesfaye, 2005).

2.14. Economic Importance of *Enset*

2.14.1. *Enset* as a source of food

Enset plays a central role in the life of people found in *enset*-based cultivation systems of Gurage, Sidama, Gamo-Goffa, Hadiya, Wolayta, Ari people, south-western Oromiya and Sheko. It provides the main staple food which is potentially available throughout the year. *Enset* is a multipurpose crop. All parts of *enset* plant are economically important. The corm, the pseudo stem and the stalk of the inflorescence of *enset* are the most important sources of food. The most important characteristic feature of *enset* is its high productivity of food per unit area and its storability for longer periods without spoilage (Seifu, 1996). According to the Ethiopian Nutrition Institute (ENI, 1981), *enset* products are nutritionally rich in carbohydrates but low in proteins and fats.

The protein content of *enset* products are estimated to be 12g/kg of dry processed *enset* products as compared to 100g/kg of dry maize (ENI, 1981). Due to poor protein and fat content, *enset* food products are not consumed by their own, except during periods of extreme famine or by poor households who do not have the means to vary their diet (Pankhurst, 1996). *Enset* food is mostly consumed together with animal products such as milk, meat, cheese, yoghurt and other crops such as cabbage, beans, peas, etc. Because of these basic reasons, *enset* is always grown alongside with cattle and other crops. The *enset* production, thus, provides the opportunity and the need for diversification of agricultural production (Pankhurst, 1996).

2.14.2. *Enset* as feed source

Enset leaves are the major source of feed to the cattle. Due to the encroaching of crop land at the expense of the grazing lands the system is dependent on cut-and carry system for its cattle feed. During the dry season cattle are substantially dependent on parts of the *enset* not normally eaten by humans, particularly the leaf and the upper parts of the leaf sheaths/midribs (Dereje, 1996; Menbere, 2014). According to Bureau of Agriculture and Rural Development (BoARD, 2009) of SNNPR and (FAO, 1987), average feed dry matter produced from *enset* crop is 8 (eight) tons per hectare. The protein content and the total amount of protein are greater in the portion of *enset* not eaten by humans (Brandt *et al.*, 1997). By comparison, the stems and any remaining leaves of cereals and other tuber crops that are left for animal feed are usually of low protein value than the leaf and the upper parts of the leaf sheaths/midribs of *enset* used as cattle feeds. The recycling of all these products has important consequences for the human carrying capacity of the system. Chemical composition and the rumen degradability suggest that the *enset* leaf have a potential to be used as feed for cattle to an increasing extent (Dereje, 1996).

2.14.3. Role of *Enset* for environmental protection

Enset's perennial canopy of leaves and the abundant accumulation of litter reduce soil erosion and organic matter decomposition to a minimum and reduces run off. *Enset* production improves soils, many *enset* fields with adequate manure have been in continuous production for decades. *Enset* is also likely to affect the macro-environments of an area in a positive manner (Brandt *et al*., 1997). It has been commonly observed that species like *enset*, with deep roots and leaf canopies of long duration, improve the hydrological dynamics of an area. As the proportion of these *enset* species increases with respect to annual species, water infiltration increases and surface runoff decreases, resulting in more water in the soil and aquifers. The result is increased water availability and greater volume and duration of discharge to springs, decreasing the effective length of the dry season (Brandt *et al*., 1997).

2.14.4. *Enset* as industrial crop

In addition to food, cattle feed source and environmental protection, *enset* has many other uses. The fiber extracted during processing is used locally for making strings, ropes and other products. *Enset* fiber has an excellent structure and its strength is only next to Musa *textiles*, a world class fiber crop (Kefale and Sandford, 1994). Data on the fiber yield of *enset* are virtually lacking. Based on the limited data available, the estimated fiber yield could vary from 600-800kg/ha (Taye, 1984). Increased production of the fiber could lead to realization of cottage industries, if the present methods of processing and fiber extraction are improved.

2.14.5. *Enset* as medicinal plant

Particular landraces or clones of *enset* are also used medicinally for both humans and livestock to cure bone fracture, broken bones, child birth problems (i.e., assisting to discharge the placenta), diarrhea, birth control (abortifacient), to cure jaundice, back-ache and heart diseases (Worku, 1996).

2.14.6. Other uses of *enset*

Fresh *enset* leaves are used as bread and food wrappers, serving plates and pit liners to store *kocho* for fermentation and future use. During *enset* harvesting, *enset* leaves are also used to line the ground where processing takes place. Dried leaf sheaths are used as wrappers for butter, *kocho, bulla* and other items to transport to local markets. *Enset* also served as immediate money source and assets in the farming families. The dried petiole and midribs of *enset* are used as a source of fuel and used as construction materials instead of using nail for the construction of houses and fences. *Enset* plays a significant role in environmental beatification. However, current significant increases in human population, decreases in livestock population and manure production, reduced the yields of crop and soil fertility, thereby reducing the long-term sustainability of the *enset* system (Worku, 1996).

2.15. Cattle in *Enset* System

2.15.1. Importance of cattle in *enset* production systems

Regardless of elevation, ethnic groups or degree of dependence on *enset* in dietary intake, cattle play a critical role in *enset* system in maintaining soil fertility and agricultural sustainability. In low input farming systems like *enset*, production of *enset* is strongly dependent on the amount of cattle manure produced and of the amount and availability of nutrients therein. There is a prudent interaction between *enset* and cattle in *enset* farming areas particularly in the altitudes where *enset* serves as a source of fodder for cattle and cattle provide manure to fertilize *enset* fields. In this production system there is a shortage of grazing land as well as arable land, which in turn tends to limit the number of cattle (Risse *et al*., 2006). In the absence of cattle in this system, the sustainability of *enset* production definitely will be disadvantaged. Limiting the number of cattle per household also limits the availability of manure to fertilize the *enset* plant and decreases in cattle manure causes reductions in the long-term sustainability of *enset* systems (Maryo *et al*., 2014).

In *enset* farming system, cattle manure is the principal source of organic matter and nutrient input and is crucial for the productivity of the system. The use of inorganic fertilizers is limited for *enset* crop because of its high cost and limited availability. Thus, cattle manure is a locally available low cost substitute for the majority of resource poor farmers. Apart from its low cost and local availability, cattle manure is highly valued by farmers because of its multiple roles and long-term benefits. Besides meeting timely requirement of nutrients, manure is regarded essential for sustainable productivity of the *enset* system because of its importance in maintaining long-term soil productivity. Manure is an excellent source of plant nutrients such as nitrogen, phosphorus and potassium as well as the secondary nutrients that plants require (Risse *et al*., 2006).

In addition, manure application can have significant influence on physical, chemical, and biological properties of the soil. Most of the effects are due to an increase in soil organic matter resulting from application of cattle manure. Soil organic matter is known to affect a number of soil chemical properties such as the cation exchange capacity and the soil buffering capacity that enable manure treated soils to retain nutrients and other chemicals for longer periods of time (Risse *et al*., 2006). However, nowadays, because of significant increase in human population and decreases in cattle size, reduction in soil fertility is one of the major constraints of *enset* production. Farmers are unable to obtain the expected amount of yield out of the crop using traditional systems. Brandt *et al*. (1997) noted that because of low productivity and high rates of mortality, the cattle production in *enset* growing region is under significant stress due to severe constraints encountered to get adequate forage for cattle feeding. A decrease in the amount of land allocated for grazing per village and transformation of some common grazing land to crop production have contributed to this decline in forage resources. Among farmers in the *enset* growing region, important cattle uses do not appear to include slaughtering to provide meat for the household. However, the consumption of milk, butter, and cottage cheese seems to make an important and possibly critical contribution to an *enset*-based diet, which in itself is very low in protein (Shank and Entiro, 1996).

2.15.2. Yield of *enset* food

Among *enset* based foods, *kocho* pre-dominates other *enset* food products such as *bulla* in its quantity of production. Consequently, quantification of *enset* yield mostly considers the yield of *kocho*. At the same time the reports on the yield of *kocho* are variable. Yield of *enset* varies with the landraces used and with the agroclimate. According to the nationwide survey on *enset* production (CSA, 1998), the average yield of *kocho* and *bulla* per mature *enset* plant is 30.2kg and 1kg respectively. Taye (1984) reported a maximum yield of 11.90 tons of *kocho* per hectare per year. Admasu (2002) reported a maximum yield of 26.26 tons of *kocho* per hectare per year for plant spacing of 2.83m^2. Shank and Entiro (1996) reported a *kocho* yield of mature *enset* to vary from 19.7 to 84.6 kilograms per plant with the average of 44.2 kg at 50% moisture. In densely populated areas of southern Ethiopia, *enset* is regarded as a food security crop. The presence of *enset* in this farming system contributes significantly to the sustainability of food supply by several mechanisms. The primary strategic importance of *enset* in food security is that *enset* helps prevent famine by surviving drought when other food crops fail. Once *enset* plants are established in areas of sufficient rainfall, they are able to tolerate occasional years of very low rainfall or a short rainy season. Secondly, it gives higher yield per unit area than other crops and thus supporting the densely populated areas in the country (Brandt *et al*., 1997). Third, *enset* foods can be stored for long-term uses. The ability to store *kocho* and *bulla* for longer periods with little storage loss provides households with a mechanism to smooth consumption during food shortage periods. Fourth, *enset* plants can be harvested at any time and any stage of growth, allowing households to weather out period of food shortage. Despite all these desirable attributes, the *enset* farming system received very little research attention as compared to that given to cereal based system (Brandt *et al*., 1997). According to Kefale and Sandford (1994), *enset* yields 1.3 to 3.5 times much more food energy per hectare as compared to maize grown under similar management conditions. Thus, for households facing a shortage of land, the higher energy productivity of *enset* relative to cereals makes *enset* an important food security crop.

2.15.3. Management of cattle among *enset* growers

There are common themes in the management of cattle among the peoples who cultivate *enset*, although regional and ethnic differences occur. Differences in management practice may be found in the different agroecological zones: *dega* (highlands), *weinadega* (midaltitude) and *kola* (lowlands). There is also variation according to wealth category, with the wealthier households possessing more cattle and requiring greater access to additional labor and grazing lands (Brandt *et al*., 1997). The management of cattle involves both taking animals to pasture and bringing forage to animals. Following harvest, crop residues are given to the cattle and among all *enset* growing groups *enset* leaves form an integral part of the dry season cattle diet and they may be used for as long as seven to eight months or only for a couple of months at the height of the dry season, depending on area and ethnic group (Brandt *et al*., 1997).

2.16. Manure Utilization

Among the cattle population of Ethiopia, about 75% of cattle are believed to be found in the highlands while 25% are in the lowlands. These animals produce a large quantity of manure every day and each farm household uses woody biomass and dung for its household energy requirement, essential for cooking and heating. However, the use of woody biomass for fuel have led to deforestation and land degradation and the use of cattle manure for fuel has led to nutrient depletion in the soils (Mekonnen and Köhlin, 2008). In the highlands, where sedentary agriculture is practiced, most of manure produced is used as fuel especially in the central and northern part of the country and only a very small fraction is used as manure. Even where it is used as manure, its use is generally limited to small area of land around the homestead or nearby farms.

The use of chemical fertilizer in Ethiopia particularly in the northern half of the Ethiopian highlands is the lowest in Sub-Saharan Africa. And the use of cattle dung in these areas as manure is also limited partly because of a significant level of dung consumption as a source of household fuel (Mekonnen and Köhlin, 2008). Manure is not only supplying nutrients but also conditions the soil favorably as plant growth media, which decreases the bulk density, increases the available water holding capacity, improves soil structure (creates water stable soil aggregates), supplies essential macro and micro nutrients, increases the available P and the organic matter content thereby increasing the carbon content of the soils by as much as 67%. Manure also plays a vital role in improving crop yields and allowing sustainable productivity and has ability of changing soil microclimate condition and restoration of ecological balance (Tadesse *et al.*, 2013).

2.17. Threats to Sustainability of *Enset* Cultivation

There may be a decline in total cattle numbers in general and also there is a definite decline for individual households' ownership because of increasing population and limited land. This decline will have an impact on manure production and the availability of draught animals. It could also have an impact on human nutrition. The cycle of increasing impoverishment of the cattle component in this mixed crop/livestock system is a serious cause for concern (Brandt *et al.*, 1997). The multiple purposes of cattle manure cannot be replaced by fertilizers and the sustainability of the *enset* cultivation system is a result of the tight articulation of the enset/crop and cattle production systems. With an increasing population in an already densely populated area, it is likely that the negative trend in cattle populations will continue with potentially severe impacts on *enset* production (Brandt *et al.*, 1997).

3. MATERIALS AND METHODS

3.1. Study Area Description

The study area, Gurage Zone, is found in the Southern Nations, Nationalities and Peoples' Region (SNNPR) of Ethiopia. It is located between 37^{O} 28' and 38^{O} 38' longitude and 7^{O} 28' and 8^{O} 27' latitude, covering an area of about 5,932 km^2. Based on the data from Gurage Zone Department of Finance and Economic Development (DOFED, 2015), the Zone has 13 administrative *Woredas* with 412 peasant associations (PAs) and 2 town administrations. The Zone borders with Oromiya Region in the north, northeast and northwest, Silti Zone in the southeast, Hadiya Zone in the south and Yem Special *Woreda* in the southwest. Wolkite, the capital of the Zone, is 155 km away from Addis Ababa in the Addis-Jimma road (DOFED, 2015).

Human population size of the Zone is estimated to be 1,624,125 (51.4% women and 48.6%, men) and 88.2 % of the population are farmers entirely dependent on subsistent agriculture (CSA, 2013; DOFED, 2015). Gurage Zone is one of the most densely populated areas in the country, with an average of 273.5 people/km^2 mainly concentrated in *dega* (highland) and *weinadega* agroecologies. Agroecological zones of the area include 4.1% (*Wirch*-extreme cold), 27.5% (*dega*), 65.3% *(weinadega)* and 3.1% (*Kola*-hot) climate. Average annual rainfall of the area is 1100.5mm that ranges between 801mm and 1400 mm (DOFED, 2015).

Based on the report of Department of Agriculture and Natural Resource Development (DANRD, 2016) of Gurage Zone, three distinct zonations of farming system are identified: First zonation includes areas with an altitude of above 2200 masl and growing mainly *Enset (E. ventricosum*), Barely (*Hordeum vulgare*), Field pea (*Pisum sativum*) and Fababean (*Phaseolus vulgaris*) (DANRD, 2016). The second zonation comprises an altitudinal range of 1800 to 2200 masl and growing major crops of *Enset (E. ventricosum*), *Teff* (*Eragrostis teff*), Maize (*Zia mays*) and Khat *(Catha edulis)*. The third zonation lays between the altitudinal range of 1600 to 1800 masl growing major crops of

Teff (*Eragrostis teff*) and Maize (*Zia mays*). The average annual temperature of the Zone is about 18^{O}C. The current land use pattern of the Zone indicates that 398,887 hectare of land allotted for crop production, 92,421 hectare for grazing, 42,933 hectare for forest, 17,168 hectare degraded land and 41,791 hectare of land for other social services giving institutions. The total livestock population is estimated at 3, 611,159 heads and composed of 1,678,455 cattle, 616,900 sheep, 260,420 goats, 820,269 chickens, 128,532 horses, 9,464 mules as well as 97,119 donkeys (DOFED, 2015).

The study was conducted in four woreda of Gurage zone in southern Ethiopia, namely *Ezia*, *Muhi*r and *Akli*l, *Cheha* and *Enemor* and *Aner (Fig.2)*.

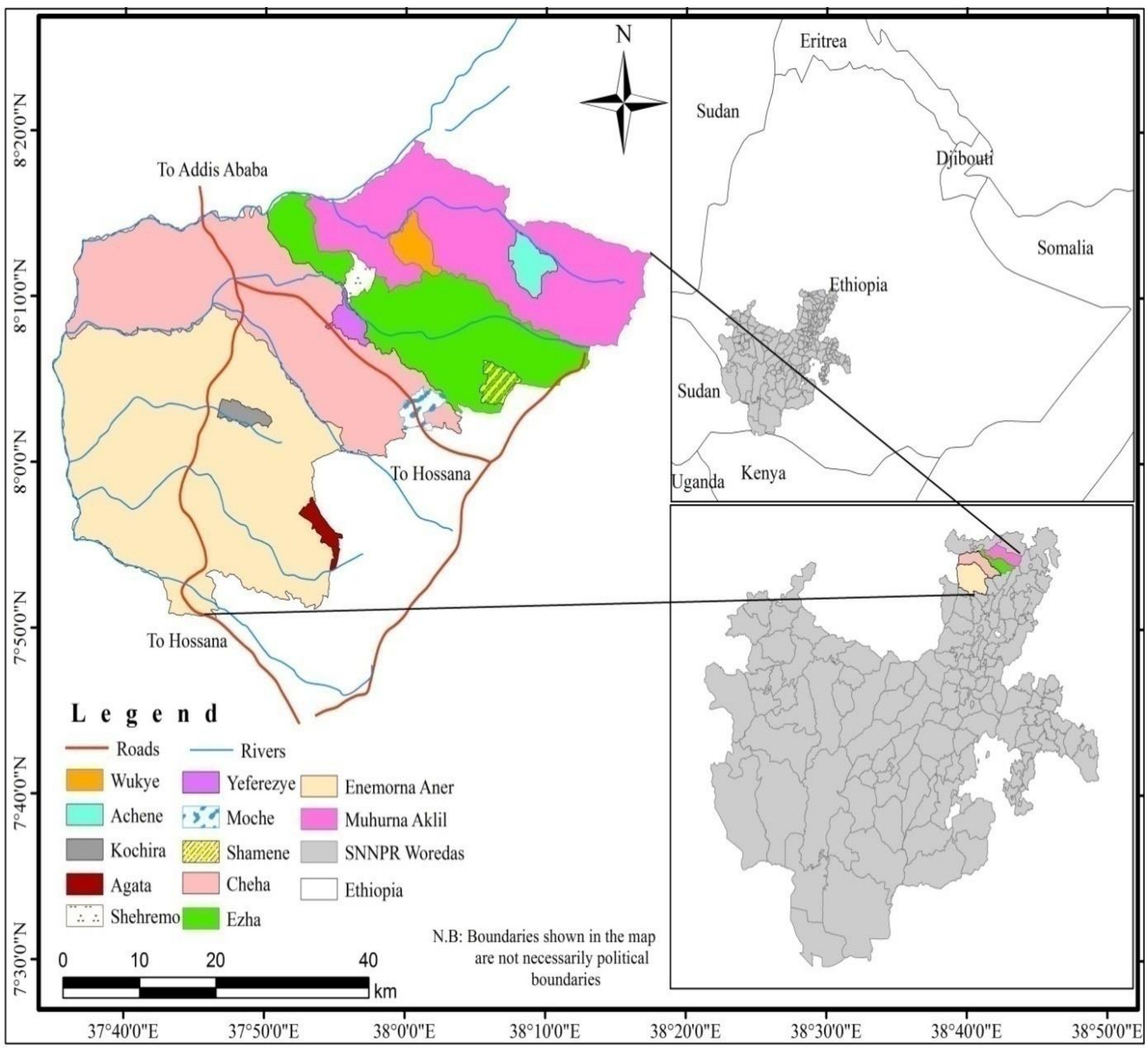


Figure 2: Location map of the study area of Gurage zone

Study Woredas were selected based on the number of cattle, *enset* production intensity, land ownership and accessibility which are described as follows:

Ezia woreda is located at 197km southwest of Addis Ababa (155km through Addis Ababa–Jimma asphalt road and 42km towards the southeast direction on Wolkite – Butajira asphalt road).The administrative town of *Ezia* woreda is *Agena*. The *woreda* is located at an elevation of between 1850 and 3100 meter above sea level. The *woreda* comprises of 30 PAs with a total area of about 59,091ha of land and out of which 31,517ha for crop production (9,554 ha annual and 21,963ha perennial crop production), 6,726ha grazing land, 7,903ha forest land, 2,200ha degraded land and the remaining 3,061ha of land is occupied by churches, mosques and other social services giving institutions. The Woreda has an estimated total human population of 106,667 of which 50,593 are males and 56,074 are females (DOFED, 2015). The bimodal annual rainfall is the characteristics of the *woreda* covering from March to April and June to September. The annual average rainfall is 1,200.5mm ranging from 1,001mm to 1,400 mm. The mean annual temperature is 15.05^{O}C and it ranges from 10.1^{O}C to 20^{O}C (DANRD, 2016). *Ezia woreda* has a livestock population of 257,616, of which 97,338 cattle, 56,670 sheep, 14,267 goats, 71,165 chickens, 11,426 horses, 850 mules and 5,900 donkeys (DOFED, 2015). Agroecological zones of the *woreda* are *dega* and *weinadega*. Farmers in the area practice mixed crop-livestock farming. Major crops grown in the *woreda* are *Enset*, barley, *teff*, maize, wheat, field pea, khat, faba bean and vegetables, (DANRD, 2016).

Muhir and Aklil woreda is located at 207km southwest of Addis Ababa (155km through Addis Ababa-Jimma asphalt road and 52km towards the southeast on Wolkite–Bozebar gravel road). Hawariyat is the administrative town of the *woreda*. *Muhir and Aklil woreda* is situated at an elevation of between 1,950 and 3200 meter above sea level. The *woreda* comprises of 30 PAs with a total area of about 50,273 hectares of land and out of which 33,867 for crop production (11,606ha annual and 22,261 ha perennial crop production), 6,488ha grazing land, 4,388ha forest land, 2,320ha degraded land and the remaining 3,210ha of land is occupied by churches, mosques and other social services giving institutions. The *Woreda* has an estimated total human population of 109, 602 of which 51,247 are males and 58,355 are females (DOFED, 2015). It has a bimodal annual rainfall covering from March to April and June to September with the annual average rain fall of 1,200.5mm that ranges from 1,001 mm to 1,400 mm. The mean annual temperature is 15.05^{O}C and ranging from 10.1^{O}C to 20^{O}C (DANRD, 2016). A livestock population of 204,625 is found in *Muhir and Aklil woreda* and is composed of 89,329 cattle, 32,281 sheep, 12,899 goats, 61,136 chickens, 4,414 horses, 699 mules and 3,867 donkeys (DOFED, 2015). The two agroecological zones found in the *woreda* are *dega* and *weinadega*. Farmers in the *woreda* practice mixed crop-livestock farming. Major crops grown in the woreda are *enset*, barley, wheat, khat, field pea, faba bean, *teff*, maize and vegetables (DANRD, 2016).

Cheha woreda is located at 185km from Addis Ababa (155km through Addis Ababa-Jimma asphalt road and 30km towards the southeast on Wolkite-Hosanna asphalt road). *Emdibir* is the capital of *Cheha woreda*. *Cheha woreda* is found between 1750 and 2500 masl. The *woreda* comprises of 41 PAs with a total area of about 44,450 hectares. Out of which 26,399ha for crop production (10,582ha annual and 15,817ha perennial crop land), 6,496ha grazing land, 6,160ha forest land, 2,504ha degraded land and the remaining 2,891ha of land is occupied by churches, mosques and other social services giving institutions. The *Woreda* has an estimated total human population of 129,682 of which 63,377 are males and 66,305 are females (DOFED, 2015). The *woreda* has a bimodal annual rainfall covering from March to April and June to September. The annual mean rain fall is 1,100.5mm and it ranges from 801mm to 1,400mm. The mean annual temperature is 18.8°C and with the range of 17.6^{O}C to 20^{O}C (DANRD, 2016). A livestock population of 205,778 are found in *Cheha woreda* and of which 129,741 cattle, 14,300 sheep, 10,834 goats, 48,189 chickens, 1,383 horses, 508 mules and 823 donkeys (DOFED, 2015). *Dega* and *weinadega* are the two agroecological zones found in the woreda. The farming system of *Cheha woreda* is a crop-livestock mixed farming system where crop and livestock subsystems are largely interdependent to each other. Major crops grown in the *woreda* are *enset*, khat, *teff*, maize, barley, coffee, wheat, field pea, fababean and vegetables (DANRD, 2016).

Enemor and Aner woreda is located at 197km southwest of Addis Ababa (155km through Addis Ababa –Jimma asphalt road and 42km towards the south on Wolkite –Hosanna gravel road). *Gunchre* is the administrative town of the *woreda*. *Enemor and Aner Woreda* is situated at an elevation of between 1700 and 2800 masl. The *woreda* has comprised of 71 PAs of lowest administrative units with a total area of 107,584 hectares of land and of which 53,018ha for crop production (11,770ha annual and 41,248ha perennial crop), 8,615ha grazing land, 12,088ha forest land, 9,972ha degraded land and the remaining 23,892ha of land is occupied by churches, mosques and other social services giving institutions. The *Woreda* has an estimated total human population of 210, 617; of which 99,546 are males and 111,070 are females (DOFED, 2015). The *woreda* has a two seasonal annual rainfall covering from March to April and June to September. The annual mean rainfall is 1,100.5mm and it ranges from 801 mm to 1,400 mm. The mean annual temperature is 18.8^{O}C that ranges from 12.6^{O}C to 25^{O}C (DANRD, 2016). Livestock populations of 616,196 are found in *Enemor* and *Aner woreda* and of which 305,629 cattle, 31,803 sheep, 42,349 goats, 197,868 chickens, 27,579 horses, 3,124 mules and 7,844 donkeys (DOFED, 2015). The two agroecological zones found in the *woreda* are *dega* and *weinadega*. Farmers in the area practice mixed crop-livestock farming and major crops grown in the *woreda* are *enset*, barley, khat, coffee, *teff*, wheat, maize, field pea, fababean and vegetables (DANRD, 2016).

3.2. Methods of Sampling and Data Collection

Data on nature of PAs in relation to cattle population and *enset* (*E. ventricosum*) production was collected from four *woreda*. Peasant associations were identified after having *enset* and cattle population data at each PA and a total of (8) PAs and (2) PAs from each *woreda* **(**one *dega* and one *weinadega***)** were purposively selected based on the number of cattle, *enset* production intensity and accessibility. The household (HH) sample size were determined using Cochran (1909) and Thrustfield (2013) sample size determination formula of $n = Z^2*P(1-P)/e^2$; n adjusted = $n/[1+((n-1)/N)]$; where: n = sample size in the population, Z-score = 1.96 for confidence level 95%, N = total HHs in 4 study districts (4192), P = proportion of population score of 1 = 0.5, 1-P = 0.5 and e =

standard error of the proportion = α = 0.05. A total of three hundred sixty (360) HHs from eight PAs (45 HHs in each PA) were selected from four districts of *Ezia, Muhir* and *Aklil, Cheha* and *Enemor* and *Aner*. The selected PAs from *dega* and *weinadega* from each *woreda*, respectively, were *Shamene* and *Shehrem*o from *Ezia*; *Achene* and *Wukiye* from *Muhir* and *Aklil*; *Moche* and *Yeferezy*e from *Cheha* as well as *Agata* and *Kochira* from *Enemor* and *Aner*. The HHs selected from each *woreda* and PA were grouped in three wealth categories depending on the number of cattle that each HH has owned (wealthy with cattle size of ≥ 6, medium with cattle size of 4 and 5 and poor with cattle size of between 1 and 3) that was determined based on group discussion made by HHs, researcher, experts and development agents (DAs).

Information was gathered from a total of purposively selected 40 HHs (5HHs/PA) through rapid field survey and consultations with experts from zonal and respective district offices to design the questionnaire used in the study. It was summarized and used as basis to design structured questionnaires to quantify the most important information to study. The survey questionnaires were also pre-tested with two HHs from each PA and the necessary adjustment was made and translated in to local (Amharic) language prior to actual survey based on the pre-test. One day training was organized for enumerators on how to administer the questionnaire. Interview was done by the researcher together with the enumerators and DAs of target PAs. The questionnaire interview, participatory group discussion and personal observation was applied to collect data on characteristics and management practices of the *enset* based smallholder dairy production systems and associated production constraints at 4 *dega* PAs of *Shamene, Achene, Moche* and *Agata* as well as at 4 *weinadega* PAs of *Shehrem*o, *Wukiye, Yeferezy*e and *Kochira*.

The interviews was done at the farmer's home to make possible counterchecking of the respondent's response with respect to household demography, level of education, land holding and land use pattern, herd size and herd composition, livestock feeding system, major annual crops produced, types and quantity of available livestock feed, *enset* production and its use, interaction of cattle and *enset* production, the level of food security within the HH, gender related activities in dairy production, uses of cattle manure, livestock housing, purpose of dairy cattle production, mating systems of cattle , sources of water for livestock , measures of productive and reproductive performance of dairy cattle, daily milk yield, methods of milking, methods of butter making, market places for cattle and milk products, market prices of cattle and milk products, available livestock health services, diseases prevalence and associated problems as well as the overall farming management practices of the HH.

A group discussion was organized along with experts and purposively selected elder farmers who had long experience and knowledge on livestock raising, *enset* production and manure uses so as to collect qualitative data to be used in prioritizing production constraints together with collected data using survey questionnaires.The group members participated in the discussion was comprised of elder farmers, experts of livestock and crop agriculture and DAs to clarify issues not well addressed through survey and to validate some information collected from individual interview. A total of 5 group discussions comprised of 44 individuals, 9 from each *Woreda* (5 farmers, 2 experts and 2 DAs) and 8 experts from Zone Offices (6 from livestock and 2 from crop agriculture) were participated in the group discussion. A checklist of different topics for focus group discussion was prepared and presented for participants and data was recorded for each topic. Topics of focus group discussion were focused on situation of dairy cattle production, major annual crops grown in the area, major constraints of cattle and dairy production, available feed resources, status of *enset* production and interdependence of *enset* with cattle production, extension services delivery, AI services, major diseases of livestock and bottlenecks associated with livestock health care services of the study area. Data was collected from December 2016 to November 2017 from individual HH interview, group discussions and personal communications. The HH was taken as unit of analysis.

3.3. Feed Quantity Assessment

The quantity of feed dry matter obtainable from natural pastures was determined by multiplying the hectare under each land use category by their respective estimated annual

DM yield per hectare i.e. 2.0tons/ha (FAO, 1984, 1987).The quantity of available crop residues dry matter output produced by farmers was estimated by conversion of grain yields to straw ratio using multipliers. Multiplier of 1.5 was used for wheat, barley and *teff* straws. Consequently, a multiplier of 1.2 was used for dry mater yield of field pea and faba bean straw as suggested by FAO (1987). The grazing potential of crop stubbles was estimated using a mean of 0.5 tons/ha of land as reported by FAO (1987). For estimation of DM output from maize stover, a multiplier of 2.0 was employed as proposed by De Leeuw *et al*. (1990). The quantity of potentially available crop residues for animal consumption was estimated by assuming 10% wastage either during utilization or used for other purposes or both (Adugna and Said, 1994). The quantity of potentially available dry matter from *enset* leaf and leaf midribs used for animal consumption was estimated by assuming a mean of 8.0tons/ha of *enset* garden as reported by FAO (1987) and BoARD (2009) of SNNPR. The amount of grain yield obtained from the respective crops was quantified by interviewing the farmers and cross checked with the data recorded by development workers and the respective offices of agriculture and natural resource development for any deviation. The assessment of potentially available crop residues was taken from December 2016 to March 2017 when almost 100% of annual crops had fully been harvested.

3.4. Estimation of Natural Pasture Yield

To determine the potential forage biomass yield and dry matter production, representative samples of grass and herbaceous vegetation were taken from seasonally (June to September) enclosed natural pasture land (locally known as Kurkur) of individual holding on the studied PAs. Forty households (20 HHs from each agroecology and 5 HHs per PA) having an enclosure of natural pasture land were randomly selected to collect the sample pasture species. Representative samples of grass, legumes and forbs were taken by making transect lines. Palatable pasture species in natural vegetation were identified together with herders and a Range Expert (Ahmed, 2006). Samples were taken from mid of August, 2017 to mid of September, 2017 when almost all the pasture plants were grown to their 50% flowering stage. From randomly selected HHs, a sample size of 80 (eighty) quadrant (1m x 1m) were considered per agroecology (5 HHs per PA and 4 sample quadrants per HH). In each quadrant (1m x 1m), harvesting was done at about 2.5cm above the ground level (Solomon, 2007). The samples were weighed immediately after cutting and transferred into plastic bags and fastened at the top.

The samples were kept in cool area until sampling for the day was completed. Immediately after completion of sample collection of the day, a composite sample of 5kg from each PA was taken and transported to Wolkite Regional Soil Analysis Laboratory and then each sample was sorted out into different species of grasses, legumes and forbs by hand. The composite samples taken from PAs of the same agroecology were mixed and dried separately using clean polyethylene plastic sheet under shade.

Sub samples were measured using sensitive balance with 1gram sensitivity and put into a paper bag having pores on the upper side of the paper bag purposively made to allow moisture evacuation from oven dried sample that was properly labeled. The paper bags with the plant material inside were oven dried at Wolkite Regional Soil Analysis Laboratory at 60^{O}C for 72 hours for DM determination. Based on the DM weights obtained, percent composition of each species of grass, legume and other herbaceous plants (forbs) was calculated and summarized to get the value for each plant species following the methods of Van Soest (1982). The same feed samples that were dried in an oven at 60^{O}C for 72 hrs were thoroughly mixed and ground to pass through 1mm sieve at Wolkite Regional Soil Analysis Laboratory and packed in an airtight clean plastic bag and stored until required for analysis.

3.5. Assessment of Livestock Feed Requirement

The total annual available feed was compared with the annual requirements of the livestock population. Livestock populations were converted in to Tropical Livestock Unit (TLU) as suggested by Gryseels (1988a) and Bekele (1991). Nutrients supplied by each feed types were estimated from the total DM output and nutrient contents of that feed on DM basis (Abdinasir, 2000). The total nutrient requirements of crude protein (CP) and metabolizable energy (ME) per day per TLU were estimated based on recommendations of Kearl (1982) and McCarthy (1986) for one tropical livestock unit of 250 kg LW.

3.6. Processing of Fresh Leaf and Leaf Midribs of *Enset (E. ventricosum)*

Fresh *enset* leaf and leaf midrib of about 72 kg (36 kg from each agroecology; 9 kg from each PA, 3 kg from each wealthy, medium and poor HHs) was randomly collected from randomly selected 24 HHs of total sample HHs. The collected sample *enset* leaf and leaf midrib was cut into slices using cultural *enset* leaf and midrib slicing knife and it was mixed per agroecology and dried separately under shade using new and clean polyethylene plastic sheet.

The drying process was carried out by thinly spreading of sliced *enset* leaf and leaf midribs on the polyethylene plastic sheet. The sliced *enset* leaf and leaf midribs was turned and mixed up several times a day to ensure uniform drying. At the end of drying process, representative samples from each agroecology were taken and dried in an oven at 60°C for 72hrs to determine dry matter contents at Wolkite Regional Soil Analysis Laboratory. The samples of the sliced leaf and leaf midribs of *enset* dried in such a way was ground in a laboratory mill lifted with 1 mm sieve screen at Wolkite Regional Soil Analysis Laboratory and packed in an airtight clean plastic bag and stored until required for analysis.

3.7. Chemical Analysis of Feed Samples

Representative samples of feed resources of leaf and leaf midribs of *enset*, crop residues (stover, straws and stubbles) and natural pasture from *dega* and *weinadega* agroecologies were collected, bulked, dried, sub-sampled and ground to pass through 1mm mesh sieve and packed in an airtight clean plastic bag and stored until required for determination of dry matter (DM), Ash, organic matter (OM), nitrogen (N), neutral detergent fiber (NDF), acid detergent fiber (ADF), acid detergent lignin (ADL) and *in vitro* dry matter digestibility (IVDMD). Sub samples from partially dried sample feeds were taken and ignited in a muffle furnace at $550^{o}{}_{C}$ for 6 hours to determine the Ash and OM contents of each feed following the methods described by AOAC (1990). Analysis of each feed for Ca and P were performed by atomic absorption spectrophotometer following the methods described by Perkin (1982) at Wolkite Regional Soil Analysis Laboratory.

Determination of IVDMD of feed samples was performed at Holetta Agricultural Research Center's Animal Nutrition Laboratory following the modified Tilley and Terry method (Van Soest and Robertson, 1985). A chemical analysis on ADF, ADL and NDF in the sample feeds were performed at Animal Nutrition Laboratory of College of Agriculture and Veterinary Medicine of Jimma University, following the procedures of Goering and Van Soest (1970). Similarly, N content of feed samples was determined at Animal Nutrition Laboratory of College of Agriculture and Veterinary Medicine of Jimma University using Kjeldahl method and crude protein (CP) was calculated as N*6.25 (AOAC, 1995).

Metabolizable Energy (ME) and Digestible Crude Protein (DCP) contents of a particular feed were estimated from IVDMD and CP contents, respectively, as per the following equations: ME (MJ/kg DM) = 0.015*IVDMD (g/kg) (MAFF, 1984).
DCP (g) = 0.929*CP (g/kg) -3.48g (Church and Pond, 1982).

3.8. Milking, Milk Processing and Milk Utilization

Milking, milk churning, milk and milk products utilization data were collected from each PA during survey at household's home through interview, at market places and using some records from respective offices. Data on milk production were collected using milk yield collecting format specially designed to collect milk produced by each HH in three phases (BoARD, 2009). Each phase comprised of one month and three milking days of 1^{st}, 16^{th} and 30^{th} of, January, May and September of the year 2017. Collection of milk data was done by the literate family members together with the development workers of the PA with close assistance of the researcher. The average of collected milk data was taken to carry out the analysis of milk production performance.

3.9. Milk Products and Cattle Market Price Assessment

Milk products and cattle market price data were collected from each study PA at the time of the survey (dry season, short rainy season and long rainy season) from market, through interviewing the farmer and using some records from Agriculture and Natural Resource Development Offices.

3.10. Assessment of Cattle Manure Production and Use in *Enset* Production

Cattle manure produced and percentage of manure utilized by HHs for different purposes in the study area was assessed in each study PA during the survey at HH's home using survey questioner. The data on the use of manure in relation to *enset* production was also collected through interviewing the HH.

3.11. Drying Process and Chemical Analysis of Cattle Manure Samples

Cattle manure used for chemical analysis was obtained from 24 randomly selected HHs (12 HHs per agroecology and 3HHs of different wealth groups per PA) in the study areas of Gurage zone. Fresh manure samples of 3kg from overnight dropping were collected from each selected HH using plastic bag. The drying process was carried out by thinly spreading of cattle manure on the polyethylene plastic sheet separately based on respective agroecology under shade. The cattle manure was turned and mixed up several times a day to break large particles formed and to ensure uniform drying. At the end of drying process, representative samples from each agroecology were taken. The air-dried cattle manure was ground in a laboratory to pass 2mm mesh based on Abassi *et al.* (2007) at Wolkite Regional Soil Analysis Laboratory and packed in an airtight clean plastic bag and stored until required for analysis.

Some selected properties of manure such as organic carbon, total nitrogen, phosphorus and potassium were determined following standard procedures. Organic carbon was determined using the Walkley-Black rapid titration method (Nelson and Summers, 1982) and calculated as:

$$\%\text{Organic carbon} = N \times \frac{V1-V2}{S} \times 0.39 \times mcf$$

Where:

N = normality of ferrous sulfate solution (from blank titration)

V1= ml of ferrous sulfate solution used for blank

V2 = ml of ferrous sulfate solution used for sample

S = weight of air-dried manure sample in gram

0.39 = $3x10^{-3}x100x1.3$ (3 = equivalent weight of carbon)

mcf = moisture correction factor.

The percent organic matter in cattle manure was calculated by multiplying the percent organic carbon by an empirical factor of (100/58) or 1.724 (Organic matter % = 1.724 x % Organic carbon), following the standard practice that organic matter conventionally assumed to contain 100/58 X % organic carbon (Nelson and Summers, 1982). Total nitrogen was analyzed by Kjeldahl method (Yerima, 1992). Accordingly, the phosphorous (P) and potash (K) contents of manure were determined by atomic absorption spectrophotometer (Perkin, 1982).

3.12. Role of Cattle in HH Food Security in Relation to *Enset* Production

Data on the role of cattle in food security of the farming families of the study areas in relation to *enset* production was collected through interview of HHs and using some records from Agriculture and Natural Resource Development Offices. Moreover, data were also gathered through group discussion conducted with farmers of cattle owners and *enset* producers, experts and DAs.

3.13. Methods of data analysis

The collected data were analyzed in such a way that they meet research objectives and answer research questions. The study involved both qualitative and quantitative data analysis techniques. Information generated from sample HHs interview, group discussion and personal observation were discussed and narrated qualitatively. Statistical package for social sciences version 20 (SPSS, 2012) was used for the analysis of collected data after checking, correcting and coding. Descriptive statistics such as table, figures or charts, percentage, mean, standard error and standard deviation was used to present the results. The HH was taken as unit of analysis.

To test association between cattle and *enset*, chi-square test of association was employed. It was used to test the association between dependent variable and independent variables and used to test either there was significant/systemic association between variables or not (Montgomery, 2001).

$$X^2_{cal} = \frac{\sum_{i=1}^{r}\sum_{j=1}^{c}(O_{ij}-E_{ij})^2}{E_{ij}} \quad (i = 1, 2.....r, j = 1, 2, 3...c)$$

Where;

X^2_{tab} = tabulated value X^2, X^2_{cal} = calculated value X^2

E_{ij} = expected frequency corresponding to $(ij)^{th}$ *and*, O_{ij} = the observed frequency.

r = number of rows, c = number of column

From this calculated value and tabulated value with degree of freedom (r-1) (c-1) the researcher decided about the existence of significant association between two variables or not.

To assess performance of milk production between *dega* and *weinadega* agroecologies, two sample t-test (Montgomery, 2001) was used to test the null hypothesis H_O: $\mu_1 = \mu_2$ against the alternative hypothesis H_1: $\mu_1 \neq \mu_2$, where: μ_1 is the mean production of *dega* and μ_2 is the mean production of *weinadega* agroecology.

$t_{cal} = \frac{(\bar{x}1-\bar{x}2)-(\mu1-\mu2)}{S_p\sqrt{(\frac{1}{n1}+\frac{1}{n2})}}$; $Sp = \frac{S_1(n_1-1)+S_{2(n_2-1)}}{n_{1}+n_{2-2}}$; $S_1 = \frac{\Sigma(X_{1i}-\bar{X})^2}{n_1-1}$; $S_2 = \frac{\Sigma(X_{2i}-\bar{X})^2}{n_2-1}$

Where,

t_{cal} = calculated value of t; t_{tabu} = tabulated value of t,

S_1 = variance for milk production of *dega*,

S_2 = variance for milk production of *weinadega and*

S_p = pooled variance of milk production of both agro ecologies.

In measuring and analysis of HH food security, the three dimensions (pillars) of food security structures (food availability, food access, and food utilization) were used. Furthermore, a modified form of a simple equation termed as HH food balance model (HFBM) was used to quantify the available food for the sample households to determine per capita calorie consumption (Mesay, 2009), which was computed using the formula described below:

$$Nij = (Gij + Pij + Bij + Rij) - (Lij + Sij + Mij + Oij)$$

Where,

Nij= the net food available for i^{th} HH in j^{th} year.

Gij = the total produced grain by i^{th} HH in j^{th} year

Pij= the total purchased grain by i^{th} HH in j^{th} year j

Bij = the total borrowed grain by i^{th} household in j^{th} year

Rij= Total Grain obtained from relatives by i^{th} HH in j^{th} year

Lij= the post-harvest losses to i^{th} HH in j^{th} year

Sij = the total grain utilized for seed by i^{th} HH in j^{th} year

Mij= total grain marketed by i^{th} HH in j^{th} year

Oij= grain given to others i^{th} h HH in j^{th} year

Non-grain food items were not considered by the above-mentioned researcher of previously used this model somewhat he considered only food grains gained and lost. In this study, however, the researcher slightly modified and used the model to compute the total available food including the food grains, *kocho, bulla* and cattle products produced by the sample HHs. This simply means that, the model has expanded to include *enset* products of *kocho* and *bulla* as well as cattle products and computed in the same way.

Therefore, the quantity of food grains, *enset (kocho and bulla)* and cattle products produced by HH was calculated and converted in to dietary calorie equivalent separately based on Ethiopian health and nutrition research institute (EHNRI) food composition table (Appendix 6). The total amount of calorie obtained from the grains, cattle and *enset* products was added together and then divided by the number of HH members to obtain the annual per capita calorie. To come across the daily per capita calorie, the annual per capita calorie was divided by the number of days in a year (365 days) and the calculated daily per capita calorie was compared against the medically recommended average daily energy intake of 2100 kcal (FAO, 1998; Wikipedia, nd). The proportion of calorie obtained from each food item (grains, cattle and *enset* products) from the total calorie produced and consumed in the study areas was computed to understand the contribution of e*ach* product to the dietary calorie supply of the HHs in the study area. Food security status of each HH was determined based on medically recommended minimum daily dietary energy requirement for healthy life of an individual. Household was categorized as food secure when individual member of the HH received a daily dietary energy of ≥2100kcal per day whereas the HH was identified as food insecure when he/she received a daily dietary energy of $<$2100kcal per day (FAO, 1998).

4. RESULTS

4.1. *Enset*-Based Dairy Cattle Production System

4.1.1. Socioeconomic characteristics of production systems

4.1.1.1. Characteristics of household

The characteristics of the household respondents in the study area of Gurage zone are indicated in Table 1. Based on the results obtained in current study around 92.8% of the respondents were male headed HHs in *dega* agroecology. However, around 74.4% of HHs in *weinadega* agroecology were male headed. On the other hand, the percentage (25.6%) of female headed HHs in *weinadega* areas was greater when comparing it with the female headed HHs of 7.2% found in *dega* agroecology.

The level of education of the HH heads in *dega* agroecology was better than the *weinadega* agroecology. Accordingly, about 65% of the farmers in *dega* agroecology have got better opportunity for different level of education when compared to those 57.3% HHs of *weinadega* (Table 1). Conversely, 35% of the HH heads in the *dega* agroecology were illiterate whereas the illiterate households for *weinadega* were 42.7%. On the other hand, house heads of 66.7% in *Achene* PA and 64.5% in *Wukiye* PA of *Muhir* and *Aklil woreda* as well as 48.9% of house heads in *Kochira* PA of *Enemor* and *Aner* woreda were illiterate. The difference in level of education between and within the study PAs could be attributed to difference in access to schools.

From a total of 360 sample HH respondents, nearly 50.0% of them were elementary (Grade 1-6) complete, 10.8% were both junior secondary (Grade 7-8) and secondary (Grade 9-12) school complete. The rest 38.9% were illiterate and 0.3% of respondents were with a literacy level of above secondary (>12 Grade) school education. The results of this study show that most (61.1%) of the sample household heads had the opportunities of getting different level of education.

Table 1: Characteristics of HHs in the study areas of Gurage zone.

Agroecologies	HH variables (%)		
	Male	Female	Over all
Dega (n=180)	92.8	7.2	100
Weinadega (n=180)	74.4	25.6	100
Total (N = 360)	83.6	16.4	100

Agroecologies	Study PAs	Level of education of household head (school grade)				
	(n = 45)	Illiterate	1-6	7-8	9-12	> 12
	Shamene	17.8	71.1	2.2	8.9	--
	Achene	64.5	33.3	--	--	2.2
Dega	*Moche*	33.3	48.9	11.1	6.7	--
	Agata	24.4	75.6	--	--	--
Subtotal (n=180)		35	57.2	3.3	3.9	0.6
	Shehremo	24.4	57.8	2.2	15.6	--
Weinadega	*Wukiye*	66.7	26.7	--	6.7	--
	Yeferezye	31.1	51.1	8.9	8.9	--
	Kochira	48.9	35.6	15.6	--	--
Subtotal (n=180)		42.7	42.8	6.7	7.8	--
Over all (N = 360)		38.9	50.0	5.0	5.8	0.3

Dega = highland, *Weinadega* = midaltitude, -- = not available, n = number of sample HHs per peasant association and per agroecology, N = total sample HHs of the study.

The average household family sizes, active and non-active labor group, age of HHs and gender distribution in *dega* and *weinadega* agroecologies in the study areas of Gurage zone are presented in Table 2. The average number of family members per HH across the agroecologies of studied areas was 7.71. The family size of *weinadega* agroecology was significantly higher than that of the *dega* agroecology ($P<0.05$). The average number of both males and females within the HH was higher ($P<0.05$) for *weinadega* agroecology as compared to the *dega* agroecology of Gurage zone. The average family size having age of between ≥15 and ≤ 65 did not differ ($P>0.05$) among the *dega* and *weinadega* agroecologies of the study areas but there is a significant difference ($P<0.05$) on age category of ≤ 14 and > 65 between agroecologies.

Table 2: Mean (±SE) family size of HHs in sex and age group in the study areas of Gurage zone.

Agroecology	Age of HHs	Size, sex and age of household family				
		Total	Male	Female	Age[1]	Age[2]
Dega	49.44±.71	7.34±.25[b]	3.64±.13[b]	3.63±.13[b]	5.66±.18	1.68±.1[b]
Weinadega	48.44±.57	8.09±.25[a]	4.02±.14[a]	4.07±.14[a]	6.03±.18	2.04±.11[a]
Overall mean	48.94±.45	7.71±.18	3.83±.1	3.85±.13	5.85±.13	1.86±.07

[a-b] means in the same column sharing different letters of superscripts are significantly different (P<0.05), *Dega* = highland, *Weinadega* = midaltitude, HHs = households, Age[1] = family members between ≥15 and ≤ 65 years old , Age[2] = Family members of ≤14 and > 65 years old.

4.1.1.2. Cattle size, structure, type and purpose of rearing

About 15% and 11.7% of the interviewed HHs in the *dega* and *weinadega* agroecologies, respectively, possessed crossbred cattle along with their local cattle breeds (Table 4). Most of these crossbred animals were calves of 1-2 years and heifers of younger age majority of which were obtained by purchase from neighboring areas. Conversely, about 85% of farmers in *dega* and 88.3% households in *weinadega* agroecologies were kept indigenous cattle breeds only. Most of the HHs participated in the interview indicated lack of AI service provision and getting opportunities for appropriate technology to improve livestock production and productivity were major bottlenecks and uncertainties which forced them to manage low productive animals. Although the level of products obtained from these indigenous cattle is low, the nature of cattle association with *enset* production farmers in the study areas urged to keep these low productive indigenous cattle breeds.

As indicated in Table 3, from a total of 1,753(100%) cattle population owned by the HHs participated in the current study, 1,675(95.55%) of the cattle were local (indigenous) breed. The rest 78(4.45%) of cattle population were crosses and most of them are obtained by purchase from neighboring zones and region. Among the crosses, some of them were obtained through AI accompanied with the estrus synchronization of cattle practiced by coordination of Federal to Woreda government offices of agriculture and livestock development. In the *enset* based farming system of the study areas of Gurage zone where *enset* cultivation has become paramount importance, cattle are the most important livestock species for milk and manure production. And from total cattle population of the area the percentage of oxen used for cultivation of land for annual crop production were 4.51% and the percentage of adult bulls used in different purpose were accounted only for 12.09%. The rest of the cattle population found in the study areas were cows, heifers and calves of both sexes.

Table 3: Cattle breeds, bulls, oxen and breed types owned by HHs in Gurage zone (%).

Agroecology	Percentage of cattle breeds, bulls and oxen				Agroecology	Households having different cattle breeds	
	Local	Cross	Bulls	Oxen		Local	Local and crosses
Dega (n_o = 875)	94.97	5.03	5.26	12.57	*Dega* (n_1 = 180)	85.0	15.0
Weinadega (n_o = 878)	96.13	3.88	4.21	11.62	*Weinadega* (n_1 =180)	88.3	11.7
Total (N_o = 1753)	95.55	4.45	4.51	12.09	Total (N_1 = 360)	86.7	13.3

Dega = highland, *Weinadega* = midaltitude, n_o = cattle number per agroecology, N_o = total number of cattle in the study areas, N_1 = total sample HHs of the study, n_1= sample HHs per agroecology.

According to the responses of HHs (Table 4), the primary objective of rearing cattle is necessities such as high demand of manure to fertilize crop land particularly *enset* fields and milk production to supplement *kocho* which is low in protein content. In general, 88.05% of cattle owning HHs in both agroecologies kept their cattle mainly to satisfy the need of manure to be utilized in the production of *enset* crop and to produce milk and milk products without which it is impossible to get necessary balanced nutrients from *enset* products alone. No HH responded ‘Yes’ for keeping of cattle to produce milk only and traction only. Households in the *enset* based cattle production systems of Gurage area never utilize manure produced from cattle for fuel or dung cake production and 100% of manure produced is utilized in fertilizing the croplands particularly of *enset* garden.

Table 4: Purpose of cattle rearing in the study areas of Gurage zone

Study *woreda*	Purpose of cattle rearing (%)				
	milk only	Manure only	traction only	milk and traction	milk and manure
Ezia (n= 90)	0	0	0	15.6	84.4
Muhir and Aklil (n= 90)	0	0	0	4.4	95.6
Cheha (n= 90)	0	0	0	8.9	91.1
Enemor and Aner (n= 90)	0	0	0	18.9	81.1
Total (N=360)	0	0	0	11.95	88.05

Woreda = districts, n = sample HH per *Woreda*, N = total sample HHs of the study.

4.1.1.3. Purpose of cattle manure production

Cattle manure plays a critical role in *enset* production system of Gurage area in maintaining soil fertility and agricultural sustainability. In this low input farming system, *enset* is strongly dependent on the amount of cattle manure produced and availability of nutrients. All of the respondent households used the whole cattle manure produced to fertilize their croplands (Table 5). The HHs also confirmed that, in the absence of cattle manure in this system, *enset* production could be deprived of sustainability as cattle manure is the principal source of nutrients crucial for the productivity of *enset*. Besides meeting timely requirement of nutrients, manure is regarded as essential for sustainable productivity of *enset* system and important in maintaining long-term soil fertility.

Table 5: Purpose of cattle manure production in the study areas of Gurage zone (%)

Study *Woreda*	Manure used as fertilizer	Manure used as fuel/dung cake
Ezia (n= 90)	100	0
Muhir and Aklil (n= 90)	100	0
Cheha (n= 90)	100	0
Enemor and Aner (n= 90)	100	0
Total (N=360)	100	0

Woreda = districts, n = sample household per study woreda, N = total sample households.

4.1.1.4. Cattle housing and barn cleaning frequency

All types of housing used for cattle in the study areas were family living house paved with stone floor (Table 6). According to the respondents, cattle were housed together with the family because of the fear of thieves, to protect animals from extreme weather conditions and also for ease of husbandry practices such as feeding, watering, milking and waste management. The frequency of barn cleaning depends on the amount of manure produced which is dependent on number and age of cattle as well as the amount and the nature of feed available to the cattle. When the number and age of cattle owned by the household increase, the frequency of manure removal and barn cleaning increased.

Similarly, when there is provision of enough amount of feed (which increases manure production) and the available feed type is high in moisture content (it increases urine production), the frequency of manure removal and barn cleaning has increased. Accordingly, about 70% of the interviewed households in the area reported that barn cleaning was practiced every 2 days whereas 30% of the respondent farmers reported that cleaning of the barn has been undertaken every 3 days. Despite housing cattle in separate house has its own advantage in avoiding direct contamination with filth and different disease causing organisms, 100% of HHs in the study area used family house for their animals rather than sheds and/or other structures designed in a proper way.

Table 6: Livestock housing and barn cleaning in the study areas of Gurage zone (%)

Agroecologies	Cattle housing	Frequency of barn cleaning	
	Family house with paved stone floor	Every two days	Every three days
Dega (n = 180)	100	74.44	25.56
Weinadega (n =180)	100	65.56	34.44
Total (N = 360)	100	70.00	30.00

Dega = highland, *Weinadega* = midaltitude, n = sample households per agroecology, N = total sample households

4.1.1.5. Sources of water for livestock

In the study PAs of *dega* agroecology (*Shamene, Achene and Agata*) 100% of water sources for livestock were rivers (Table 7) whereas in *Moche* PA of the same agroecology, the river was main (77.8%) source of water while pond, spring and shallow well, respectively, supplied about 6.7%, 4.4% and 11.1% of water need. According to the responses of the respondents in the study PAs of *weinadega* agroecology (*Shehremo, Wukiye, Yeferezye and Kochira*), the river fulfilled the water requirement of livestock, respectively, 68.9%, 42.2%, 93.3% and 80%. Based on the result of the current study (Table 7), about 82.78% of the interviewed livestock keepers relied on rivers as major water sources for their livestock. Despite the greater contribution of rivers as water sources for livestock production, water supply was reported as limiting factor for survival and lowering of productivity of cattle reared by HHs particularly living in *dega* agroecology and for those living far away from permanent rivers during dry periods.

Table 7: Sources of water for livestock in the study areas of Gurage zone (%)

Study *Woreda*	Study PA	River	Pond	Spring	Tap	Shallow well
Ezia	Shamene (n=45)	100	--	--	--	--
	Shehremo (n=45)	68.9	--	2.2	28.9	--
	Total (n = 90)	84.4	--	1.1	14.4	--
Muhir and Aklil	Achene (n=45)	100	--	--	--	--
	Wukiye (n=45)	42.2	2.2	28.9	26.7	--
	Total (n = 90)	71.1	11	14.4	13.35	--
Cheha	Moche(n=45)	77.8	6.7	4.4	--	11.1
	Yeferezye (n=45)	93.3	6.7	--	--	--
	Total (n = 90)	85.6	6.7	2.2	--	--
Enemor and Aner	Agata (n=45)	100	--	--	--	--
	Kochira (n=45)	80	20	--	--	--
	Total (n = 90)	90	10	--	--	--
Over all (N=360)		82.78	4.44	4.44	6.95	1.39

Woreda = districts, n = sample HH per PA and per *Woreda*, N = total sample HHs of the study, -- = not available.

4.1.1.6. Distance to watering point and watering frequency

As indicated in Table 8, in both *dega* and *weinadega* agroecologies of the study areas, only 17.5% of HHs were in a position to get water for their animals at a distance of 1-2km. On the other hand, about 36.9% and 45.6% of HHs found in both agroecologies traveled a distance of 2-4 km and greater than 4 km, respectively, to get water for their animals. Frequency of watering to livestock varies from one agroecology to another, which is affected by different factors of season, accessibility (getting easily), type of predominant feed (dry or wet) and feeding systems (indoor or outdoor where some water is available). In the drier period of the year, most (86.4%) of the households provide water to their animals once a day except those households living around or near watering points or rivers. About 13.3%, 8.9% and 5.6% of the households of three study PAs located at *dega* agroecology of *Ezia, Muhir* and *Aklil* and *Enemor* and *Aner*, respectively, reported the provision of water once per two days for all types of livestock (cattle, shoats and equines) in the dry period.

Table 8: Distance traveled to watering point and watering frequency of livestock in the drier season of the year in the study areas of Gurage zone (%).

Distance traveled to watering point	*Ezia* (n = 90)	*Muhir and Aklil* (n =90)	*Cheha* (n = 90)	*Enemor and Aner* (n = 90)	Total (N = 360)
1-2 km	20.0	25.6	13.3	11.1	17.5
Between 2-4 km	43.3	35.6	26.7	42.2	36.9
>4km	36.7	38.9	60.0	46.7	45.6
Watering frequency					
Ad libtum	--	--	--	--	--
Twice/day	--	6.7	20.0	--	6.7
Once a day	86.7	84.4	80.0	94.4	86.4
Once per two days	13.3	8.9	--	5.6	6.9

n = sample HHs per study *Woreda*, N = total sample HHs of the study, -- = not available.

4.1.1.7. Average land holdings and land use pattern in the study areas

All HHs included in this study in both *dega* and *weinadega* mixed crop-livestock production systems have possessed their own land used for different purpose of livestock and crop agriculture. Based on the result obtained from the analysis of surveyed data, the average land holding per HH in *weinadega* agroecology was 2.08ha while it was 1.44ha for *dega* agroecology Table 9. Out of the total land holdings of households in the *weinadega* agroecology, 0.71ha, 0.46ha, 0.51ha, 0.20ha and 0.20ha, respectively, were allocated for annual crop production, *enset* production, grazing, forest development and production of perennial crops like khat, coffee and fruits. Correspondingly, the allocation of land owned by households in *dega* agroecology was 0.58ha, 0.29ha, 0.35ha, 0.12ha and 0.10ha for annual crop production, *enset* production, grazing, forest and production of potato and vegetables, respectively.

Mean (±SE) of total land holding per HH in the *dega* and *weinadega* agroecologies in Gurage zone is presented in (Table10). The overall average land holding per HH across the production system of surveyed areas was 1.75±.05. The overall average of land holding per household in the *weinadega* agroecology was significantly higher ($P<0.05$) than the *dega* agroecology. In the same way, the average land holding for *enset* production and grazing per HH were higher ($P<0.05$) for *weinadega* agroecology when comparing with *dega* agroecology of Gurage zone. Similarly, in the *weinadega* agroecology the average landholding for forest development was larger ($P<0.05$) than the *dega* agroecology. The differences observed in landholding in the *weinadega* agroecology is related to availability of open land which was not owned by individuals but it was under control and close supervision of community and local governments which could be transferred to individuals who had no opportunity of getting land from his relatives (father and mother) enough to produce products to lead normal life of the newly established family. However, now a day these lands are nonexistent, because the lands have been transferred to investors engaged in different investment options, town municipalities, governmental and nongovernmental organizations, and other social service giving institutions.

Major crops grown and their area coverage in the study area of *weinadega* agroecology comprised of 0.46ha *enset*, 0.43ha *teff*, 0.20ha khat, 0.18ha maize and 0.09ha wheat. Similarly, crops commonly grown and their area of coverage in the *dega* agroecology include 0.29ha *enset*, 0.32ha barley, 0.14 ha field pea, 0.05ha faba bean, 0.07ha wheat and 0.10ha potato and vegetables. *Enset*, *teff*, maize, khat and coffee are well adapted to the *weinadega* agroecology whereas *enset*, barley, field pea and vegetable were crops majorly grown in *dega* agroecology (Table 9).

Table 9: Mean (±SE) landholdings and use pattern by agroecologies of Gurage zone.

Land allocation for different activities (ha)	Agroecologies		
	Dega (n =180)	*Weinadega* (n=180)	Overall (N= 360)
Land holding per HH	1.44 ± 0.04^{b}	2.08 ± 0.09^{a}	1.75±0.05
Annual crops	0.58 ± 0.02^{b}	0.71 ± 0.04^{a}	0.64±0.02
Wheat	0.07 ± 0.01^{b}	0.09 ± 0.01^{a}	0.08±0.01
Maize	--	0.18 ± 0.01^{a}	0.09±0.01
Field pea	0.14±0.01	--	0.07±0.01
Faba bean	0.05±0.01	--	0.03±0.00
Vegetables	0.10±0.01	--	0.05±0.00
Teff	--	0.43±0.03	0.21±0.02
Barley	0.32 ± 0.01^{a}	0.00 ± 0.00^{b}	0.16±0.01
Khat, coffee and fruits	--	0.20±0.01	0.10±0.01
Enset	0.29 ± 0.01^{b}	0.46 ± 0.02^{a}	0.37±0.01
Grazing	0.35 ± 0.02^{b}	0.51 ± 0.03^{a}	0.43±0.02
Forest	0.12 ± 0.01^{b}	0.20 ± 0.01^{a}	0.16±0.01

$^{a-b}$ means in the same row with different letter of superscripts are significantly different ($P<0.05$), n = number of respondents, *Dega* = highland, *Weinadega* = midaltitude, HHs = households -- = not available, ha = hectare.

4.1.1.8. Average landholding & land use pattern per wealth group

Households included in the current study in both *dega* and *weinadega* mixed crop-livestock production systems of Gurage zone were grouped in to three wealth groups based on the numbers of cattle that the individual HH owned. The parameter used in wealth grouping was made by the group members of elders having deep knowledge and long experience on cattle and crop (*enset*) production and experts from different agricultural professions.

Depending on the discussion made by the group, the sample HHs were grouped in to three wealth groups of poor (HHs possessing 1-3 cattle), Medium (HHs possessing 4-5 cattle) and wealthy (HHs possessing ≥ 6 cattle). Based on the result obtained from the analysis of surveyed data, the average (M±SE) land holding between different wealth groups of poor, medium and wealthy, respectively, was 1.34ha,1.67ha and 2.19ha and there was a significant difference (P<0.05) between the HHs grouped in different wealth categories. Out of the total land holdings of HHs with different wealth groups the allocation of land for annual cereal crop production, *enset* production, grazing and forest development was highly different (P<0.05) (Table 10).

From a total of land owned by the HHs of different wealth groups the higher proportion of land was allocated for *enset* (*E. ventricosum*). Between the wealth groups found in the study areas of Gurage zone, the average land holding for *enset* production per HH was higher (P<0.05) for wealthy households as compared to the medium and poor HHs. Similarly, the average landholding for annual crop production, grazing and forest development was substantially larger (P<0.05) in the case of wealthy households than the medium and poor HHs. On the other hand, although statistical differences were observed between medium and poor HHs, there was no significant difference (P>0.05) on average land allocation for annual crop production, grazing and forest development.

Table 10: Mean (±SE) landholding and land use pattern per wealth group in the study area of Gurage zone.

Land holding and allocation for different activities (ha)	Household wealth groups			
	Poor n =120	Medium n = 120	Wealthy n = 120	Overall N= 360
Total land holding	1.34±0.06^{c}	1.67±0.07^{b}	2.19±0.11^{a}	1.75±0.05
Annual crops	0.51±0.03^{c}	0.62±0.03^{bc}	0.79±0.05^{a}	0.64±0.02
Vegetables	0.05±0.01	0.05±0.01	0.05±0.01	0.05±0.01
Chat, coffee & fruits	0.08±0.01	0.11±0.01	0.11±0.01	0.1±0.01
Enset	0.26±0.01^{c}	0.34±0.01^{b}	0.52±0.02^{a}	0.37±0.01
Grazing	0.36±0.03^{c}	0.39±0.03^{bc}	0.54±0.04^{a}	0.43±0.02
Forest	0.14±0.01^{c}	0.15±0.01^{bc}	0.20±0.02^{a}	0.16±0.01

$^{a\text{-}b\text{-}c}$ means in the same row with different letter of superscripts are significantly different (P<0.05), Poor = HHs with cattle number of 1-3, Medium = HHs with cattle number of 4 and 5,Wealthy = HHs with cattle number of ≥6, n = number of sample HHs per wealth group, N = total sample HHs of the study.

4.1.2. Grain and crop residues production in the study areas

The average grain yield of field crops and their residues produced in *dega* and *weinadega* agroecologies of the study areas of Gurage zone are indicated in Table 11. From the result of current study it is clear that the types of cereals grown were very limited in number and were not more than three crops from each agroecology. This could limit the amount of produced crop residues for livestock feeding in both agroecologies of the study areas. The only cereal crop commonly grown in both agroecologies in measurable quantity was wheat crop. The average production of wheat and wheat straw per HH was higher (P<0.05) for *weinadega* agroecology than the *dega* agroecology.

In both agroecologies of the study areas, HHs mainly focused on the production of *enset* (*E. ventricosum*) which provides not only food for the family members but also the major source of feed for livestock feeding particularly cattle. Therefore, farmers in these areas have tried to improve the production and productivity of the *enset* plant per unit of land mainly through cultural practices instead of focusing on the production of cereal crops.

The main reason of farmers to limit the types and amount of annual crop production was due to reduced land availability, lack of improved seed and chemical fertilizer to produce enough food crops to feed the family members and crop residues that can support their livestock.

Bearing the difficulties of provision of cultivable land, appropriate agricultural technologies and input in mind, the major cereal crops grown in the study areas of Gurage zone in their order of importance are barley, wheat, field pea and faba bean in *dega* whereas maize, *teff* and wheat are crops majorly produced in *weinadega* agroecology (Table 11). Greater amount of crop residues was produced from barley, wheat, field pea and fababean in *dega* and from maize, *teff* and wheat in *weinadega* areas.

Table 11: Grain and crop residues yield (tHH^{-1}) for common field crops grown in *dega* and *weinadega* agroecologies in the study areas of Gurage zone.

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

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

4.1.3. . Grain and crop residues produced by HHs of different wealth groups

The average yield of cereal crops and their residues produced by HHs of different wealth groups participated in the current study are indicated in Table 12. The types and quantity of annual crops grown in the study area were limited when compared with the types and quantity of cereal crops grown in other parts of the country. In this area farmers mainly focused on the production of *enset* to produce enough food to feed his/her family thereby more feed from *enset* parts for cattle feeding.

The amount of crops and crop residues produced in the study area varied with the level of wealth groups of HHs (based on the number of cattle that the individual HH owned). The estimated mean dry matter production differ significantly (P<0.05) among the wealth groups of HHs (Table 12). The average estimated tons of dry matter produced from cereal crops in the study areas of Gurage zone based on different wealth groups of HHs of poor, medium and wealthy, respectively, were 0.18±0.02, 0.29±0.03 and 0.32±0.03 (wheat straw), 0.42±0.04, 0.48±0.05 and 0.56±0.06 (barely straw), 0.28±0.04, 0.32±0.04 and 0.55±0.09 (*teff* straw), 0.50±0.07, 0.77±0.09 and67±.08 (maize stover), 0.09±0.01,0.09±0.01 and 0.10±0.01 (field pea straw) as well as0.03 ±0.01,0.03±0.01 and 0.04±0.01 (fababean straw).

Significant differences (P<0.05) on the production of crop residues (straws and stover) among wealth groups were observed. In the majority of the cases, higher dry matter (DM) yield from crop residues of straws and stover production was observed in the case of wealthy HHs followed by the medium ones and the least crop residues production was observed in the case of poor HHs. The number of cattle ownership by individual HH has its own positive effect on amount of land owned which has direct effect on the amount of crop production and on quantity of crop residues produced for livestock feeding.

Though the amount of land available to produce crops and grazing is inadequate, it is known that HHs who have greater number of cattle do have relatively larger area of land when compared to those HHs owning lesser number of cattle (Table 12). These wealthy farmers also do have better opportunity of getting greater amount of annual income which permits the wealthier HHs to get relatively better amount of inorganic fertilizer, chemicals, improved seeds, daily labors and plowing oxen, which permit for the production of higher amount of cereal crops to feed their family members as well as producing more crop residues that can support their livestock.

Table 12: Grain and crop residue yield (t/yr) for common field crops grown by different wealth groups in the study areas of Gurage zone.

Crop types	Poor		Medium		Wealthy	
	Grain	Straw	Grain	Straw	Grain	Straw
Wheat	$0.12{\pm}0.02^{c}$	$0.18{\pm}0.02^{c}$	$0.19{\pm}.02^{ab}$	$0.29{\pm}0.03^{ab}$	$0.22{\pm}0.02^{a}$	$0.32{\pm}0.03^{a}$
Barely	0.28±0.03	0.42±0.04	0.32±0.03	0.48±0.05	0.38±0.04	0.56±0.06
Teff	$0.19{\pm}0.02^{bc}$	$0.28{\pm}0.04^{bc}$	$0.21{\pm}.03^{b}$	$0.32{\pm}0.04^{b}$	$0.37{\pm}0.06^{a}$	$0.55{\pm}0.09^{a}$
Field pea	0.08±0.01	0.09±0.01	0.08±0.01	0.09±0.01	0.08±0.01	0.10±0.01
Fababean	0.02±0.01	0.03 ±0.01	0.03±0.00	0.03±0.01	0.03±0.01	0.04±0.01
Maize	$0.25{\pm}0.03^{c}$	$0.50{\pm}0.07^{c}$	$0.38{\pm}0.04^{a}$	$0.77{\pm}0.09^{a}$	$0.34{\pm}0.04^{ab}$	$.67{\pm}.08b^{ba}$

^{abc} means in the same row with different letter of superscripts are significantly different (P<0.05), Poor = HHs with cattle number of 1-3, Medium = HHs with cattle number of 4 and 5, Wealthy = HHs with cattle number of ≥ 6.

4.1.4. Herd size and structure per agroecology

The average livestock holding per HH in *dega* and *weinadega* agroecology in TLU, respectively, was 4.02±0.029 and 4.14±0.03 with over all mean of 4.07±0.03 (Table 13). There was no significant difference (P>0.05) on the average cattle holding per HH between the agroecologies. However, marked difference (P<0.05) was observed on the average holding of sheep, goats, horses, and donkey per HHs of *dega* and *weinadega* agroecologies. The average number of sheep and horses per HH was higher (P<0.05) in the *dega* agroecology whereas the average number of goats and donkeys was higher (P<0.05) in the *weinadega* system of the study area of Gurage zone.

The differences observed in the average number of sheep and horses in *dega* as well as goats and donkeys in *weinadega* agroecologies could be attributed to the existence of suitable weather conditions, availability of suitable and better feeds to specific classes of livestock in each agroecology. Moreover, the owning of higher average number of horses per HH in the *dega* area and donkeys in the *weinadega* might be related to the animals suitability to overcome the transport problems of people and luggage associated with rugged terrains.

Table 13: Herd size and herd structure (Mean ±SE) per household in the *dega* and *weinadega* agroecology in the study area of Gurage zone.

Livestock species	Agroecologies (in number)			Agroecologies (in TLU)		
	Dega	*Weinadega*	Overall	*Dega*	*Weinadega*	Overall
Cattle	4.86±0.17	4.88±0.18	4.87±0.12	3.34±0.12	3.37±.14	3.35±0.09
Cows	2.08±0.07	2.21±0.094	2.14±0.06	1.78±0.07	1.87±.09	1.82±0.06
Oxen	0.23±0.03	0.21±0.033	0.22±0.02	0.26±0.04	0.23±0.04	0.24±0.03
Bulls	0.61±0.04	0.57±0.040	0.59±0.03	0.67±0.04	0.62±0.04	0.65±0.03
Heifers	0.73±0.06	0.83±0.065	0.78±0.04	0.38±0.03	0.43±0.03	0.40±0.02
Calves	1.21±0.07	1.07±0.052	1.14±0.04	0.25±0.04	0.22±0.01	0.24±0.01
Sheep	$1.94±0.08^a$	$.56±0.07^b$	1.25±0.06	$0.19±0.01^a$	$0.06±0.01^b$	0.12±0.01
Goats	$.01±0.01^b$	$1.42±0.1^a$	0.71±0.06	$0.01±0.00^b$	$0.14±0.01^a$	0.07±0.01
Horses	$0.55±0.04^a$	$0.02±0.01^b$	0.28±0.02	$0.44±0.03^a$	$0.01±0.01^b$	0.23±0.02
Mules	_	0.47±0.04	0.24±0.02	_	0.38±0.03	0.19±0.02
Donkeys	$0.09±0.02^b$	$0.35±0.04^a$	0.22±0.02	$0.04±0.01^b$	$0.18±0.02^a$	0.11±0.01
Overall	_	_	_	4.02±0.03	4.14±0.03	4.07±0.03

a-b means with different letters of superscripts in the same row for *dega* and *weinadega* agroecologies differ significantly *(P<0.05)* for livestock number and TLU, TLU = tropical livestock unit, *Dega* = highland, *Weinadega* = midaltitude.

4.1.5. Herd size and structure among wealth groups

The average livestock number in tropical livestock unit (TLU) owned by the HHs of different wealth groups was analyzed and the result is indicated in (Table 14).The average livestock holding per poor, medium and wealthy HH in the study areas of Gurage zone, respectively, in TLU was 2.2, 3.98 and 6.05 and there was significant difference (*P*<0.05) on the average cattle holding among HHs of different wealth groups. The average number of cattle per wealthier HH was much greater (*P*<0.05) than the HHs of medium and poor wealth groups. Similarly, significant difference (*P*<0.05) was observed on the average holding of horses between the HHs categorized under poor and the rest of medium and wealthy, however there was no variation (*P*>0.05) on horse holdings among the HHs of medium and wealthy groups.

On the other hand, noticeable difference (*P*<0.05) was observed on the average holding of mules and donkeys between the HHs classified in wealthy and poor wealth groups.

However, there was no significant differences (*P*>0.05) between the HHs of wealthy and medium as well as between the medium and poor wealth groups. The average number of sheep per HH was different among HHs of different wealth groups. But the statistical difference was not significant (*P*>0.05) on the average number of sheep owned by the HHs of wealthy and medium and among medium and poor wealth groups. The differences observed in the occupation of average number of livestock between HHs of different health category in the current study could be associated with better opportunities of wealthier HHs to have greater amount of land holdings for grazing, to produce annual crops and plant higher amount of *enset* thereby producing higher amount of dry matter from grazing, crop residues and *enset* leaf and leaf midribs to feed their livestock.

Table 14: (Mean ±SE) herd size & structure/wealth groups in study areas of Gurage zone.

Livestock species	Different wealth groups (in number)			Different wealth groups (in TLU)		
	Poor	Medium	wealthy	Poor	Medium	Wealthy
Cattle	$2.58{\pm}.05^{c}$	$4.57{\pm}.07^{b}$	$7.46{\pm}.16^{a}$	$1.68{\pm}0.05^{c}$	$3.22{\pm}.07^{b}$	$5.17{\pm}0.14^{a}$
Cows	$1.19{\pm}.05^{c}$	$2.10{\pm}.06^{b}$	$3.14{\pm}.10^{a}$	$0.97{\pm}.05^{c}$	$1.78{\pm}.06^{b}$	$2.73{\pm}.10^{a}$
Oxen	$0.07{\pm}.02^{bc}$	$0.17{\pm}.04^{b}$	$0.42{\pm}.05^{a}$	$0.08{\pm}.03^{bc}$	$0.18{\pm}.04^{b}$	$0.46{\pm}.05^{a}$
Bulls	$0.26{\pm}.04^{c}$	$0.66{\pm}.04^{b}$	$0.85{\pm}.05^{a}$	$0.28{\pm}.04^{c}$	$0.72{\pm}.05^{b}$	$0.94{\pm}.05^{a}$
Heifers	$0.44{\pm}.06^{c}$	$0.63{\pm}.06^{b}$	$1.27{\pm}.08^{a}$	$0.22{\pm}.03^{c}$	$0.32{\pm}.03^{b}$	$0.66{\pm}.05^{a}$
Calves	$0.62{\pm}.05^{c}$	$1.01{\pm}.05^{b}$	$1.78{\pm}.08^{a}$	$0.13{\pm}.01^{c}$	$0.22{\pm}.01^{b}$	$0.38{\pm}.02^{a}$
Sheep	$1.02{\pm}.09^{bc}$	$1.22{\pm}.11^{ab}$	$1.51{\pm}.12^{a}$	$0.10{\pm}.01^{cb}$	$0.12{\pm}.01^{ba}$	$0.15{\pm}.01^{a}$
Goats	0.54±.09	0.76±.10	0.83±.14	0.05±.01	0.08±.01	0.08±.01
Horses	$0.19{\pm}.04^{b}$	$0.34{\pm}.05^{a}$	$0.33{\pm}.04^{a}$	$0.15{\pm}.03^{b}$	$0.27{\pm}.04^{a}$	$0.26{\pm}.03^{a}$
Donkeys	$0.14{\pm}.03^{bc}$	$0.22{\pm}.04^{ab}$	$0.30{\pm}.04^{a}$	$0.07{\pm}.02^{cb}$	$0.11{\pm}.02^{ba}$	$0.15{\pm}.02^{a}$
Mules	$0.18{\pm}.04^{bc}$	$0.23{\pm}.04^{ab}$	$0.30{\pm}.04^{a}$	$0.15{\pm}.03^{c}$	$0.18{\pm}.03^{ba}$	$0.24{\pm}.03^{a}$
Overall	--	--	--	$2.2{\pm}.03^{c}$	$3.98{\pm}.03^{b}$	$6.05{\pm}.04^{a}$

^{abc} means with different letters of superscripts in the same row for different wealth groups of HHs differ significantly *(P<0.05)* for livestock number and TLU, TLU = tropical livestock unit, *Dega* = highland, *Weinadega*= midaltitude.

4.1.6. Herd size and structure in the study PAs

The average cattle holding in tropical livestock unit (TLU) per HH in the PAs of *Shamene, Achene, Moche, Agata, Shehremo, Wukiye, Yeferezye,* and *Kochira* of the study area in Gurage zone were indicated in Table 16. There was no significant difference *(P>*

0.05) on the average cattle holding per HH found in all PAs of the study areas. However, marked difference (*P*<0.05) was observed on the average holding of heifers and calves per HHs found at different peasant associations of the study areas. The average TLU of heifers per HH was higher in *Moche*, *Shehremo* and *Wukiye* whereas average holdings of calves in TLU was higher at *Agata* peasant associations. The least average holdings of heifers per HH was recorded at *Shamene* and *Yeferezye* PAs while the least average calves holdings was reported at *Shehremo* PA.

The mean number of sheep greatly higher (*P*<0.05) at *Shamene* and *Agata* PAs of *dega* agroecology than the *Achene* and *Moche* study PAs of the same agroecology and those PAs found in the *weinadega* agroecology. There was no differences (*P*>0.05) on the average number of sheep ownership among *Agata* and *Moche*; *Achene* and *Moche* as well as between *Shehremo, Wukiye, Yeferezye* and *Kochira* PAs *found* at *weinadega* agroecology (Table 15). The average number of goats per HH in the *Kochira* PA was higher (*P*<0.05) than *Yeferezye* and *Wukiye* PAs. However, there was no significant difference (*P*>0.05) in average number of goats between the *Kochira* and *Shehremo* and between *Shehremo, Yeferezye* and *Wukiye* PAs. The mean number of horses markedly varied (*P*<0.05) at *Shamene* PA than the rest of the study sites within *dega* agroecology. In the study areas of the Gurage zone the horses majorly used as transport vehicle for humans and transporting of goods.

Donkeys, on the other hand, are mainly used as pack animals in both *dega* and *weinadega* agroecologies of the study area. The average number of donkeys per HH in the *Kochira* PAs was higher (*P*<0.05) than the *Shamene*, *Achene* and *Moche* in the *dega* agroecology, however, there was no significant difference *(P*>0.05) on mean number of donkeys holdings between *Kochira*, *Shehremo*, *Wukiye* and *Yeferezye* PAs. Mules are used for both human transport and as pack animals and they are predominately found in the *weinadega* agroecology of the study area. The average number of mules per HH in the *Yeferezye* and *Kochira* PAs was higher (*P*<0.05) than the *Shehremo* and *Wukiye* PAs of the same agroecology.

Table 15: Herd size and herd structure (Mean ±SE) per HH in each study PAs in the study area of Gurage zone (in number).

Livestock species	*Shamene*	*Achene*	*Moche*	*Agata*	*Shehremo*	*Wukiye*	*Yeferezye*	*Kochira*	Overall
Cattle	4.98±.30	4.22±0.25	4.91±0.33	5.33±.43	4.53±0.28	4.80±0.40	5.27±0.38	4.91±0.34	4.87±0.12
Cows	2.29±0.12	1.76±0.11	1.89±0.14	2.40±.17	1.93±0.15	1.80±0.17	2.84±0.24	2.24±0.15	2.14±0.06
Oxen	0.24±0.07	0.16±0.06	0.33±0.07	0.20±0.06	0.16±0.06	0.36±0.09	0.16±0.06	0.16±0.06	0.22±0.02
Bulls	0.64±0.09	0.64±0.07	0.58±0.07	0.58±0.08	0.51±0.08	0.58±0.08	0.49±0.09	0.69±0.07	0.59±0.03
Heifers	$0.51±.011^{b}$	$0.67±0.10^{ab}$	$0.98±0.13^{a}$	$0.76±0.12^{ab}$	$1.04±.11^{a}$	$1.04±0.16^{a}$	$0.53±0.09^{b}$	$0.71±0.13^{ab}$	0.78±0.04
Calves	1.29±0.10	1.00±0.11	1.13±0.13	1.40±0.19	0.89±0.11	1.02±0.11	1.24±0.11	1.11±0.09	1.14±0.04
Sheep	$2.36±0.18^{a}$	$1.60±0.12^{c}$	$1.76±0.12^{bc}$	$2.04±0.18^{ab}$	$0.38±0.10^{d}$	$0.42±0.07^{d}$	$0.67±0.16^{d}$	$0.76±0.17^{d}$	1.25±0.06
Goats	--	--	--	--	$1.49±0.15^{ab}$	$1.11±0.16^{b}$	$1.29±0.25^{b}$	$1.78±0.24^{a}$	0.71±0.06
Horses	$0.73±0.08^{a}$	$0.51±0.07^{b}$	$0.49±0.07^{b}$	$0.47±0.07^{b}$	$0.07±0.04^{c}$	--	--	--	0.28±0.02
Donkeys	$0.18±0.06^{cb}$	$0.09±0.04^{d}$	$0.09±0.04^{d}$	--	$0.27±0.07^{b}$	$0.33±0.07^{ba}$	$0.31±0.07^{b}$	$0.49±0.07^{a}$	0.22±0.02
Mules	--	--	--	--	$0.40±0.07^{c}$	$0.22±0.06^{b}$	$0.60±0.07^{a}$	$0.67±0.07^{a}$	0.24±0.02

$^{a-d}$ means with different letters of superscripts in the same row for different PAs of study area differ significantly (*P<0.05*) for livestock number, -- = not available, PAs = peasant associations.

Table 16: Herd size and herd structure (Mean ±SE) per HH in each study PAs in the study area of Gurage zone (in TLU).

Livestock species	*Shamene*	*Achene*	*Moche*	*Agata*	*Shehremo*	*Wukiye*	*Yeferezye*	*Kochira*	Overall
Cattle	3.48±0.24	2.97±0.20	3.35±0.23	3.57±0.29	3.06±0.21	3.32±0.22	3.65±0.26	3.44±0.24	3.35±0.09
Cows	$1.96±0.13^{bc}$	$1.52±0.11^{bc}$	$1.60±0.13^{bc}$	$2.03±0.16^{ab}$	$1.61±0.13^{bc}$	$1.55±0.16^{bc}$	$2.41±0.23^{a}$	$1.93±0.14^{cb}$	1.83±0.06
Oxen	0.27±0.07	0.17±0.06	0.37±0.08	0.22±0.07	0.17±0.07	0.39±0.09	0.17±0.06	0.17±0.06	0.24±0.03
Bulls	0.71±0.09	0.71±0.08	0.64±0.08	0.64±0.09	0.56±0.08	0.64±0.09	0.54±0.10	0.76±0.08	0.65±0.71
Heifers	$0.28±0.06^{b}$	$0.36±0.05^{ab}$	$0.50±0.07^{a}$	$0.39±0.06^{ab}$	$0.54±0.06^{a}$	$0.53±0.08^{a}$	$0.27±0.05^{b}$	$0.36±0.07^{ab}$	0.40±0.02
Calves	$0.26±0.02^{ab}$	$0.21±0.03^{ab}$	$0.24±0.03^{ab}$	$0.29±0.04^{a}$	$0.18±0.02^{b}$	$0.21±0.03^{ab}$	$0.26±0.03^{ab}$	$0.22±0.02^{ab}$	0.24±0.01
Sheep	$0.24±0.02^{a}$	$0.16±0.01^{c}$	$0.18±0.01^{bc}$	$0.20±0.02^{ab}$	$0.03±0.01^{d}$	$0.04±0.01^{d}$	$0.07±0.02^{d}$	$0.07±0.02^{d}$	0.12±0.01
Goats	--	--	--	--	$0.15±0.02^{ab}$	$0.11±0.02^{b}$	$0.13±0.03^{b}$	$0.18±0.02^{a}$	0.07±0.01
Horses	$0.59±0.06^{a}$	$0.41±0.06^{b}$	$0.39±0.06^{b}$	$0. 37±0.06^{b}$	$0.05±0.03^{c}$	--	--	--	0. 23±0.02
Donkey	$0.09±0.03^{c}$	$0.04±0.02^{d}$	$0.04±0.02^{d}$	--	$0.13±0.03^{ab}$	$0.17±0.04^{ab}$	$0.16±0.04^{ab}$	$0.24±0.04^{a}$	0.11±0.01
Mules	--	--	--	--	$0.32±0.06^{b}$	$0.18±0.05^{c}$	$0.48±0.06^{a}$	$0.53±0.05^{a}$	0.19±0.02
Total	4.4±0.06	3.58±0.05	3.96±0.05	4.14±0.06	3.74±0.06	3.82±0.05	4.49±0.07	4.46±0.06	4.07±0.03

$^{a-d}$ means with different letters of superscripts in the same row for different PAs of study area differ significantly (P<0.05) for TLU, TLU = tropical livestock unit, PAs = peasant associations, -- = not available.

4.1.7. Measures of Productive and reproductive performance of cattle

4.1.7.1. Daily milk yield

Based on the data collected and analyzed in the current study, the estimated average daily milk yield differ significantly (P<0.05) among the study PAs (Table 18). In the study areas of Gurage zone the cattle breeds owned by the households are typically of mixed local (indigenous) breeds of central Ethiopia, which are characterized by low milk yield and small in size. The average daily milk yield obtained in the study areas of Gurage zone was about 1.53kg/day/cow (Table 19) with the mean difference of 0.22kg, leaving out the milk suckled by the calf (Table 18). The higher milk yield/cow/day was observed at *Shamene* PA (1.74kg/day/cow) and followed by Achene PA (1.72kg/day/cow) both of them are found in *dega* agroecology and the lowest milk yield was recorded at *Yeferezye* PA (1.27kg/day/cow) found in *weinadega* agroecology.

The relatively higher milk yield observed in the study PAs of *Shamene* and *Achene* could be associated with better ability of farmers to feed their milking cows. Moreover, these two sites are found in the *dega* agroecology, which is more appropriate for dairy production and farmers in the *dega* areas relatively produce with better quality and quantity of grasses, crop residues and leaf and leaf midribs *of enset*. Milk production is affected by genetic and environmental factors. Among the environmental factors, the quantity and quality of available feed resources are the major ones (Topps and Oliver, 1993).

In addition to the mean comparison on milk yield produced by sample HHs of the study PAs, analysis of mean differences on the performance of milk yield between *dega* and *weinadega* areas using two sample t-test (Montgomery, 2001) was applied and significant difference (P<0.05) were observed on the production performance of milk between *dega* and *weinadega* agroecology (Table17).

Table 17: Two sample t-test milk yield result between *dega* and *weinadega* agroecologies of Gurage zone.

Description		t-test for Equality of Means						
		t-value	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
							Lower	Upper
Milk yield	Equal variances assumed	4.040	358	.000	.220	.05467	.11333	.32834

df = degree of freedom, Sig. = level of significance, Std. Error = standard error.

4.1.7.2. Lactation length

In most dairy farms a lactation length of 305 days is commonly accepted as a standard. The overall estimated mean lactation length of cows obtained in the current study for both *dega* and *weinadega* agroecologies was 217 days (Table 18) and there was no significant difference (*P*>0.05) among PAs. Based on the perceptions of HHs found in the study areas of Gurage zone, without optimum management of cows the extended lactation length could negatively affect the future performance of the cows, reduces milk yield and makes the system costly.

4.1.7.3. Age at first service

The estimated mean of age at first service for the study areas is indicated in Table 18. It is the age at which heifers attain body weight, body condition and sexual maturity for accepting bull service and conceive for the first time. It influences both the productive and reproductive life of the female through its effect on her lifetime calf crop. The overall estimated mean age of heifers at first service for the current study was 53.44months. Age at first service can be influenced by genotype, nutrition and other environmental factors. Improved management levels such as good nutrition, housing and health care enhance growth rate of heifers to come on first heat at early age. Estimated mean ages at first service were significantly (*P*<0.05) longer for cows owned by HHs in *Yeferezye*, *Wukiye* and *Kochira* PAs which all are found in *weinadega* agroecology.

4.1.7.4. Age at first calving

Age at first calving determines the beginning of the cow's productive life and influences her lifetime productivity (Ojango and Pollott, 2001). The estimated mean age at first calving for the study areas is shown in Table 18. Age at first calving has a significant influence on total cost of raising dairy replacements with older calving heifers being more expensive than younger ones (Tozer and Heinrichs, 2001). There are different factors to advance or delay age at first calving. The time taken by animal to attain puberty and sexual maturity depends mainly on the quality and quantity of feed available, which affects growth rate and hence age at first calving. There has been substantial evidence that dietary supplementation of heifers during their growth will reduce the interval from birth to first calving since heifers that grow faster will cycle earlier and exhibit behavioral estrus. The overall estimated mean age of heifers at first caving for the current study was 62.44 months. Estimated mean ages at first calving for study PAs were significantly different (P<0.05). The observed difference could be attributed to differences in level of management between producers found in different PAs and agroecologies.

4.1.7.5. Days open

Overall estimated mean of days open for the cows in the study areas of Gurage zone is indicated in Table 18. An increase in the number of days between calving and conception influences profitability of the dairy production due to increased breeding cost, increased risk of culling and replacement costs and reduced milk production (De Vries and Risco, 2005). The overall estimated mean of days open for the current study was 211.44 days. There was no marked difference (P>0.05) in length of days open among most of study PAs in both agroecologies. However, the average estimated values of days open recorded on the *dega* PAs of *Achene* and *Shamene* was significantly lower (P<0.05) than the *weinadega* PA of *Wukiye*. As to the perception of the households of the study areas participated in the study, the main causes to prolong the days between caving and conception were mainly of feed shortage, allowing calves to suckle, tethering of cattle around homestead which restricts cow’s opportunity to get bull.

4.1.7.6. Calving interval

Calving interval is a function of calving-to-conception or days open, which is considered to be the most important component in determining the length of calving interval. The overall estimated mean of calving interval of current study for the cows in the study areas of Gurage zone is indicated in Table 18. The overall estimated mean of calving interval reported in *Wukiye* PA of *weinadega* agroecology was significantly longer (P<0.05) than the estimated mean of calving interval reported at PAs of *Shamene* and *Achene* in *dega agroecology*. Nevertheless no marked difference (P>0.05) was observed in caving interval among the rest of study PAs of both agroecologies. The overall estimated mean of caving interval for the current study was 481.44days (16months). Nutritional conditions that vary seasonally and yearly have major effects on calving interval. Increased calving interval is undesirable, particularly in a production system in which there is a high demand for pregnant and lactating cows.

Table 18: Mean (±SE) productive and reproductive performance of dairy cattle in all study PAs of Gurage zone.

	Productive and reproductive performance variables					
Study PAs	MY (kg/day)	LL (days)	AFS (months)	AFC (months)	CI (days)	DO (days)
Shamene	$1.74\pm.08^{a}$	220.89±4.4	$51.24\pm.5^{ab}$	$60.24\pm.5^{ba}$	474.67 ± 3.8^{a}	204.67 ± 3.8^{a}
Achene	$1.72\pm.09^{a}$	221.00±4.6	$50.89\pm.6^{a}$	$59.89\pm.6^{a}$	476.00 ± 4.4^{a}	206.00 ± 4.4^{a}
Moche	$1.58\pm.08^{ab}$	216.22±4.1	$52.73\pm.7^{ab}$	$61.73\pm.7^{ba}$	483.00 ± 3.2^{ba}	213.00 ± 3.2^{ab}
Agata	$1.53\pm.07^{ab}$	213.44±3.9	$53.16\pm.7^{abc}$	$62.16\pm.7^{abc}$	482.67 ± 2.9^{ab}	212.67 ± 2.9^{ab}
Shehremo	$1.48\pm.07^{bc}$	211.22±4.2	$53.56\pm.7^{bc}$	$62.56\pm.8^{bc}$	484.56 ± 3.6^{ba}	214.56 ± 3.6^{ba}
Wukiye	$1.41\pm.06^{bc}$	217.44±3.9	$55.29\pm.7^{c}$	$64.29\pm.7^{c}$	487.11 ± 3.1^{b}	217.11 ± 3.1^{b}
Yeferezye	$1.27\pm.06^{c}$	211.11±4.3	$55.38\pm.9^{c}$	$64.38\pm.9^{c}$	485.11 ± 2.4^{ab}	215.11 ± 2.4^{ab}
Kochira	$1.52\pm.09^{ab}$	222.44±4.7	55.24 ± 1.1^{c}	64.24 ± 1.1^{c}	478.44 ± 2.9^{ab}	208.44 ± 2.9^{ab}
Mean	1.53±.04	216.72±1.5	53.44±.3	62.44±.3	481.44±1.2	211.44±1.2

$^{a-c}$ means in the same column followed by the same letter of superscript for a trait are not significantly different (P>0.05), PAs = peasant associations, MY = milk yield, LL = lactation length, AFS = age at first service, AFC = age at first calving, CI = calving interval, DO =days open.

4.1.8. Major constraints of dairy cattle production

Depending on the results obtained from HHs' interview, feed shortage, low production and reproductive performance of indigenous animals, water scarcity during dry season and animal diseases were the major challenges identified in a descending order for dairy production and productivity in the study areas of Gurage zone (Table 19).

4.1.8.1. Feed shortage

Around 68.1% of the interviewed HHs of both agroecologies of the study areas of Gurage Zone indicated feed shortage as the first constraint of livestock production and productivity. Land shortage for grazing and fodder production due to the expansion of crop agriculture in the expense of grazing land was the major reason for feed shortage. It was also indicated during the group discussion that the quantity as well as the quality of natural pasture produced was very low to meet the nutrient requirement of animals. Prolonged dry period, erratic rain fall and uneven distribution of rainfall could affect the growth performance of natural grasses and crops which can limit residues production. Moreover, the absence and/or low availability of improved forage seeds and extension services rendered to this regard was almost insignificant and aggravated the shortage of livestock feed in the study area.

Establishment of clear land use and management policies, introduction of extension service on storage and efficient utilization of crop residues, establishment and management practices of improved forages and technical interventions to improve the existing grazing lands were some of important points raised by interviewed HHs and group discussants to words the alleviation of livestock feed shortage. The HH participants and group discussants also described that the number of animals allowed for grazing are greater than the carrying capacity of the grazing lands. Because of this imbalance, grasses are overgrazed and little ground cover was left, which favors soil erosion.

Farmers in the study area have also encountered problems of crop failure because of erratic rainfall, diseases, decreased soil fertility, increased in soil acidity, low capacity of most farmers to purchase and utilize farm inputs to produce crops enough to support year round consumption of the family members of the HH. Because of the aforementioned problems and others, farmers in the study area are highly dependent on *enset (E. ventricosum*) production which has strong interdependence with cattle production and therefore considered as a life-saving strategy by the HHs of the area. Destocking as a strategy to restore the grazing lands was not practiced, but used as copping mechanism only when the HHs encountered with serious feed shortage (Table 21).

4.1.8.2. Low performance of local animals

As indicated in Table 19, low productive and reproductive performance of local animals was the second most important problem and prioritized by 58.9% of the participants. It was emphasized that indigenous animal breeds of the area are generally characterized by small size, low milk yield, slow growth rate and remain unproductive for a longer period. The amount of average milk obtained per cow per day was not more than1.5litters, which is insufficient to satisfy family consumption. As far as artificial insemination is concerned, some attempts were done in the study areas. But the results obtained from the program were insignificant because of lack of integration among the technical and managerial stakeholders. Increasing AI service and crossbreeding with exotic genotype by improving the existing technical and managerial inefficiencies together with adequate supply of feed and veterinary services would contribute in solving the problems.

4.1.8.3. Scarcity of water in dry season

About 51.7% of the HH participants were categorized water as a third major problem for livestock production (Table 20) and it was also recognized as major bottleneck by the groups involved in discussion. For most HHs particularly living in highland agroecology and for those living far away from permanent rivers, water supply was crucial for survival of livestock during dry periods. The HHs of this areas indicated that moving cattle to distant places in search of drinking water took much time and is tedious work.

4.1.8.4. Livestock diseases

Animal disease was the fourth constraint and prioritized by 47.8% of HH participants (Table 19). Prevalent diseases described by participants include: Anthrax (Amharic name: *Aba Senga,* Guragigna name*: Sutiye)*, Blackleg (Amharic name: *Aba Gorba*, Guragigna name*: Yorche Bashe*), Foot and Mouth Disease (FMD) (Amharic name: *Aftegir,* Guragigna name*: Ama)*, Bovine Pasteurollosis (Amharic name: *Gororsa),* Lump Skin Disease (LSD) *(*Amharic name: *Gurbrib*). It was reported that most of these diseases mostly occur between months of July to December. However, the Anthrax was reported to occur during dry season of the year (November to April) when the condition of animals becomes poor as the result of feed inadequacy. The other common disease of livestock in the study areas include: Mastitis (Amharic name: *Yetut Beshta*, Guragigna name *Yetiw Bashe*), Pneumonia (Amharic name: *Yesamba Beshta*) and Metritis (Amharic name: *Yemahtsen Beshta*). These diseases have no common time to occur but can attack the animals at any time within the year when the environments become suitable to multiply and disseminate to the cattle population.

Ecto parasites of Tick (Amharic name: *Meziger*, Guragigna name: *Hereb*), Lice (Amharic name: *Kimal*, Guragigna name: *Kimar*), Fleas (Amharic name: *Kunicha*, Guragigna name: *Kirach*), Minge mites (Amharic name: *Ekek*) were common in the area and their infestation was also reported to be high immediately after long rainy season of the year (October to December). The other parasitic diseases in the study area reported were the internal parasites including Faciolla/Liver Fluke (Amharic name: *Yegubet Till*), Lung Worm (Amharic name: *Yesamba Till*) and Ascaris (Amharic name: *Wosfat*) which was common in wet season of the year (early June to September). Measures of disease prevention (vaccination) and disease control (treatments of disease using drugs) were practiced in the study areas. In most cases the provision of drugs and chemicals used to treat these livestock diseases and parasites were delivered by government. Most drugs and vaccines have delivered through payment of 1.50 to 10.0 birr except for the LSD vaccine which is free of charge. As far as livestock health service giving organizations were concerned, it was reported that at least one livestock health post per three PAs and one livestock health center per *Woreda* town were available.

Table 19: Major challenges on cattle production in study area of Gurage zone

Major constraints (N = 360)	Priority levels of households				
	1	2	3	4	Rank
Feed shortage	245 (68.1)	42 (11.7)	39 (10.8)	34 (9.4)	1st
Local Performance of breeds	19 (5.3)	212 (58.9)	60 (16.7)	69 (19.1)	2nd
Water scarcity	25 (6.9)	64 (17.8)	186 (51.7)	85 (23.6)	3rd
Livestock diseases	71 (19.7)	42 (11.7)	75 (20.8)	172 (47.8)	4th

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

4.1.9. Season of feed shortage

Out of the total sample HHs of both agroecologies, 51% of HHs responded that they encountered feed shortage in dry seasons of the year. About 31%, however, reported problems of getting enough feed to feed their livestock at wet seasons. On the other hand, 18% of the interviewed farmers from both *dega* and *weinadega* agroecologies indicated the existence of feed shortage in both dry and wet season of the year. Feed shortage reported in wet season of the year were a serious problem of HHs found in *dega* agroecology due to lack of open grazing land when compared with *weinadega* areas. As the result, the farmers in the *dega* areas urged to tether their cattle around the homestead and the road sides (*Jeforo*). Based on the results of current study in most study areas, however, feed shortage is more severe during dry season than other seasons. The main reason to reduce the households' ability to produce enough pasture for grazing and hay making was shortage of pasture land due to conversion of grazing lands in to crop agriculture. Simultaneously, shortage of agro industrial by-products together with uncontrolled market price of concentrate feeds (determination of market price is on the hands of the retailers if there are any) were described by farmers as the main problems of feed supply in different seasons of the year.

4.1.10. Households' strategy to overcome feed shortage

Households in the study area have owned grazing land and they provided grazing pasture to their livestock when pasture is available for grazing. When HHs encountered with shortage of feed from their own grazing land, they can use combination of different coping mechanisms to alleviate feed problem during seasons of critical feed shortage. During the dry periods of the year 100% of cattle owners in all study areas utilize *enset* leaf and leaf midribs to feed cattle. In addition to utilization of leaf and leaf midribs of *enset* as cattle feed, about 82.8% HHs in the *dega* and 50% HHs in the *weinadega* agroecology, used crop residues produced from their own farm to feed their animals. Moreover, about 42.7% HHs of *dega* and 33.3% HHs in *weinadega* were used a rented grazing lands as coping mechanisms to alleviate feed shortage (Table 20).

In the study area of both agroecologies, destocking of cattle was practiced only by 22.2% of HHs. Destocking was performed only when the HHs capacity to manage their animals was becoming at risk mostly due to shortage of feed. Although their availability and their contribution as cattle feed were not in significant amount, about 12.2% and 14.2% of HHs in the study area, respectively, utilized nonconventional feed sources (*Atela*/local beer by product) and purchased agro-industrial by-products to their cattle particularly to the milking cows and fattening oxen.

Table 20: Coping mechanisms used by HHs during feed shortage in the study areas of Gurage zone (%).

Agroecologies	industrial byproduct	crop residues	*enset* leaf & midribs	lands renting	*atela*	destocking
Dega (n=180)	15.6	82.8	100.0	42.7	8.9	23.9
Weinadega (n=180)	12.8	50.0	100.0	33.3	15.5	20.6
Total (N=360)	14.2	62.4	100.0	38.0	12.2	22.2

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

4.1.11. Effects of feed shortage on the performance of cattle

The consequences of feed shortage on the performance of cattle in all study areas of Gurage zone include lower milk yield, weight loss, mortality and problem of sign of estrus (Table 21). From total HH respondents, about 91.1% and 89.2%, respectively, indicated milk yield reduction and weight loss were consequences associated with problem of feed shortage. At the same time, mortality due to feed shortage and problem of sign of estrus were reported by 31.4% and 23% of the respondents, respectively.

Table 21: Effects of feed shortage on performance of cattle in study areas of Gurage zone

Effects of feed shortage	HHs response per study *woreda* (%)				Over all (N= 360)
	Ezia (n = 90)	*Muhir and Aklil* (n = 90)	*Cheha* (n = 90)	*Enemor and Aner* (n = 90)	
Lowered milk yield	92.2	94.4	91.1	86.7	91.1
Weight loss	88.9	86.7	90.0	91.1	89.2
Mortality	31.1	24.5	38.9	31.1	31.4
Problem of estrus	27.7	21.1	16.6	26.6	23.0

Woreda = districts, n = number of sample HHs/woreda, N = sample HHs of the study.

4.1.12. Mating systems

About 82.8% and 84.4% of the respondents in *dega* and *weinadega* agroecology, respectively, used natural mating system using local bulls (Table 22). Households of 16.1% from *dega* and 14.5% from *weinadega* agroecology used combined mating system of artificial insemination and natural mating to breed their cattle particularly those HHs living in PAs nearer to towns of *Woreda* Administration where some AI service giving centers were found.

Based on the results obtained from respondent HHs, AI service designed to be delivered in regular program (conventional AI delivery) has almost collapsed since 2002 following the decentralization programme of the government. The structural linkage between the study areas and AI center has become extremely loosen. There was neither collaboration nor regular communication between National AI Center and AI service providers of the areas. Due to lack of concern by the government bodies of the area, the AI technicians lost their interest in the area of insemination. The absence or shortage of the provision of consumable material and equipment used in insemination process such as, sheath, gloves, apron, inseminating gun, containers of liquid nitrogen, motor cycle and others have become determining factor for lower performance of AI and for loss of working interest of the AI technicians.

There are different factors that determine performance of breeding methods in the area. These factors include: knowledge of selection criteria of cows for AI, access and cost of AI service, ease of getting AI/breeding bull service, number of services required per conception, skill of estrus detection and insemination. When the aforementioned factors are well addressed, about 97% of the HHs in the study area of Gurage zone primarily prefer AI/breeding bull to improve genetic potential of their cattle. Genetic improvement of cattle is the key element in the production of milk and milk products which determines the potential of dairy cattle in the study area. In order to respond to high milk demand in this *enset* based production system and to exploit potentials and resources available there, provision of genetically superior dairy cattle and/or good breeding services as per the needs of producers is the prerequisite for the development of dairying.

Table 22: Mating systems of cattle used by HHs in the study areas of Gurage zone (%)

Production system	Mating system		
	NMS	AI	Both AI & NMS
Dega (n = 180)	82.8	1.1	16.1
Weinadega (n = 180)	84.4	1.1	14.5
Total (N = 360)	83.6	1.1	15.3

Dega = highland, *Weinadega* = midaltitude, n = number of sample HHs per agroecology, N = total sample HHs of the study, NMS = natural mating system, AI = artificial insemination.

4.1.13. Seasonal availability of feed resources

Feed resources available at the different months of a year for both *dega* and *weinadega* agroecologies are indicated in Table 23. In the *dega* agroecology, *enset* leaf and leaf midribs, natural pasture and crop residues (straws of barley, wheat and field pea) were the major feed resources. Similarly, in the *weinadega* areas, *enset* leaf and leaf midribs, natural pasture and crop residues (*teff* straw and maize stover) were the major feed resources. The result of current study revealed that in all study PAs, *enset* leaf and leaf midribs was the most common feeds used by HHs particularly in dry season of the year almost covering about 8 months (October to May).

The amount of feed dry matter produced from *enset* leaf and leaf midribs accounted for the most parts of total dry matter feed available to the livestock in the *dega* and *weinadega* agroecologies. When there are extreme cases of feed shortage due to different manmade and natural calamities, HHs in the study areas have utilized the whole parts of *enset* (leaf and leaf midribs, pseudo stem and corm) to maintain the cattle from being endangered. This indicated that *enset* plant is not only the plant that provides food for family members of the HHs but also it is the plant that safeguards life of livestock particularly of cattle thereby keeping the livelihoods of households from being at risk. Crop residues (straws of barley, field pea, wheat and faba bean) in *dega* agroecology and (straws of *teff* and wheat) in *weinadega* agroecology were also used as main feeds during both dry and rainy seasons of the year (December to August) and maize stover was used between months of September to January. Grazing land is dominantly utilized in wet season of the year, mainly between the months of late August to December.

The other feed resources in the study areas of both agroecologies were crop stubbles of different types. On both *dega* and *weinadega* agroecologies of the study areas, stubbles were allowed to be grazed by the livestock of the owners of stubble land between the months of November to February. The livestock of other farmers can use the remains of stubbles after the animals of the owners have grazed much of the available feed. Even though not in significant amount, crop weeds, maize thinning and older leaves of maize were detached and fed to animals during rainy season of July to mid-September to supplement the limited supplies from grazing lands.

The pattern of feed resource availability in all agroecologies is strongly influenced by seasons of the year. Between the months of June to August HHs in the study areas of both agroecologies keep their livestock around and in front of home stead, on the road sides commonly known as *Jeforo* as well as tethered them on the sides of crop lands. At this period of the year, farmers have been encountered with serious problems of getting feed from natural pasture and *enset* crop. Therefore, the HHs of the study area tried to avert the problem of feed by utilizing the crop residues stored for later use.

Table 23: Seasonality of feed resources across months of the year in the study areas of Gurage zone

Feed sources of the study areas	Months of the year from September to August (2*,1**)											
	S	O	N	D	J	F	M	A	M	J	J	A
Stubbles	1	1	2	2	2	2	1	1	1	1	1	1
Straws	1	1	1	1	2	2	2	2	2	2	2	2
Maize stover	2	2	2	2	2	1	1	1	1	1	1	1
Natural pasture	2	2	2	2	1	1	1	1	1	1	1	2
Enset leaf	1	2	2	2	2	2	2	2	2	1	1	1
Weeds of crops	2	1	1	1	1	1	1	1	1	1	2	2

2* = feed is available in the specified months, 1** = feed is not available in the specified months, S = September, O = October, N = November, D = December, J = January, F = February, M = March, A = April, M = May, J = June, J = July, A = August.

4.1.14. Crop residues storage time and mechanisms of utilization

Collection of crop residues follows harvesting of the grain. Crop residues storage time and forms of crop residues utilization in the study areas of Gurage zone is shown in Table 24. In both *dega* and *weinadega* agroecologies, about 24.4% of the respondents provided crop residues to their livestock immediately after collection. Provision of crop residues immediately after collection is most likely related with availability of few grazing lands and absence of other alternative feed resources to feed the animals adequately. On the other hand, around 42.5% and 33.1% of respondent of both agroecologies stored crop residues for more than 1 and 2 months, respectively, before feeding to livestock.

Concerning the mechanism/forms of crop residues feeding, 70.5% of the HHs offered crop residues to their livestock without any physical or chemical treatment (Table 26). About 17% of the HHs provided crop residues to their animals after chopping (physical treatment) while the rest of 12.5% provided the residues of crops by mixing with other feeds such as green grasses, leaf and leaf midribs of *enset* (*E. ventricosum*).

Table 24: Length of storage time and mechanisms of crop residues feeding in the study areas of Gurage zone (%)

Study *woreda*	Feeding time (n = 90)			Mechanism of feeding (n = 90)		
	Soon after collection	After 1 month	After 2 months	Without change	Chopped	Mixed other feed
Ezia	25.6	44.4	30.0	64.4	20.0	15.6
Muhir & Aklil	25.6	38.9	35.5	75.6	13.3	11.1
Cheha	30.0	41.1	28.9	73.3	21.1	5.6
Enemor& Aner	16.6	45.6	37.8	68.9	13.3	17.8
Overall (N=360)	24.4	42.5	33.1	70.5	17.0	12.5

Woreda = district, n = number of sample HHs/*woreda*, N = sample HHs of the study.

4.1.15. Types of crop residues storage

In the study areas of *weinadega* agroecology, 30.6% of HHs stacked the collected crop residues under shelter whereas 69.4% of farmers from the same agroecology stacked crop residues outside with no shade in the form of conical shape to protect the residues from being damaged by rain. On the other hand, about 67.2% of farmers at *dega* agroecology, stacked the residues of crop under shelter. The remaining 32.8% of HHs heaped the residues outside in conical shape pattern to reduce damage by rain and stored for future use (Table 25). Based on the results of current study, farmers in both agroecologies of the study areas did not practice balling of livestock feeds mainly due to lack of opportunity for balling technology. Heaping crop residues either inside or outside of shade in loose manner requires vast area of storage and it was the only practice done by the HHs. This method of crop residues storage can affects the efficiency of crop residues mainly those heaped outside with no shade due to rain and other weather conditions.

Table 25: Storage type for crop residues practiced by HHs of study areas of Gurage zone

	Types of crop residues storage (%)			
Agroecology	Stack outside	Stack inside	Balled outside	Balled inside
Dega (n = 180)	32.8	67.2	0	0
Weinadega (n = 180)	69.4	30.6	0	0
Overall (N= 360)	51.1	48.9	0	0

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

4.1.16. Composition of natural pasture lands in the study areas

Pasture samples collected from grazing lands represented about 89% and 86% grasses species and 4.2% and 3.1% legumes from *dega* and *weinadega* agroecologies, respectively, in dry matter base. The types of legumes found in natural pasture in the study areas were the Trifolium S*pps* known as *Trifolium repens* (white clover) and *Trifolium pretense* (red clover). *Trifolium repens* (white clover) were highly dominant in *dega* than *weinadega* areas whereas *Trifolium pretense* (red clover) was found in greater proportion in weinadega areas than *Trifolium repens* (white clover). Besides the Trifolium *Spps,* some Desmodium *Spps of Desmodium intortum* (Greenleaf Desmodium) and *Desmodium uncinatum* (Silverleaf Desmodium) were observed in the *weinadega* agroecology of the study areas.

Biomass yield of grasses, forage legumes and forbs in kilogram, respectively, was 1484.84, 70.07 and 113.45 for *dega* whereas it was 1399.53, 50.45 and 177.38 for *weinadega* areas per hectare of land (Table 26). The lower proportion of legumes monitored in the study areas might probably be due to sprawling nature of growth of legumes which make them more susceptible to grazing pressure. Furthermore, the percent biomass composition of legumes in *weinadega* agroecology area was found to be lower than that of *dega* agroecology. The variation observed among *dega* and *weinadega* areas might be associated with the altitudinal differences in elevation of highland and midaltitude.

Table 26: Percentage of grasses, forage legumes and forbs from area closure in the study areas of Gurage zone.

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

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

4.1.17. Improved forage resources

At present, in the study areas in particular and in Gurage zone in general a little attention has been given for the development of improved forage resources. Very few households in the *dega* agroecology have tried to plant a forage plant called Tree Lucerne/Tagasaste (*Chamaecytisus palmensis*) in front of their living home which primarily used as life fence and tree of ornament. Similarly, farmers of very few number in the *weinadega* agroecology, have planted the forage plant known as Susbania (*Susbania susban*) around their homestead together with fences and most of the farmers used this forage plant for life fence purpose and fire wood. On the other hand, nearly few HHs mostly in *dega* agroecology reported to use improved forages, such as Oat (*Avena sativa*) and Vetch (*Vicia sativa*) as green animal feed which were insignificant in amount.

4.1.18. Major reasons hindering the development of improved forages

The use of improved forages as animal feed was not well adopted by farmers in all study areas of Gurage zone. There are many reasons of hindering the development and utilization of improved forages in the study areas. Households of 15.6% from *dega* and 27.8% from *weinadega* agroecology reported that the major constraint for improved forage development was shortage of land. Similarly, 17.8% and 10% of HH respondents from *dega* and *weinadega*, respectively, indicated that shortage of forage seeds and other inputs were major bottlenecks to bring change in the improved forage development. On the other hand, 52.2% HHs from *dega* and 53.9% HHs at *weinadega* agroecology reported that they don't have awareness on how to establish, grow and utilize improved forages (Table 27).

The result of current study indicated that the extension service rendered in improved forage development was somewhat weak. Personal communications with some members of farmers as well as experts were made to understand the reason for weak extension services rendering. Accordingly, one of the reasons for hindering the development of improved forages and the existence of weak extension service is lack of ability of some DAs to aware the farmers on how to establish, grow and utilize improved forage plants. Those development agents who have capacity of empowering the farmers in areas of animal production, improved forage development and utilization, on the other hand, have lost their interest to work in their field of study (profession) and have changed their occupation either through changing their area of study or by leaving their job from livestock subsector because of different reasons.

The reasons for changing of their profession and leaving existing employment is mostly associated with lack of incentives, differences in scale of salary from other professionals having similar qualifications, external and internal pressure to carry out the activities of crop agriculture leaving aside the activities of livestock agriculture. Furthermore, attention given by the concerned governing and policy making bodies to the livestock resource development is insignificant. Though Office of Livestock and Fisheries Development have been established since 2015 in each administrative levels, the newly established Zonal and *Woreda* offices have no power to undertake activities by their own and to bargain on such activities with administrative and other concerning bodies to bring change in production and productivity of the sub-sector but simply running her and there to accomplish a routine activities which had already been in the past (Dirsha D, Personal communication).

Table 27: Improved forage development constraints of in study areas of Gurage zone

Agroecologies	HHs response on constraints of improved forage development (%)			
	Shortage of land	Shortage of seed	Lack of knowledge	lack of finance
Dega (n = 180)	15.6	17.8	52.2	14.4
Weinadega(n = 180)	27.8	10.0	53.9	8.3
Over all (N = 360)	21.7	14.0	53.0	11.3

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

4.1.19. Feed resources and feeding practices

In both *dega* and *weinadega* agroecologies of Gurage zone, cattle production system is dominated by extensive system of production where most of the time farmers depend largely on feeding their livestock with leaf and leaf midribs of *enset* (*E. ventricosum*), natural pasture and crop residues. Based on the responses of interviewed HHs as indicated in Table 28, about 26.7% from *dega* and 42.8% from *weinadega* agroecology were practiced a combination of cut and carry and grazing system of feeding. A combination of cut and carry, tethering and grazing were the feeding practices under taken by 28.9% farmers of *dega* and 33.9% from *weinadega* agroecology. Tethering and cut and carry system were other alternative feeding practices carried out by 44.4% and 23.3% of HHs in *dega* and *weinadega* agroecology, respectively.

Although not in significant amount, freshly cut green feeds of crop weeds, maize thinning and older leaves of maize were detached and fed to the animals during rainy season to supplement the inadequate feed supplies from grazing. The daily feed supply to animals was not measured by any of the cattle owners and feed was somewhat provided roughly based on feed availability and daily milk yield.

Table 28: Feeding practices of cattle in the study areas of Gurage zone

Agroecology	Responses of HHs on feeding practices of cattle (%)		
	Grazing & cut and carry	Tethering ,grazing and cut & carry	Tethering & cut and carry
Dega (n = 180)	26.7	28.9	44.4
Weinadega (n = 180)	42.8	33.9	23.3
Over all (N = 360)	34.7	31.4	33.9

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

4.1.20. Feeding priority of cattle

Feeding strategy depends on the nature of the farming system, objective of herding animals and the availability of feed resources in specific area which is to be affordable by the farmers. In line with this, farmers in the current study areas were interviewed about feeding priority of crop residues and supplements to their animals. From a total of 360 HHs included in the study, about 42.5% of HHs were given priority of feeding to lactating cow. Around 35% of the HHs gave more attention to calf whereas the rest 12.8% and 9.7% of HHs, respectively, gave priority of feeding for weak animal and plowing oxen. Therefore, farmers in the study area of Gurage Zone gave more attention to the lactating cows, calves and weak animals than the plowing oxen (Table 29).

The HHs in study areas (*enset* growers) have perceived that why the first priority is given to lactating cows is because of its advantage in providing (1) milk and milk products for home consumption with *kocho* (food prepared from a mixture of scraped pulp of the *enset* pseudo stem excluding the fibers and decorticated corm of *enset*), (2) manure to fertilize the *enset* garden and (3) calf for herd replacement. The calves were given the second priority because of their advantages of (1) permanent milk production of milking cows (if the calf dies, the cow will immediately stop giving milk) and (2) to produce replacement stock in the herd. Furthermore, the HHs realized that the individual land holding is limited, as the result they have given less attention to produce annual crops of cereals and pulse by giving more attention for *enset* (*E. ventricosum*) cultivation to produce *kocho* to nourish his/her family members and therefore, *enset* production system encourages the use of human labor than oxen to cultivate crop land.

Table 29: Feeding priority of cattle by households in the study areas of Gurage zone (%)

Study *Woreda* (n = 90)	Lactating cow	Calf	Week animal	Oxen	Total
Ezia	39 (43.3)	31 (34.5)	11 (12.2)	9 (10.0)	100
Muhir and Aklil	38 (42.2)	29 (32.2)	13 (14.5)	10 (11.1)	100
Cheha	40 (44.4)	32 (35.6)	12 (13.3)	6 (6.7)	100
Enemor and Aner	36 (40.0)	34 (37.8)	10 (11.1)	10 (11.1)	100
Over all (N = 360)	153 (42.5)	126 (35.0)	46 (12.8)	35 (9.7)	100

Woreda = district, n = number of sample HHs/*woreda*, N = sample HHs of the study.

4.1.21. Length of grazing hours

Cattle owners in the study areas let their cattle to graze on own grazing lands between 8:00amto 6:00pm. The estimated average grazing hours were 6.27hrs in *dega* and 8.11hrs/day in *weinadega* with overall average grazing hours of 7.19/day. As indicated in Table 30, the length of estimated average grazing hours in *weinadega* agroecology was significantly higher ($P<0.05$) than in *dega* agroecology. Most of the time, herders in the *dega* agroecology brought their cattle back to home from grazing field earlier which contributed to the shorter grazing period as compared to cattle found in *weinadega* agroecology. The purpose of bringing cattle back to home earlier is to protect the limited available grazing lands from being intensively over grazed and to provide some additional supplementary feeds to the cattle such as leaf and leaf midribs of *enset*, crop residues of different types and cut grass.

Table 30: Length of livestock grazing hours in *dega* and *weinadega* of Gurage zone

Agroecology	(Mean ±SE)	Minimum	Maximum
Dega	$6.27 \pm .06^{b}$	5	8
Weinadega	$8.11 \pm .11^{a}$	6	10
Over all	7.19±.08	5	10

$^{a\text{-}b}$ means in the same column with different letter of superscript are significantly different ($P<0.05$), *Dega* = highland, *Weinadega* = midaltitude.

4.1.22. Milking method, time and frequency

Hand milking is the only milking method practiced across all the study PAs of both *dega* and *weinadega* agroecologies (Table 31). Every necessary prerequisites, such as the sanitation of the barn, personnel involved in milking and the utensils used to collect and store milk were given due attention to produce relatively hygienic milk. Cleaning of the cows' udder and teats before milking with clean water was done which contributed in the production of milk with good sanitation. Practically, all the producers in the study areas were practiced the cleaning of milking and milk storage utensils mostly using hot water and the utensils were smoked with woody plants having good aroma such as Weyira (*Olea africana*). The method of smoking of milking and milk storage utensils was believed to improve the flavor, taste, quality of milk and milk products as well as extends the shelf life of dairy products.

Different types of utensils are used for milking, milk handling and milk processing in the *enset* based dairy production system of Gurage zone. In all study PAs of both *dega* and *weinadega* agroecologies, most HHs used equipment (clay pots) made of mud in *Guragigna* known as *Yeb-Enjaba*, *Yeb-Egujet* and *Yeb-Wesher* for milking, storage and churning, respectively. Now a day, however, a number of HHs of the study area have utilized plastic utensils specially for milking purpose which is replacing the *Yeb-Enjaba*. The result obtained in *enset* based dairy production system of both agroecological zones of Gurage area indicated that hundred percent (100%) of the HHs milk their cows twice a day; at 6-8am in the morning and 7-9pm in the evening (Table 31).

Table 31: Milking method, time and frequency in the study areas of Gurage zone

Study *woreda* (n = 90)	Milking method (%)		Milking time (%)		Milking frequency (%)		
	Hand	Machine	Morning	Evening	Once	Twice	Thrice
Ezia	100	0	100	100	0	100	0
Muhir & Aklil	100	0	100	100	0	100	0
Cheha	100	0	100	100	0	100	0
Enemor &Aner	100	0	100	100	0	100	0
Total (N = 360)	100	0	100	100	0	100	0

Woreda = districts, n = number of sample HHs per *woreda*, N = total sample HHs of the study, M&E = morning and evening.

4.1.23. Milk selling, collection and churning

4.1.23.1. Milk selling

As indicated in Table 32, marketing of fluid milk is not common in *enset*-based dairy production system of all study sites of Gurage zone. Most of milk produced was consumed at home with *kocho* whereas butter and *ayib* produced from milk left after family consumption are commonly marketed dairy products. The absence of fluid milk selling and presence of milk churning practice were reported by all HHs participated in the current study. There is no any taboos and cultural reasons forcing the producers not to sell the fluid milk. The main reason for the absence of milk selling in the study area was low production of milk by individual HH. Because of almost all breeds of cattle maintained in this area are indigenous zebu, amount of milk produced per day per individual cow was very low and it never gives opportunity of selling liquid milk by the HHs of the study areas.

4.1.23.2. Practices of milk collection for churning

To produce butter and *ayib*, wives of HHs collect some days' milk together and process it in to butter and *ayib* for sale or home consumption. Collecting of milk for butter and *ayib* making (for churning) is practiced in two ways:

1. First method of collecting milk for churning is common practice that has been done in most areas of Ethiopia by collecting some days' (2-4days) milk produced by individual HH, let the milk to sour and allowed the sour milk to be churned.
2. Second method of milk collection for churning is practiced by collecting of measurable amount of milk from a group made by a number of 3-4 HHs wives of neighborhood and ruled by bylaws (unwritten) established by the group members of HHs wives. The milk measuring equipment could be glass, jog or locally made equipment in *Guragigna* called *Jerr, Enjaba, Kuarye*, etc.).

The method of milk collection by forming groups from neighboring HH wives in *Guragigna* known as *Wujo* and mainly performed by those HHs wives who have small number of milking cow(s) and/or possessing milking cow(s) of low milk production potential. Milk collection by members of milk group (*Wujo* performer) was carried out by 48.9% of HHs wives participated in this study (Table 32). The milk group members revealed that making the group to collect milk for churning through *Wujo* helped the members in providing opportunity of collecting and bringing small amount of milk produced by individual group member which might not be considered for churning.

The *Wujo* performers also disclosed that milk collecting process is done by round depending on the amount of milk produced in the days allocated (mostly, 2-3 days) to collect 6-8kg of milk to be churned by the member of the group. However, the amount of milk to be collected by the group members for one churning (one group member) depends not only on the number of days fixed for milk collection but also by seasonal variation of the year. In drier seasons, there is the extension of number of days to collect amount of milk enough for one churn. In spite of availability of better quantity and quality feed for milking cow(s) in wet seasons, there is a chance of shortening the number of days needed to collect milk enough for one churn. Hence, the extending or shortening of the days to collect milk for churning largely dependent on the quantity and quality of feed available to feed the milking cows.

Table 32: Milk selling, collection and churning in the study areas of Gurage zone (%)

Study *woreda*	Milk selling		Milk churning		Milk collection from neighbor to churn	
	Yes	No	Yes	No	Yes	No
Ezia (n = 90)	0	100	100	0	54.2	45.8
Muhir and Aklil (n = 90)	0	100	100	0	42.6	57.4
Cheha (n =90	0	100	100	0	46.7	53.3
Enemor and Aner (n = 90)	0	100	100	0	52.2	47.8
Overall (N = 360)	0	100	100	0	48.9	51.1

Woreda = districts, n = number of sample HHs/*woreda*, N = Total sample HHs of the study.

4.1.23.3. Churning process of milk

The traditional butter making (churning) in the Gurage area is based on sour milk. The milk for processing can be collected either from single milking cow, from large number of cows or milk collected by group members of *Wujo* performers. The equipment commonly used in churning is clay pot. Some members in the area might use a stick with 4 (common) - 6 finger-like projections at one end (in Amharic called *Mesbekia* and in Guragigna called *shirmet*) to mix and steer the sour milk before commencement of churning. This milk steering/mixing is important to reduce the size of formed curdles of sour milk and to fasten the process of butter making. In most cases, the use of stick *(shirmet*) is uncommon and the HH wives use only churning pot made of clay. In the study areas of Gurage zone, milking is performed two times (morning and evening) per day and as soon as milking is over, the milk is transferred in to a clay pot (in *Guragigna* called *Yeb-Egujet*) of clean and well smoked with different woody items having good aroma and kept closed at room temperature until the commencement of churning.

Milk from different milking times is added in to the *Yeb-Egujet* and kept for churning until enough amount of milk for churning is collected. Usually the quality of the formed curdle of sour milk is visually evaluated and its readiness is determined by the female member of the HH who has long experience on doing so. The churning operation commences usually after stirring the content (sour milk) and transferring the sour milk in to another clean and smoked churning clay pot (in *Guragigna* called *Yeb-Wosher*). After transfer, the opening or mouth of the churning pot (*Yeb-Wosher*) is sealed using dried but well prepared, unteared and well soaked *enset* leaf sheaths (internal surface of the sheath, in Guragigna called *Aniwa*) and tied it firmly using jute rope (*kacha*) made of decorticated pseudo stem of *enset*.

At the neck part of the churning pot, there is a small hole (in Guragigna called *Fifwet*) made for releasing the developed gas at the time of churning and to visualize the completion of churning process (butter formation) without opening the mouth of the churn. The churn (*Yeb-Wosher)* containing sour milk is agitated by placing it on a mat (made of *kacha* and dried *enset* midribs in *Guragigna* called *Wedere*), unprocessed skin or hide, sacks, grass, worn out blankets or other garments on the floor and rocking the churn back and forth until butter is made. The developed gas is released every 1-5 minutes by opening the *Fifwet* made at the neck part of the *Yeb-Wosher* during churning. The process of butter making may take 1:00-1:30 2hrs depending on the temperature of the day and amount of sour milk under churning.

The HHs wives of the study area of Gurage zone have appreciated the role of cooler temperature to shorten the process of butter making. Butter formation and completion of churning process was determined by visually checking the presence or absence of fat granules by over flowing a small amount of milk under churning process through *Fifwet* of the churn. If granules of fat are observed, the process of churning will continue. When the fat granules are absent and the sour milk become clear in content, the process of churning will stop and the butter is taken out from *Yeb-Wosher*. The back and forth movement of the churning pot (*Yeb-Wosher*) containing the sour milk is manually performed in a traditional way. In most cases, the process of butter making in current study areas of Gurage zone was similar to the process of churning in most parts of the country as reported by Fekadu (1994), in southern Ethiopia and Zelalem and Inger (2000), around Holetta and Debre Zeit areas.

4.1.24. Milk products consumption and marketing

The type of dairy products usually sold and market types to sell dairy products in the *enset* based dairy production system of Gurage zone are indicated in Table 33. Consumption pattern of milk and milk products produced at home varies depending upon the amount of milk produced per HH, season of the year, and fasting period particularly for the followers of Orthodox Christian. Fresh and fermented milk, homemade cheese (*Ayib*) and butter are the most common products produced in all agroecologies of the study areas and the major dairy products commonly marketed in the study areas are butter and *Ayib*. About 66.7% of HHs participated in the study revealed that butter was the major dairy product to be sold by the households. Furthermore, around 19.7%

respondents were reported their participation in practicing selling of both butter and *Ayib* and the rest 13.6% of the respondents disclosed their involvement in selling of *Ayib* only.

In the study areas, milk products are marketed mainly through informal markets where producers sell the products of milk to direct consumer, unlicensed traders and retailers directly either on homestead or open local market (Table 33). Based on the results obtained from interviewed HHs of *enset*-based dairy production systems of Gurage zone, 67.2% of the marketed dairy products of butter and *Ayib* were sold at locally established open markets. Accordingly, 15% and 17.8% respondents of both agroecologies were sold their marketable dairy products to consumers or retailers at home gate and by combination of home gate and local open market, respectively.

Table 33: Dairy product marketing and market type in study areas of Gurage zone (%)

Agroecology	Dairy product marketing				Dairy product market type		
	Whole milk	Butter	Cheese (*Ayib*)	Butter & *Ayib*	HS	LM	HS & LM
Dega (n=180)	0	70.6	13.3	16.1	16.7	68.3	15.0
Weinadega(n=180)	0	62.8	13.9	23.3	13.3	66.1	20.6
Over all (N=360)	0	66.7	13.6	19.7	15.0	67.2	17.8

Dega = highland, *Weinadega* = midaltitude, n = number of sample HHs per agroecology, N = total sample HHs of the study, *Ayib* = homemade cheese, HS = homestead, LM = local market.

4.1.25. Market price of dairy products

The selling and/or buying price of milk products in the study area was usually set through negotiation between the seller (producer) and the buyer (consumer). The average price of milk products of butter and *Ayib* in long dry season (Late of October to Mid of February), short rainy season (Late of February to May) and long rainy season (June to Mid of October) in the study areas is indicated in Figure 3 and Table 34. The price for locally processed products of milk (butter and *Ayib)* was highest in the long dry season in both *dega* and *weinadega* agroecologies and, respectively, were 164.26 and 170.02 Birr for butter as well as 56.01 and 62.22 Birr for *Ayib*. The overall average price of butter and

Ayib for both agroecologies of *dega* and *weinadega* in long dry season was 167.14 Birr and 59.11 Birr, respectively.

In all three seasons of the year (long dry, short rainy and long rainy seasons), price for butter was highest at *weinadega* agroecology than *dega* agroecology and there was significant difference (P<0.05). Similarly, price for *Ayib* in *dega* agroecology was significantly lower (P< 0.05) than that in *weinadega* agroecology (Table 34). Price variations for butter and *Ayib* among agroecologies could be attributed to proximity of the study PAs of *weinadega* agroecology to towns of each *Woreda* Administration and to the Capital of Gurage Zone, Wolkite town where demand for both products is high.

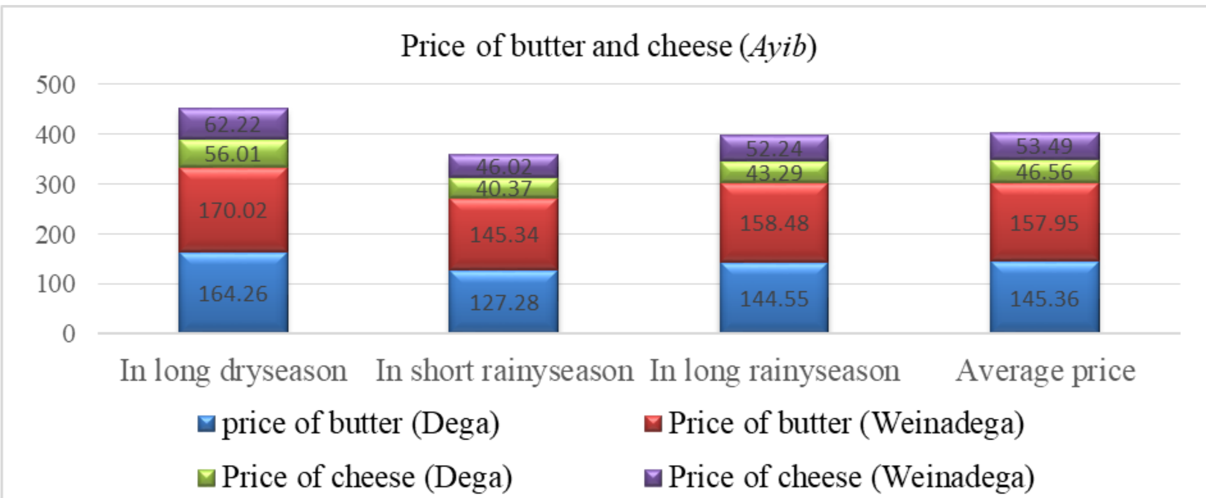


Figure 3: The price of butter and cheese (*Ayib*) in birr in the study areas of Gurage zone.

Price variations for butter and *Ayib* among agroecologies could also be attributed relatively to lower production of these products in the *weinadega* than the *dega* PAs of the study areas. Moreover, lowering in the market price of milk products in *dega* PAs could also be associated with the availabilities of different types of pulse crops, potatoes and vegetables particularly cabbage of different kind to be eaten together with *kocho* by replacing dairy products. On the other hand, variations on the market price of milk products of butter and *Ayib* between seasons of the year has been observed in both agroecologies. The highest average price of 167.14 Birr for butter and 59.11 Birr for *Ayib* was recorded in long dry season and the lowest average price of 136.31 Birr for butter and 43.19 Birr for *Ayib* was recorded in short rainy season (Table 34). The price for butter and *Ayib* was highest in the long dry season whereas it was the least in the short rainy season in all study areas. This is mainly due to absence of competitive purchaser for these products in the area during this season as the short rainy season is the season of longest fasting period of the followers of the Ethiopian Orthodox Church in which these products are prohibited from being eaten and this situation might lower the price of both butter and *Ayib* than any other seasons of the year.

Table 34: Average market price of dairy products at different seasons of the year in the study areas of Gurage zone (2016, December to 2017, November)

Seasons of the year.	Market price of butter and *Ayib* in Birr		
Butter	*Dega* (n =180)	*Weinadega* (n =180)	Average
Long dry season	164.26± 0.58^{b}	170.02±0.64^{a}	167.14±0.46
Short rainy season	127.28±0.66^{b}	145.34±1.02^{a}	136.31±0.77
Long rainy season	144.55±0.63^{b}	158.48±0.86^{a}	151.51±.65
Homemade cheese (*Ayib*)			
Dry season	56.01±.41^{b}	62.22±0.58^{a}	59.11±0.39
Short rainy season	40.37±.51^{b}	46.02±0.42^{a}	43.19±0.36
Rainy season	43.29±0. 34^{b}	52.24±0.72^{a}	47.77±0.46

$^{a-b}$ means with different letters of superscripts in the same row for *dega* and *weinadega* agroecologies of study area differ significantly ($P<0.05$) for market price of butter and *Ayib* at different seasons, *Dega* = highland, *Weinadega* = midaltitude, n = number of sample HHs per agroecology, *Ayib* = homemade cheese.

4.1.26. Calf rearing practices

Free colostrum feeding were practiced by 100% of the respondent HHs and practiced for about 6 to10 days after calving by allowing three times suckling (in morning, mid-day and in evening). Herders in the study areas are well aware of the use of colostrum feeding for the new born animals and understand the beneficial effect on health of the young. Partial suckling of calves prior to milking, during milking and at the end of milking was common practices in almost all sample HHs of current study and calves were allowed to suckle when milking was practiced (Table 35). This practice was believed to stimulate milk letdown. When the calf dead, hide of the dead calf was distended with cereal straw or dried grass with four legs made of sticks. Sometimes salt diluted with water was added to the distended calf hide at the time of milking and the cow was allowed to lick on it in order to simulate presence of calf and milk letdown.

About 89.2% HHs were provided supplementary feeding mostly fresh grasses to calves at one month of age whereas in 10.8% of the cases supplementary feed were provided starting from 15 days after birth. Gathering cut-and-carry forages and providing water for calves kept in or near the family house before weaning was undertaken majorly by female members of the family, mostly above the age of 15 years. Most of the practices of weaning in the study areas were commonly carried out: when the cow is in advanced pregnancy; when the dam dry off, when the cow became aggressive or reduced milk production in descending order of importance. With regarding to weaning age, 63.3% of respondents in *dega* and 65.6% of HHs in *weinadega* agroecology were practiced calf weaning at the age of 6-8 months. Households of about 23.9% in *dega* and 26.7% in *weinadega* agroecology exercised calf weaning at the age between 9-12 months. The rest 12.8% of HHs *in dega* and 7.7% in *weinadega* practiced calf weaning at the age greater than 12 months.

Table 35: Suckling practices and calf weaning age in the study area of Gurage zone (%)

Agroecology	Suckling and colostrum feeding		Weaning age of calf in months		
	Yes	No	6-8	9-12	>12
Dega (n = 180)	100	0	63.3	23.9	12.8
Weinadega (n = 180)	100	0	65.6	26.7	7.7
Over all (N = 360)	100	0	64.4	25.3	10.3

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

4.1.27. Gender labor division for cattle related activities

Milking was commonly done twice a day (once in the morning and once in the evening) in both *dega* and *weinadega* agroecologies. Milking was predominantly (66.4%) handled by HH wives or adult females whereas 22.5% of milking were done by both sexes and the rest 11.1% of milking was done by males (fig. 4/a). Simultaneously, 100% of milk products marketing was practiced by females in both *dega* and *weinadega* agroecologies of the study areas (fig. 4/b). About 56.7% of activities related to calf rearing (fig. 4/c) were associated with the female members of HH whereas the remaining 37.5% and 5.8% activities related to calf rearing was practiced, respectively, by both sexes of family members and male members of the family. Alternatively, 51.7%, 17.5% and 30.8% of cattle herding (fig. 4/d) was practiced by males, females and both sexes of the family members, respectively.

The frequency of barn cleaning varies between seasons and the number of animals owned by individual HHs especially on number of cattle owned. Around 76.67% activity of barn cleaning was mainly done by females whereas 8.33% of barn cleaning was done by male members and the remaining 15% done by both sexes (fig. 4/e). For the most part (72.5%) of activities related to herd feeding and watering was carried out by males, 18.3% was done by both sexes (fig. 4/f). Similarly, in all study areas of Gurage zone, about 76.1% of livestock feed collection activities were the task of males (fig. 4/g). In generalizing gender labor division on cattle related activities (fig. 4/h) in the study areas of Gurage Zone; 39.35%, 38.18% and 22.47% were undertaken by males, females and both sexes of family members, respectively.

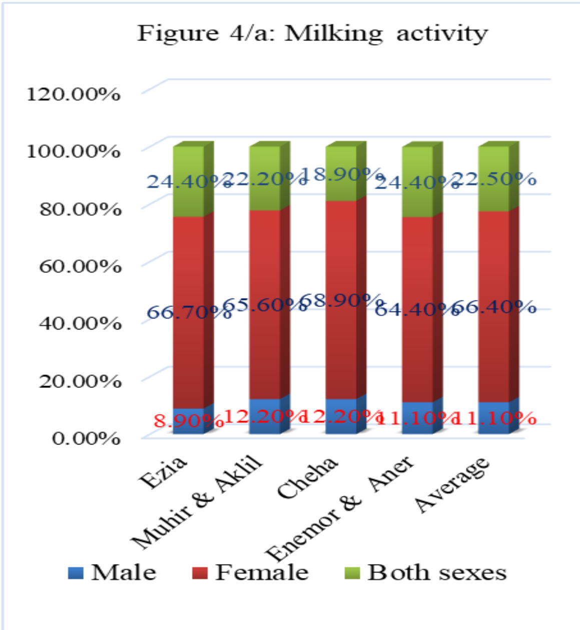


Figure 4/a: Milking activity
120.00%
100.00%
80.00%
60.00%
40.00%
20.00%
0.00%
24.40% 22.20% 18.90% 24.40% 22.50%
66.70% 65.60% 68.90% 64.40% 66.40%
8.90% 12.20% 12.20% 11.10% 11.10%
Ezia
Muhir & Aklil
Cheha
Enemor & Aner
Average
Male
Female
Both sexes

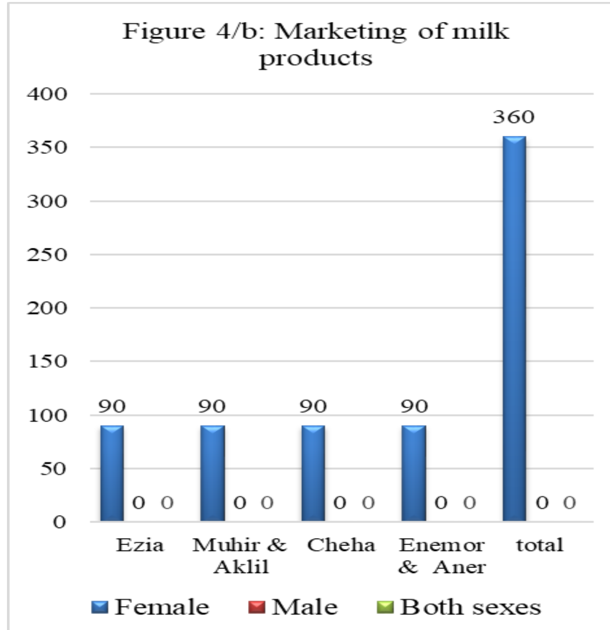


Figure 4/b: Marketing of milk products
400
350
300
250
200
150
100
50
0
360
90 90 90 90
0 0 0 0 0 0 0 0 0 0
Ezia
Muhir & Aklil
Cheha
Enemor & Aner
total
Female
Male
Both sexes

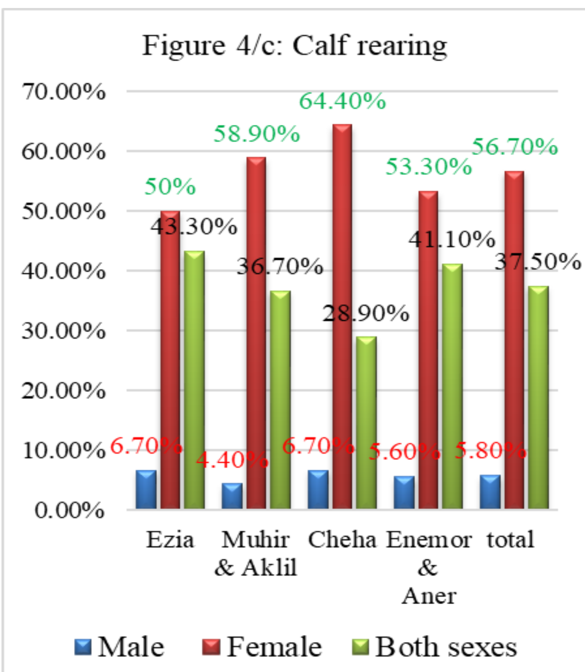


Figure 4/c: Calf rearing
70.00%
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
50% 58.90% 64.40% 53.30% 56.70%
43.30% 36.70% 28.90% 41.10% 37.50%
6.70% 4.40% 6.70% 5.60% 5.80%
Ezia
Muhir & Aklil
Cheha
Enemor & Aner
total
Male
Female
Both sexes

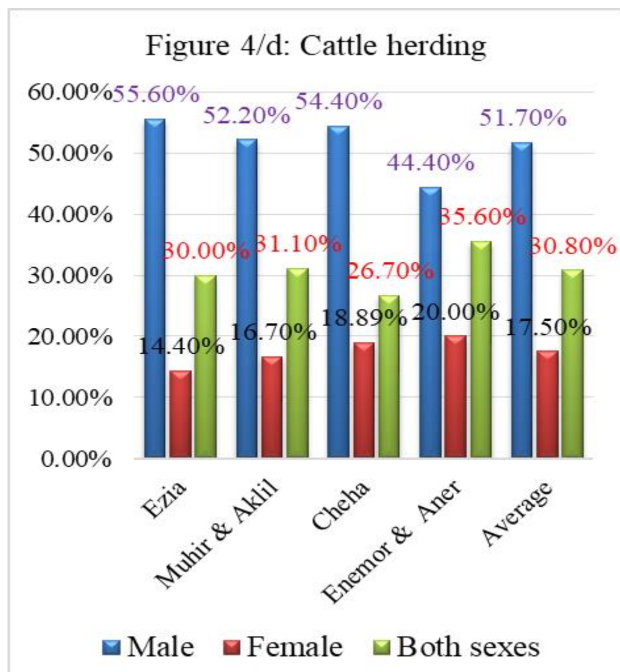


Figure 4/d: Cattle herding
60.00%
50.00%
40.00%
30.00%
20.00%
10.00%
0.00%
55.60% 52.20% 54.40% 44.40% 51.70%
30.00% 31.10% 26.70% 35.60% 30.80%
14.40% 16.70% 18.89% 20.00% 17.50%
Ezia
Muhir & Aklil
Cheha
Enemor & Aner
Average
Male
Female
Both sexes

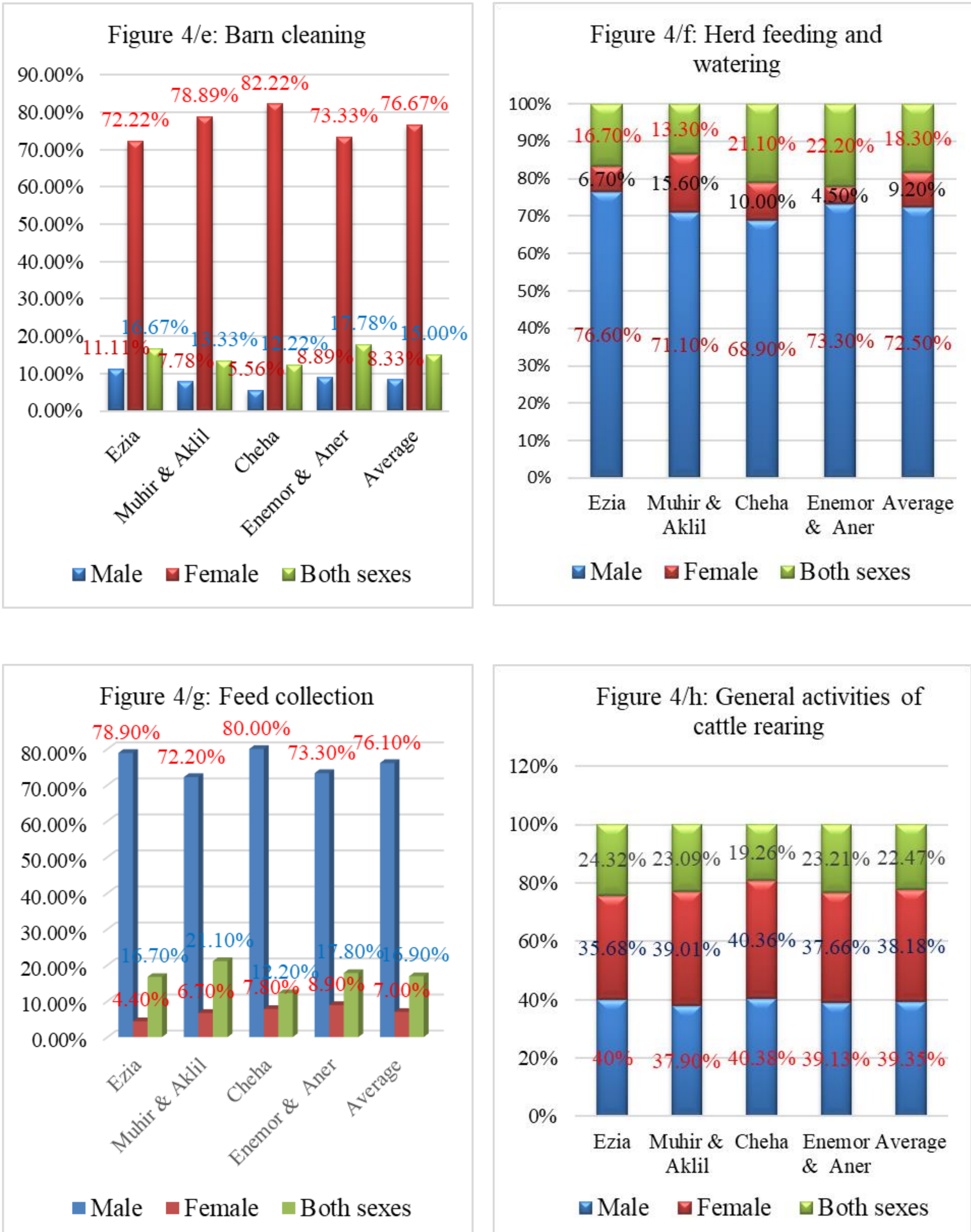


Figure 4: Gender labor division for cattle related activities in Gurage zone

4.1.28. Marketing of cattle

Most often, in the study areas of Gurage zone, brokers are not involved in the market to negotiate the price difference between sellers and purchasers for the milking cows. The price of milking cow is determined by negotiation between the seller and buyer. When there is disagreement between these two partners of market, elders having experience of selling and purchasing skill on milking cows in the local market and/or in the village took the place of negotiation and creates conducive condition between seller and buyer. However, in most cases of other cattle marketing, brokers were the major actor of market on determining the market price of livestock taking the advantage of negotiation between sellers and purchasers. The average local market prices for crossbreds and local breed cattle in the study areas are shown on Figure 5.

The range of the selling/purchasing price of crossbred milking cows and pregnant cows was ranged from Birr 27,500 to 37,000 and 25,000 to 32,000 with an average of 32,250 and 28,500, respectively. Minimum and maximum selling/purchasing prices for in-calf cross breed heifers were ranged between Birr of 20,000 to 25,000 with the average price of 22,500. The range of market price for cross breed dry cows and non-pregnant heifers were 15,000 to 22,000 and 18,000 to 20,000 with an average market price of 18,500 and 19,000 Birr, respectively. The crossbred male calves were sold at early age mostly for slaughtering purposes and the range of the market price for these crossbred male calves were 3,500 to 4,500 with the average prices of 4,000 Birr. On the other hand, the market price of crossbred female calves ranged from 7,000 to 9,000 which averaged to about 8,000 Birr.

The market prices of local female cattle was in the range of 11,000 to 15,000; 9,000 to 11,000; 7,000 to 8,000; 8,000 to 10,000; 5,000 to 8,000 and 3,000 to 5,000 with an average Birr of 13,000, 10,000, 7,500, 9,000, 6,500 and 4,000 for milking cow, pregnant cow, dry cow, in calf heifer; non-pregnant heifer and female calf, respectively. Similarly, the range of the market prices for local bull, oxen and male calves, respectively, was 8,000 to 10,000, 10,000 to 14,000, and 3,000 to 4,000, with the average market prices of

9,000, 12,000 and 3,500 Birr. During the study period (2017), the average exchange rate of $1.0 was about 23.57 Birr.

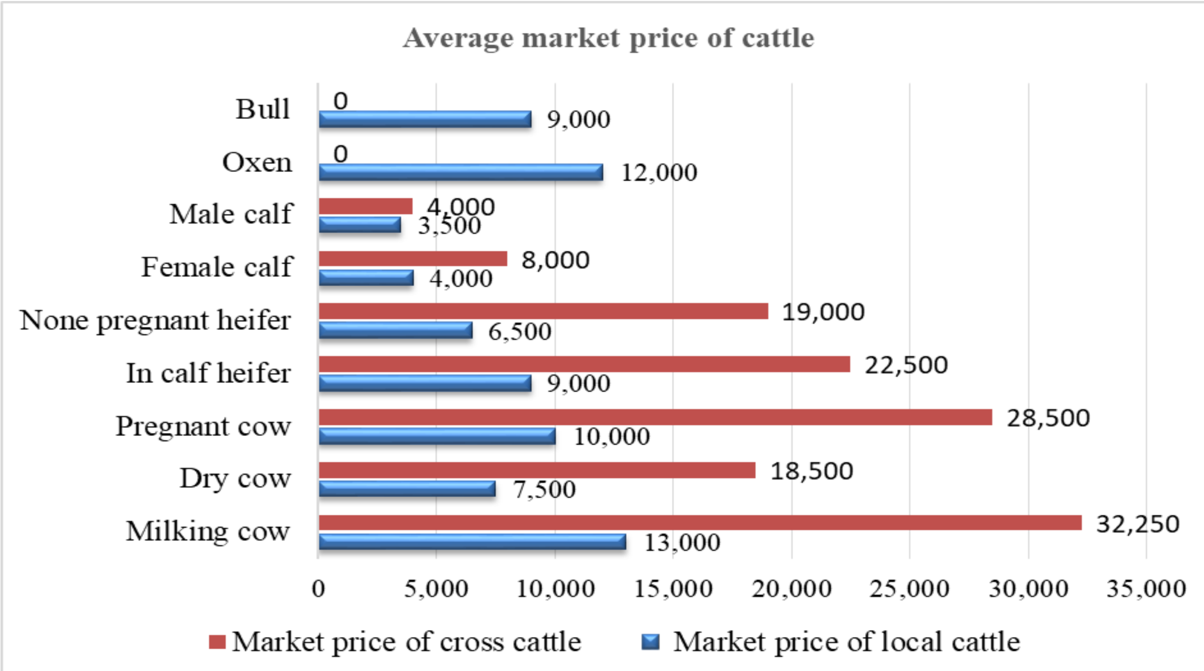


Figure 5: The average market price of cattle in the study areas of Gurage zone in birr.

4.2. Chemical Composition and Nutritive Value of Feeds

4.2.1. Chemical composition of feedstuffs

Chemical composition and nutritive value of the major feedstuffs utilized for livestock feeding in the study areas of Gurage zone was analyzed (Table 36) and the dry matter (DM) content of feeds available for livestock feeding in both *dega* and *weinadega* agroecologies was above 90%. The ash content of the major cereal crop residues in the study area ranged from 6.49% to 9.32% for straws and from 4.23% to 9.81% for stubbles. Wheat straw had the highest ash content of 9.32% in *weinadega* and barely straw has 9.02% in *dega* agroecology (Table 36). The ash content of maize stover recorded in this work is 9.98%. The variations observed on ash contents between crop residues of cereal crops could be associated with environmental factors of rain fall, soil character, temperature, contamination of the residues by other external factors and the nature of crops. The ash content of native grasses was 10.88% for *dega* and 11.97% for *weinadega* agroecology whereas the ash content of leaf and leaf midribs of *enset* in *dega* and *weinadega* agroecologies, respectively, were 7.12% and 7.31%. The variation observed on ash content of native grasses and *enset (E. ventricosum)* leaf and leaf midribs could possibly be due to variation in agroecology of the study areas.

The crude protein (CP) content of crop straws varied from 2.63% barley to 5.54% field pea (Table 36). The percentage of CP obtained from crop straws that are considered as available feed resources for livestock feeding in the study areas is much lower than that set as a minimum level of nitrogen (7%) to limit intake (Milford and Minson, 1966; Van Soest, 1982).The stubbles of barely, wheat, field pea and faba bean in the study areas had higher CP content than that of their corresponding straws. Although there are findings indicating that crop stubbles have lower leaf to stem ratio than the corresponding straws which can reduces the CP contents of the stubbles to minimum level, the content of CP found in most of the stubbles in the current study were higher than the CP content of the corresponding straws. This may be associated with the presence of grasses and other species of legumes that had grown on the crop field and left aside with the stubbles of crops on crop grown fields during harvest. The CP content reported in current study from all residues of crops (Table 38), however, was at lower level to fulfill the optimum CP requirement of livestock.

Grasses from *dega* and *weinadega* agroecologies of the study areas, respectively, had CP content of 8.23% and 6.34%. The value for CP content of grasses from *dega* agroecology was higher than that of *weinadega* area. Such differences may be associated with the differences in the proportion of legumes in the pasture across the agroecology. The CP values from natural grasses are closer to the minimum value required for optimum rumen microbial function, hence, can support maintenance requirement of ruminants with slight supplementation. Conversely, 11.39% and 9.34% CP contents (Table 36) were recorded from leaf and leaf midribs of *enset* (*E. ventricosum*) in *dega* and *weinadega* agroecologies, respectively. The CP values obtained from *enset* parts in both agroecologies have been far exceeded from all available livestock feeds in the study area and also higher than the minimum value of 7%, required for optimum rumen microbial function that can support maintenance requirement of ruminants.

The neutral detergent fiber (NDF) content of straws of cereal crops in current study was between 69.4% *teff* to 48.94% barley. Stubbles of most cereal crops had slightly lower NDF contents than their respective straws (Table 36). Roughage feeds with NDF content of less than 45% categorized as high quality, 45-65% as medium quality and those with more than 65% as low quality (Singh and Oosting, 1992). The NDF content of straws of field pea, faba bean, barley and all crop stubbles identified in current study was found in the range of 45-65% and could be classified as medium quality roughages that may not impose drawbacks on animal performance. The NDF content of leaf and leaf midribs of *enset (E. ventricosum)* was 64.92% for *dega* and 61.26% for weinadega agroecology which has laid between the ranges of 45-65% and it could be classified udder medium quality livestock feed. The NDF content of maize stover for current study was 68.8% and the NDF content of native grass reported in this study was 74.1% in *dega* and 75.54% in *weinadega* (Table 36). The higher NDF content could be a limiting factor on feed intake, since voluntary feed intake and NDF content are negatively correlated (Ensminger *et al.*, 1990) and therefore, feeds with NDF content of greater than 65% in current study could be classified as low quality roughages, which could impose limitations on feed intake and animal productivity.

The ADF content of crop straws varied from 47.2% in faba bean to 66% in wheat whereas ADF content of crop stubbles ranged from 35.2% in barley to 65.6% in field pea (Table 36). Conversely, ADF content for native grass for *dega* and *weinadega* agroecologies, respectively, was 40.01% and 41.08%. The ADF content of maize stover was 47.6%. Kellems and Church (1998) categorized roughages with less than 40% ADF as high quality and above 40% as low quality. The percentage level of ADF on leaf and leaf midribs of *enset* (*E. ventricosum*) was as low as 38.34% in *dega* and 39.18% in *weinadega* (Table 36), which is lower than the higher limit category of 40% of ADF for high quality roughages and therefore, the leaf and leaf midribs of *enset* can possibly be grouped under high quality roughages used in livestock particularly in cattle feeding based on its ADF contents.

Acid detergent lignin (ADL) contained in different crop residues found in the study areas ranged from 6.95% to 14.44%. Highest concentration of lignin was found in field pea straw 14.44% followed by faba bean straw 12.62%. The percentage of lignin in crop stubbles reported in the current study also varies between 6.95% in *teff* stubble to 13.31% in field pea stubble (Table 36). The ADL content of legume crop residues recorded in current study 14.44% for field pea and 12.62% for faba bean straw as well as 13.31% for field pea and 11.02% for faba bean stubbles (Table 38) were imperatively higher than the maximum level (7%) that limits DM intake and livestock production (Reed *et al*., 1986). This indicates the existence of great differences in level of lignification between crop residues of cereals (monocotyledons) and legumes (dicotyledons). As reported in the current study, non-legumes species (monocots) have much higher fiber concentrations (ADF and NDF) than legumes (dicots) and conversely grasses have lower concentration of ADL than legumes which indicates grasses have lower readily digestible cell contents.

Even though lignin has a negative impact on the fiber digestibility of legumes, the fact that legumes contain much lesser fiber ADF and NDF than grasses which lessens its impact on overall digestible energy concentration (Table 36). The lignin percentage in maize stover of the study area was 10.59% while the percent lignin content of native grasses of *dega* and *weinadega* agroecologies, respectively, was 7.69% and 7.87%, which are little bit greater than limiting lignin content of 7%. ADL in the leaf and leaf midribs of *enset* (*E. ventricosum*) in the current study was 6.37% for *dega* and 6.31% for *weinadega agroecology* with the overall average lignin content of 6.34% which is free of fear and lower than the maximum level of 7%.

4.2.2. Nutritive value of feedstuffs

The *in vitro* dry matter digestibility (IVDMD) for maize stover was 49.93%. The level of IVDMD from leaf and leaf midribs of *enset (E. ventricosum)* was about 58.18% and

60.45% whereas it was 55.91% and 54.35% for natural grasses in *dega* and *weinadega* agroecologies, respectively. The IVDMD of crop straws ranged from 40.74% to 55.5% in which the faba bean straw had the highest (55.5%) content followed by field pea straw (52.64%). The value reported for wheat straw (40.74%) in this work (Table 36) was lower than from all reported values for the straws of cereal crops of current study. The IVDMD percentage of the stubbles of cereal crops were ranged from 35.68% to 48.23%. The highest value was reported for the faba bean stubble (48.23%) and the lowest value for wheat stubble (35.68%). From crop residues utilized for livestock feeding in the study areas, greater value of IVDMD was recorded for those straws and stubbles of legume origin (Table 36).

Metabolizable energy (ME) content of annual crops residues in current study ranged from 5.35MJ/kg DM of wheat stubble to 8.33MJ/kg DM of fababean straw. Comparing average energy content of residues of legume in one hand and that of non-legume crops on the other hand, average energy content of 8.12MJ/kg DM straw and 7.23MJ/kg DM stubbles of legume origin were higher in energy content (Table 36) than those non-legume origin of 7.14MJ/kg DM for straws and 6MJ/kg DM for stubbles. Energy content of native grass in current study was 8.39 MJ/kg DM in *dega* and 8.15 MJ/kg DM in *weinadega* agroecology whereas the energy content of maize stover in the study area was 7.49MJ/kg DM. Energy value reported for leaf and leaf midribs of *enset* (*E. ventricosum*) from *dega* and *weinadega* agroecological zones, respectively, were 8.73MJ/kg DM and 9.07MJ/kg DM. The observed variations on the energy content of leaf and leaf midribs of *enset* between agroecologies could probably be associated with differences in the agroecology and the type of *enset* landraces (clones) grown in each agroecology.

4.2.3. Calcium and Phosphorus content of feeds

Minerals perform four broad types of function in animals such as forming structural components of body organs and tissues, minerals occur in body fluids and tissues as electrolytes concerned with the maintenance of osmotic pressure and acid–base balance, controlling of membrane permeability and transmission of nerve impulses, minerals can act as catalysts in enzyme and endocrine systems, as integral and specific components of the structure of metalloenzymes and hormones or as activators (coenzymes) within those systems, minerals also regulate cell replication and differentiation, (calcium ions) influence signal transduction and selenocysteine influences gene transcription, leading to its nomination as 'the 21st amino acid' (Suttle, 2010).

Of the minerals, calcium (Ca) and phosphorus (P) are the two determining minerals in both function and amount in the production and productivity of livestock. The Ca content of crop residues in the current study for both agroecologies varied from 0.5g/kg DM in faba bean stubble to 3g/kg DM in field pea straw. The Ca content for natural pasture was 1.12g in *dega* and 1.05g/kg DM in *weinadega* agroecology. The maize stover had a Ca content of 2g/kg DM whereas 3.99 and 3.29g/kg DM (Table 36) was recorded for leaf and leaf midribs of *enset (E. ventricosum)* from *dega* and *weinadega* agroecologies, respectively. The P level contained in the crop residues in both agroecologies ranges from 0.35g/kg DM of *teff* straw to 1.57g/kg DM of field pea straw. The P content in natural grass from *dega* was 1.51g/kg DM and 1.35g/kg DM in *weinadega* agroecology. The P content of maize stover was 0.47g/kg DM whereas the P content in *enset* leaf and leaf midribs was 1.28g/kg DM in *dega* and 1.09g/kg DM in *weinadega* agroecology (Table 36).

Table 36: Chemical composition and nutritive value of feedstuffs in the study areas of Gurage zone

	Chemical composition of feedstuffs (%)							Nutritive value of feedstuffs				
Feedstuffs of *dega*	DM	DM Ash	DM OM	NDF	ADF	ADL	CP	DCP (g/kg)	IVDMD (%)	ME (MJ /kg DM)	Ca (g/kg)	P (g/kg)
Field pea straw	92.30	6.53	93.47	55.64	63.20	14.44	5.54	47.99	52.64	7.90	3.00	1.57
Field pea stubble	91.22	4.23	95.77	55.88	65.60	13.31	4.96	42.60	47.91	7.19	2.60	1.07
Faba bean straw	94.05	6.49	93.51	65.00	47.20	12.62	3.50	29.04	55.50	8.33	2.00	1.12
Fababean stubble	93.01	4.28	95.72	51.40	45.60	11.02	5.84	50.77	48.23	7.24	0.50	1.01
Barley straw	93.44	9.02	90.98	48.94	50.20	10.50	2.63	20.95	50.99	7.65	2.99	1.40
Barley stubble	92.13	6.10	93.90	57.44	35.20	9.49	3.79	31.76	44.89	6.73	1.70	1.07
Wheat straw	93.22	9.11	90.89	67.60	66.00	10.62	2.92	23.65	40.74	6.11	2.99	0.41
Wheat stubble	92.31	6.38	93.62	56.40	49.20	8.22	3.38	27.92	36.38	5.46	2.50	1.40
Enset leaf	92.65	7.12	92.88	64.92	38.34	6.37	11.39	102.33	58.18	8.73	3.99	1.28
Natural pasture	92.54	10.88	89.12	74.10	40.01	7.69	8.23	72.98	55.91	8.39	1.12	1.51
Feedstuffs of *weinadega*												
Wheat straw	93.62	9.32	90.68	62.40	64.40	10.62	3.19	26.16	40.74	6.11	2.80	0.37
Wheat stubble	92.01	5.97	94.03	55.08	51.40	8.46	2.34	18.26	35.68	5.35	2.36	1.23
Maize stover	94.03	9.98	90.02	68.80	47.60	10.59	3.79	31.73	49.93	7.49	2.00	0.47
Teff straw	93.12	9.07	90.93	69.40	49.20	10.12	3.50	29.04	51.02	7.65	2.61	0.90
Teff stubble	93.18	9.81	90.19	61.26	46.00	6.95	2.63	20.95	43.13	6.47	1.80	0.35
Enset leaf	92.40	7.31	92.69	61.06	39.18	6.31	9.34	83.29	60.45	9.07	3.29	1.09
Natural pasture	92.60	11.97	88.03	75.54	41.08	7.81	6.34	55.42	54.35	8.15	1.05	1.35

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

Table 37: Size and structure of herds in the study PAs of Gurage zone in number and TLU

Livestock species	*Dega*								*Weinadega*								Total	
	Shamene		*Achene*		*Moche*		*Agata*		*Shehremo*		*Wukiye*		*Yeferezye*		*Kochira*			
	No.	TLU	No.	TLU	No.	TLU	No.	TLU	No.	TLU	No.	TLU	No.	TLU	No.	TLU	No.	TLU
Cows	103	88.4	79	68.2	85	72	108	91.4	87	72.6	81	69.8	128	108.4	101	86.8	772	657.6
Oxen	11	12.1	7	7.7	15	16.5	11	12.1	7	7.7	16	17.6	6	6.6	8	8.8	79	89.1
Bulls	29	31.9	29	31.9	26	28.6	24	26.4	23	25.3	26	28.6	23	25.3	30	33.0	212	231.0
Heifers	23	12.7	30	16	44	22.4	34	17.4	47	24.1	47	23.9	24	12.2	32	16.4	281	145.1
Calves	58	11.8	45	9.6	51	10.8	63	13	40	8.2	46	9.6	56	11.8	50	10.0	409	84.8
Sheep	106	10.6	72	7.2	79	7.9	92	9.2	17	1.7	19	1.9	30	3	34	3.4	449	44.9
Goats	1	0.1	--	--	--	--	--	--	67	6.7	50	5.0	58	5.8	80	8.0	256	25.6
Horses	33	26.4	23	18.4	22	17.6	21	16.8	3	2.4	--	--	--	--	--	--	102	81.6
Mules	--	--	--	--	--	--	--	--	18	14.4	10	8	27	21.6	30	24.0	85	68.0
Donkey	8	4.0	4	2.0	4	2.0	--	--	12	6.0	15	7.5	14	7.0	22	11.0	79	39.5
Total	-	198.0	-	161.0	-	177.8	-	186.3	-	169.1	-	171.9	-	201.7	-	201.4	-	1467.2

Dega = highland, *Weinadega* = midaltitude, No = size of livestock in number, TLU = tropical livestock unit, -- = not present.

4.3. Available Feeds in the Study Areas of Gurage Zone

The total estimated feed dry matter (DM), digestible crude protein (DCP) and metabolizable energy (ME) production in the *dega* and *weinadega* agroecologies were indicated in Table 38. The major feed resources in *dega* agroecology include leaf and leaf midribs of *enset* (*E. ventricosum*), natural grasses, straws of barley, wheat and field pea whereas leaf and leaf midribs of *enset* (*E. ventricosum*), maize stover, natural grasses, *teff* straw and wheat straw were the major feeds available in *weinadega* agroecology to feed the livestock.

4.3.1. Estimated annual feed availability in both agroecologies

Households in both agroecologies substantially depend on leaf and leaf midribs of *enset* (*E. ventricosum*) to feed their livestock particularly cattle. The largest portion of DM was obtained from *enset* parts which accounted for 506.4 tons (52.73%) of the total dry matter (TDM) produced in *dega* and 662.96tons (49.36%) of TDM produced in *weinadega* agroecology. In general, the amount of DM produced from *enset* parts in both agroecologies of the study areas accounted for 1169.36 tons (50.77%) of the TDM of 2303.47tons which is greater than half of total feed produced and available for livestock feeding (Table 40). Dry matter produced from natural grass in *dega* agroecology was 141.62tons (14.75%) while it was about 207.33tons (15.44%) of TDM produced in *weinadega* agroecology.

The DM production from maize stover accounted for about 233.14tons or 17.36% of TDM. Crop straws of barley, wheat and field pea in *dega* and *teff* and wheat straws and maize stover in *weinadega* areas represented the largest share of DM produced and used mainly as dry season feed (Table 38). Use of improved fodder trees as well as those of agro industrial by-products as livestock feed in the study areas of Gurage zone was negligible and the dry matter computation in the current study did not consider these feed resources. The total estimated digestible crude protein (DCP) and metabolizable energy (ME) production per annum from individual feed resource per *dega* and *weinadega* agroecology were also analyzed and the result was indicated in Table 38. In *dega* agroecology, the total amount of DCP produced per annum was 70,556.5kg and in *weinadega* agroecology the amount of DCP produced per year was about 80,507.49kg. At the same time, the amount of ME produced in both *dega* and *weinadega* agroecologies of the study areas were computed and the results, respectively, were 7,905,333.6MJ and 11,133,246.4MJ.

Table 38: Estimated annual DM, DCP and ME produced in *dega* and *weinadega* agroecologies in the study areas of Gurage zone.

Feedstuffs	Agroecological zones					
	Dega			*Weinadega*		
	DM(t)	DCP (kg)	ME (MJ)	DM(t)	DCP (kg)	ME ('MJ)
Field pea straw	33.26	1596.15	262754	--	--	--
Field pea stubble	12.61	537.17	90665.9	--	--	--
Faba bean straw	11.89	345.29	99043.7	--	--	--
Fababean stubble	4.13	209.68	29901.2	--	--	--
Barley straw	175.05	3667.3	1339132.5	--	--	--
Barley stubble	29.18	926.76	196381.4	--	--	--
Wheat straw	40.13	949.07	245194.3	55.18	1443.51	337149.8
Wheat stubble	6.08	169.75	33196.8	8.36	152.65	44726
Maize stover	--	--	--	233.14	7397.53	1746218.6
Teff straw	--	--	--	137.86	4003.45	1054629
Teff stubble	--	--	--	38.29	802.18	247736.3
Enset leaf	506.4	51819.91	4420872	662.96	55217.94	6013047.2
Natural pasture	141.62	10335.43	1188191.8	207.33	11490.23	1689739.5
Total	960.35	70,556.5	7,905,333.6	1,343.12	80,507.49	11,133,246.4

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

The mean feed dry matter in tons, digestible crude protein in kilogram and metabolizable energy in mega joule produced per year per individual HH in both agroecologies of *dega* and *weinadega* were also evaluated and the results were presented in Table 39. The amount of feed dry matter available for livestock feeding in *weinadega* agroecology was significantly higher (P<0.05) than that was in *dega* agroecology. The average tons of dry matter produced per individual HH for *dega* and *weinadega* agroecologies, respectively, were 5.99±.19 and 8.09±0.30 with overall mean of 7.04±.19 per farmer. At the same time, the kilogram of DCP produced by individual HH found in both production system was also analyzed and there was a significant difference (P<0.05) among the two agroecologies with the overall mean of 422.26±11 (Table 39). Similar analysis on the mean annual production of ME in mega joule was made, the results for *dega* and *weinadega* agroecologies, respectively, were 44951±1490 and 61851±2232 with overall mean of 53401±1412 and there was significant difference (P<0.05) among the agroecologies.

Table 39: Mean (± SE) DM, DCP and ME produced/HH in both agroecologies of Gurage zone

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

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

The total estimated DM, DCP and ME produced per annum per individual HH in each PA were analyzed and the result has been indicated in Table 40 for *dega* and Table 41 for *weinadega* PAs. In all study PAs of the study areas, HHs depend mainly on leaf and leaf midribs of *enset* to feed mainly cattle. The amount of DM produced from leaf and leaf midribs of *enset* in each study PA of *Shamene, Achene, Moche, Agata, Shehremo, Wukiye, Yeferezye and Kochira* in Gurage zone, respectively, was 90.5tons (42.15%), 99tons (56.91%), 198tons (56.09%), 118tons (54.16%), 145.7tons (54.37%), 146.3tons (55.6%), 180.48tons (48.67%) and 190.4tons (49.35%). Besides the leaf and leaf midribs of *enset* (*E. ventricosum*), the farmers in the study areas relay on natural grasses and crop residues of straws and stubbles. Barley straw, barley stubble and field pea straw were the major crop residues utilized by livestock owners of *dega* agroecology, however, HHs of *weinadega* agroecology, depend majorly on crop residues of maize stover, *teff* straw and *teff* stubble to feed their livestock.

As indicated in Table 40 and 41, farmers in the study areas of Gurage zone produced a dry matter (DM), digestible crude protein (DCP) and metabolizable energy (ME) from wheat straw 40.13 tons (4.19%) DM, 926.76kg (1.31%) DCP and 245,194.3 MJ (3.1%) ME in *dega* whereas it was 55.18tons (4.11%) DM, 1443.51kg (1.79%) DCP and 337,149.8MJ (3.03%) ME in *weinadega* agroecology. Even though wheat straw was produced and collected by the farmers, HHs in the study area hardly provided wheat straw to their livestock when there was sufficient feed to sustain their animals. Households in the study area, however, stored wheat straw together with other crop residues as feed reserve and provided it to their livestock when they were encountered in feed shortage and when there was no alternative feeds particularly during long dry season (December to March) in which grazing grasses were almost vanished and long rainy season (July to August) when crop lands were covered with annual crops.

Estimation of DM, DCP and ME produced per year per PA were also studied as indicated in Table 40 for *dega* and Table 41 for *weinadega* PAs. The total amount of DM, DCP and ME produced in the study PAs of *dega* agroecology/year was (215.54tons DM, 14,177.11kg DCP and 1,751,145.1 MJ ME) at *Shamene* PA; (173.95 tons of DM, 13,249.56kg DCP and 1,442,628.7MJ ME) at *Achene* PA; (353.01 tons of DM, 27,078.25kg DCP and 2,922,528.2MJ ME) at *Moche* PA and (217.85 ton of DM, 15,966kg DCP and 1,781,776 MJ ME) at *Agata* PA. Similarly, total DM, DCP and ME produced in the study PAs of *weinadega* agroecology was computed and the results were (267.99 tons of DM, 16,800.28kg of DCP and 2,258,699.3MJ ME) for *Shehremo* PA; (263.24 tons of DM, 16,578.58kg DCP and 2,221,002MJ ME) for *Wukiye* PA; (370.78 tons of DM, 22,427.7kg DCP and 3,095,510.6MJ ME) for *Yeferezye* PA and (405.1tons of DM, 23234 kg DCP and 3,219,895.5 MJ ME) was for *Kochira* PA of Gurage zone.

Table 40: Estimated DM, DCP and ME produced from individual feed available per annum per study PAs of *dega* agroecology of Gurage zone.

Feedstuffs	*Dega* agroecology											
	Shamene			*Achene*			*Moche*			*Agata*		
	DM (t)	DCP (kg)	ME (MJ	DM (t)	DCP (kg)	ME (MJ	DM (t)	DCP (kg)	ME (MJ	DM (t)	DCP (kg)	ME (MJ
FP straw	8.22	394.48	64938	5.87	281.7	46373	10.1	484.7	79632	9.08	436	71732
FP stubble	3.12	132.91	22432.8	2.23	94.99	16033.7	3.82	162.73	27465.8	3.44	147	24733.6
FB straw	4.13	119.94	34402.9	1.35	39.2	11245.5	4.11	119.06	34236.3	2.30	67	19159
FB stubble	1.44	73.11	10425.6	0.47	23.86	3402.8	1.43	72.6	10353.2	0.80	41	5792
Bar straw	57.02	1194.15	436270	30.8	636.88	232713	51.5	1078.9	393822	36.12	756	276318
Bar stubble	9.51	302.04	64002.3	5.07	161.02	34121.1	8.58	272.5	57743.4	6.02	191	40514.6
Wt straw	4.94	117.07	30244.4	4.92	116.36	30061.2	15.7	371.31	95927	14.55	345	89206
Wt stubble	0.75	20.94	4095	0.75	20.66	4095	2.38	66.45	12994.8	2.21	62	12066.6
Enset leaf	90.48	9260.86	789890	99.0	10130.6	864619.2	198	20261	1730286	118.7	12075	1036251
Nat pasture	35.10	2561.60	294489	23.9	1744.22	200521	57.6	4189	481586	25.31	1846	212350.9
Total	214.71	14177.1	1751200	174	13249.6	1443185	353	27078	2924047	218.54	15966	1788124

Dega = highland, DM = dry matter, DCP = digestible crude protein, ME = metabolizable energy, t = ton, kg = kilogram, MJ = mega joule, FP= field pea, FB = faba bean, Bar = barley, Wt = wheat, Nat = natural.

Table 41: Estimated DM, DCP and ME produced from individual feed available per annum per study PAs of *weinadega* agroecology of Gurage zone.

Feedstuffs	*Weinadega* agroecology											
	Shehremo			*Wukiye*			*Yeferezye*			*Kochira*		
	DM (t)	DCP (kg)	ME (MJ	DM (t)	DCP (kg)	ME (MJ	DM (t)	DCP (kg)	ME (MJ	DM (t)	DCP (kg)	ME (MJ
Wt straw	6.67	174.49	40753.7	5.94	155.39	36293.4	23.33	609.53	142546.3	19.24	502	117556.4
Wt stubble	1.01	18.44	5403.5	0.9	16.43	4815	3.54	64.64	18939	2.92	53	15622
Mze stover	54.2	1719.77	405508.6	54.79	1735.63	410377	56.95	1805.44	426555.5	67.25	2135	503702.5
Teff straw	21.5	627.26	165087	21.08	612.74	161262	46.44	1350.36	355648.5	48.71	1414	372631.5
Teff stubble	5.99	125.49	38755.3	5.86	122.56	37914.2	12.92	270.26	83592.4	13.53	283	87539.1
Enset leaf	146	12120.8	1322406	146.3	12185.3	1326941	180.5	15032	1636954	190.4	15858	1726928
Nat pasture	39.5	2188.54	321843.5	34.39	1905.89	280278.5	70.46	3905	574249	62.97	3491	513368.5
Total	275	16974.8	2299757	269.3	167344	22578814	394.1	23037.2	3238484	405	23736	3337348

Weinadega= midaltitude, DM = dry matter, DCP = digestible crude protein, ME = metabolizable energy, t = ton, kg = kilogram, MJ = mega joule, FP= field pea, FB = faba bean, Mze = maize stover, Bar = barley, Wt = wheat, Nat = natural.

4.3.2. Annual feed balance estimate in both agroecologies

Annual available feed was compared with annual requirements of livestock population. The daily requirement of DM, DCP and ME per tropical livestock unit (TLU) of animal for maintenance were estimated based on the recommendations of Kearl (1982) and McCarthy (1986) for one TLU. The total estimated annual nutrient supply, requirement and nutrient balance of livestock per PA in the study areas of Gurage zone are shown in Table 42. The overall estimated feed supply in the study area met only for 76.81% of DM and 69.9% DCP maintenance requirement of livestock while the total estimate of ME were 1.67% in surplus per year (Table 42). Within *dega* agroecology, the available feed on year round basis in *Moche* PA satisfied about 97.18% DM and 96.08% DCP maintenance requirement whereas the estimated ME was 28.84% in surplus. On the rest of three PAs of *dega* agroecology (*Shamene, Achene and Agata)*, however, livestock were in serious negative feed balance and the available feeds could only satisfied the maintenance requirements of (53.06%, 52.8% and 57.39 %) DM; (48.61%, 55.86% and 58.43 %) DCP and (69.29%, 70.23% and 75.2%) ME, respectively.

Even though there existed negative feed balance in all study areas, there was relatively better feed availability in PAs of *weinadega* (*Shehremo, Wukiye, Yeferezye* and *Kochira*) and the available feed resources met about (79.47%, 76.63%, 95.61% and 98.39%) DM; (68.25%, 66.11%, 77.55% and 80.02%) DCP and the estimated ME was (6.55%, 2.91%, 25.79% and 29.82%) in surplus, respectively. The reason for betterment of available livestock feed in *weinadega* agroecology could be associated with relative better availability of land for grazing, cropping and production of *enset* (*E. ventricosum*). Estimation on the amount of available feed supply and demand per year per agroecology were also made and there were differences in available feed demand and supply (Table 42). In *dega*, the available feed supply met only about 64.98%, 66.24% and 85.66% of DM, DCP and ME of the maintenance requirement of livestock per farm per year, respectively. In *weinadega* agroecology, on the other hand, the available feed supply satisfied about the livestock maintenance requirement of 88.31% DM and 73.46% DCP and the total ME estimates were 17.22% in surplus per year.

Table 42: Estimated annual nutrient supply, requirement and nutrient balance of livestock per PAs in the study areas of Gurage zone

Study PAs	Annual nutrient supply			Annual nutrient demand			Annual nutrient supply and demand balance		
	TDM(t)	TDCP(t)	TME(MJ)	TDM(t	TDCP(t)	TME (MJ)	TDM(t)	TDCP(t)	TME (MJ)
					Dega PAs				
Shamene TLU=198	214.71	14.18	1751200	404.72	29.17	2527282	-190(46.94)	-15.(51.39)	-776081.9 (30.71)
Achene TLU=161	174.00	13.28	1443185.5	329.08	23.72	2055012	- 155.1(47.12)	-10.5(44.14)	-611826.6(29.77)
Moche TLU=177.8	353.10	27.08	2924046.5	363.42	26.19	2269448.1	- 10.24 (2.82)	+0.91 (3.92)	+654598.4(28.84)
Agata TLU=186.3	218.54	15.99	1788123.7	380.80	27.45	2377942.5	- 162.31(42.6)	-11.41(41.6)	-589818.81(24.8)
Sum =723.1	960.35	70.53	7906035	1478.1	106.53	9229684.55	-517.6(35.02)	-35.96(33.76)	-1323649.25(14.3)
					Weinadega PAs				
Shehremo TLU=169.1	274.70	16.97	2299757.6	345.64	24.91	2158400.9	-70.96 (20.53)	-7.91(31.75)	+141356.74 (6.55)
Wukiye TLU=171.9	269.30	16.76	2257881.2	351.36	25.32	2194140.2	-82.1 (23.37)	-8.58 (33.89)	+63741.01(2.91)
Yeferezye TLU=201.7	394.10	23.04	3238484.3	412.27	29.71	2574508.9	-18.1 (4.39)	-6.67 (22.45)	+663975.4(25.79)
Kochira TLU=201.4	405.02	23.74	3337348	411.66	29.67	2570679.7	-6.62 (1.61)	-5.93 (19.98)	+766668.3(29.82)
Sum =744.1	1343.1	80.51	11133344	1520.9	109.62	9497729.65	-177.8 (11.69)	-29.09(26.54)	+1635614.6(17.2)
Total 1467.2	2303.5	151.04	19039379	2999	216.15	18727414	-695.36(23. 2)	-65.05(30.1)	+312612.65 (1.67)

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

4.3.3. Reasons for feed insufficiency

According to the survey result, feed was the major problem identified constraining livestock production in the Gurage zone. From a total of 360 respondent HHs around 46.9% reported that feed shortage due to crop encroachment on grazing lands was the main reason of feed constraint (Table 43). Absence of commercial feed industries and unavailability of commercial feeds in local market to supplement livestock was reported by 27% of HHs as the second reason for feed insufficiency. About 18.6% of HH respondents reported over grazing being the third reason to encounter feed insufficiency in the study area and the remaining 3% and 4.5% of HHs, respectively, reported that higher feed price and lack of capital to purchase feed were another component of reasons for encountered feed insufficiency which hindered production and productivity of livestock in the area.

Table 43: Reasons of feed insufficiency as per households' response

Study *woreda*	Major reasons for feed insufficiency (%)				
	Crop encroachment	No commercial feed	Over grazing	Lack of capital	High feed price
Ezia (n = 90)	50.0	22.2	16.7	6.7	4.4
Muhir & Aklil (n = 90)	51.1	25.6	13.3	5.6	4.4
Cheha (n = 90)	44.2	30.3	21.1	2.2	2.2
Enemor & Aner (n = 90)	42.4	29.9	23.3	3.3	1.1
Grand total (N = 360)	46.9	27.0	18.6	4.5	3.0

Woreda = districts, N = total sample HHs of the study, n = number of sample HHs per *woreda*.

4.4. Interaction of Cattle and *Enset* Production

Livestock particularly cattle comprises a major and integral component of the farming system in the study area of Gurage zone and there is a close interaction between cattle and *enset (E. ventricosum*) production. Based on data collected from interviewed HHs included in current study, cattle production is one of the vital and essential components in *enset* culture both in terms of supplying farm yard manure and provision of milk, milk products and meat without which consumption of *kocho* could not satisfy ever nutrient that required for healthy life of human.

Households of the study areas of Gurage zone have perceived that *enset* which is well fertilized with cattle manure grows better, faster and its major product *kocho* (*Wussa* in *Guragigna*), could possess better taste, quality and larger in quantity than *enset* that has grown without or with minimum application of cattle manure. Households participated in the current study also noted that no alternative fertilizers of either inorganic or organic ones there to be used in fertilizing the *enset* fields to date. At the same time, HHs in both agroecologies of *dega* and *weinadega* areas of the study pointed out that the number of mature *enset* plant to be harvested by the farmers is directly related to the number of cattle owned by HH. The higher the number of cattle owned by a farmer, the more could be the amount of manure produced and to be used in *enset* garden fertilization that would positively affects the number of mature *enset* to be harvested per individual HH per year per unit of land.

As indicated in Table 44, the overall average number of mature *enset* harvested per year per HH across the surveyed areas was 72. Nevertheless, the mean number of mature *enset* harvested between wealth groups was different one from the other. And the number of mature *enset* harvested per HH in the study areas was significantly different ($P<0.05$) based on the level of wealth (number of cattle owned by HHs). It has been seen in the current study that wealthy HHs harvested greater number of mature *enset* than poor HHs which is related to the larger number of cattle owned by wealthy groups. This larger number of cattle ownership in its turn called for production of relatively more manure that can increase the productivity of the land under *enset* cultivation by making sustainable the soil fertility.

In the same way, *enset* production is very important in production of cattle in that *enset* provides leaf and leaf midribs to feed the cattle for the entire period of 7-8 months within a year. Households in both agroecologies substantially depend on leaf and leaf midribs of *enset* (*E. ventricosum*) to feed their cattle. When there is extreme case of feed shortage and condition of extended drought, on the other hand, the whole *enset* parts including the leaf, leaf midribs, pseudo stem and the corms can be fed to animals and it can save the life of livestock (cattle).

Table 44: Mean (±SE) of mature *enset* harvested/year/HH based on the number of cattle owned in the study area of Gurage zone.

Description	Harvested *enset* number per wealth group member				One Way
	Poor	Medium	Wealthy	Average	Anova
Mature *enset* harvested	55.39±2.3[c]	69.08±3.1[b]	91.95±4.0 [a]	72.14±2.02	F=32.96
Number of households	120	120	120	360	P=.000***
Minimum	17	23	25	17	
Maximum	109	150	210	210	

Source: data from own field survey (2016/17). [abc] means in the same raw sharing different letters of superscripts are significantly different ($P<0.05$), HH = Household, Poor = HH having cattle size of 1-3, Medium = HHs having cattle size of 4-5, Wealthy = HHs having cattle size of ≥ 6.

4.4.1. Major reasons of *enset* cultivation

As indicated in Table 45, HHs of the study area were asked to respond on the major reason for giving more attention on *enset* (*E. ventricosum*) cultivation and the reasons of HHs for giving prior attention for *enset* cultivation over other crops include the followings:

1. The ability of *enset* in providing food items such as *kocho*, *bulla* and *Amicho* in a sustainable manner once *enset* garden has been well established and properly managed,
2. The capability of *enset* plant in providing greater amount of yield than the annual crops per plot of land,
3. Special advantage of *enset* in providing higher amount of feed dry matter which reduces the risk of feed shortage and support in cattle feeding,
4. *Enset's* relative advantage to resist longer season of drought, higher rain, flooding and poor soil fertility,

5. The storable capacity of *kocho* and *bulla* for longer period of time without or with minimum loss during storage,

6. *Enset's* use as traditional medicine in curing wounds, broken and fractured bones, reducing pain of the damaged body parts, help in dead calf delivery and remove the retained placenta and

7. *Enset's* multipurpose nature for food, feed, protecting soil erosion, keeping soil fertility, source of income, and use as money store.

Table 45: Major reasons of *enset* cultivation in the study areas of Gurage zone (%)

Reasons for *enset* cultivation	Households' response in study *woreda* (n = 90)				Overall (N = 360)
	Ezia	*Muhir& Aklil*	*Cheha*	*Enemor& Aner*	
Used as staple food	100	100	100	100	100
High yield/ plot of land	100	100	100	100	100
Used as cattle feed	100	100	100	100	100
Resistant to natural hazard	100	100	100	100	100
Used as traditional medicine	71.1	54.4	61.1	65.6	63.1
Long period storability	100	100	100	100	100
Multipurpose crop	100	100	100	100	100

Woreda = district, n = number of sample HHs per *woreda*, N = total sample HHs of the study.

4.4.2. Effects of *enset* farm size decline on cattle population since last 5 years

Based on perceptions of HH respondents of both agroecologies, about 61.7% of HHs reported that cattle population per individual HH tremendously reduced because of decline in *enset* farm size in the last five years. On the other hand, 27.2% and 11.1% of HH respondents indicated that even though there was decrease in the size of *enset* farm per individual HH in the last five years, the trend in size of cattle population was at increasing and constant trend, respectively (Table 46). A Pearson chi-square test indicated the decline of cattle population in both *dega* and *weinadega* areas was significantly higher ($P<0.05$) due to decline in the size of *enset* farm size which signifies the existence of strong association between the size of *enset* farm and cattle population.

The result of current study indicated the existence of a real interaction between *enset* and cattle in the study areas where *enset* serves as a source of fodder for cattle and cattle provide manure to fertilize *enset* fields. In these study areas there is a shortage of grazing and arable land, which in turn tend to reduce the number of cattle. According to the results of the study (Table 38), majority 1169.36tons (50.77%) of livestock feed particularly of cattle feed was harvested from *enset* parts which automatically and negatively affect production, productivity and size of cattle population if there is reduction in the size of *enset* production..

Table 46: Households responses on effects of *enset* farm size decline on cattle population since last 5 years

Agroecological zones	Size of cattle population due to reduction in *enset* farm (%)			Total
	Decreasing	Increasing	No change	
Dega (n = 180)	68.3	15.6	16.1	100
Weinadega (n = 180)	55.0	38.9	6.1	100
Overall average	61.7	27.2	11.1	100
Pearson chi-square	$\chi 2$ value = 28.69 , level of significance = .000***			

Dega = highland, *Weinadega* = midaltitude, n = sample HHs per agroecology.

4.4.3. Effects of cattle size decline on size of *enset* farm since last 5 years

As indicated in Table 47, about 70.5% HHs participated in interview indicated that although there is an increases in area coverage of *enset* crop in the study areas, *enset* farm size per individual HH was greatly reduced because of decline in cattle population since the last five years. About 18.1% and 11.4% of respondent HHs of both agroecologies of the study areas reported, however, the trend in size of *enset* farm per individual HH in the last five years was at increasing and unchanged condition, respectively. A Pearson chi-square test also indicated the decreasing trends of *enset* farm size on both agroecologies and was significantly higher (P<0.05) because of decline in cattle population which indicated existence of solid association between size of cattle population and *enset* farm. Regardless of agroecology, ethnic groups and/or degree of dependence on *enset* in dietary intake, cattle play a critical role in *enset* system in maintaining soil fertility and agricultural sustainability. *Enset* is strongly dependent on the amount of cattle manure produced. In the absence of cattle in this system, sustainability of *enset* production could definitely and negatively be affected. Reducing the number of cattle per HH also reduces the availability of manure to fertilize *enset* garden that affects *enset* farming system.

Table 47: Households responses on effects of cattle size decline on size of *enset* farm since the last 5 years in the study area of Gurage zone (%).

Agroecological zones	Households responses			Total
	Decreasing	Increasing	No change	
Dega (n = 180)	69.4	15.0	15.6	100
Weinadega (n = 180)	71.7	21.1	7.2	100
Overall average	70.5	18.1	11.0	100
Pearson chi-square	$\chi2$ value = 7.55, level of significance = .025**			

Dega = highland, *Weinadega* = midaltitude, n = sample HHs per agroecology.

4.4.4. *Enset* and cattle products as source of food

Enset plays a central role in life of people found in *enset*-based cultivation systems of Gurage, Sidama, Hadiya, Kembata, etc. It provides the main staple food which is potentially available throughout the year. All parts of *enset* plant are economically important. The corm, pseudo stem and the stalk of inflorescence of *enset* are most important food. In the study areas, *enset* is considered as a major staple food components of the diverse farming system and the fermented product *kocho* obtained from *enset* is the stable food. *Enset* products are rich in carbohydrates but low in proteins. According to the Ethiopian Nutrition Institute (ENI, 1981), the protein content of *enset* products is estimated to be 12g per kg of dry processed *kocho*.

Due to poor protein content, *enset* food products are not consumed by their own, except during periods of shortage of other food resources or by poor HHs who do not have the means to diversify their diet. Therefore, *enset* food is mostly consumed together with animal products of milk, meat, cottage cheese, fermented milk (Ergo). This indicates the existence of strong interdependence between *enset* and cattle not only on the system of production but also on products of *enset* and cattle that could be eaten by the farming families. From a total of 360 HHs participated in the study, about 59.2% of HHs consume *kocho* mainly together with cattle products of meat, cheese, milk, yogurt and with addition of some vegetables or pulses. Furthermore, 22.7% and 18.1% of sample HHs of the area consumed *kocho* majorly with vegetables and pulses with some additional cattle products of different types (Table 48).

Table 48: Major products eaten with *kocho* in the study areas of Gurage zone

	Response of HHs about products eaten with *kocho* **(%)**					
Study *Woreda*	Milk+	Yogurt+	Cheese+	Meat+	Pulses+	Vegetable+
Ezia (n = 90)	12.2	6.7	20.0	22.2	15.6	23.3
Muhir and Aklil (n = 90)	13.3	8.9	17.7	16.7	16.7	26.7
Cheha (n =90)	11.1	4.5	15.6	25.6	23.3	20.0
Enemor & Aner (n = 90)	15.5	7.8	16.7	22.2	16.7	21.1
Total (N =360)	13.1	6.9	17.5	21.7	18.1	22.7

n = number of sample HHs per district, N = total sample HHs of the study, + = some cattle products, vegetables and pulses.

4.4.5. *Enset* parts used as cattle feed and months of utilization

Leaf and leaf midribs of *enset* (*E. ventricosum*) is major source of cattle feed. Due to encroachment of crop cultivation on grazing lands, HHs in the study areas of Gurage zone are dependent on cut-and carry system to feed their cattle. From a total of 360 HH respondents, 100% were pointed out *enset* leaf and leaf midribs was used as major source of cattle feed between the months of October to May within a year. In cases of extreme drought, on the other hand, the HHs in the study areas are forced to use the whole of parts *enset* including leaf and leaf midribs, pseudo stem and the corm to feed their cattle.

4.4.6. Interdependence of cattle and *enset* production

Households of 100% participated in the current study from both agroecologies of the study areas realized that the production and productivity of *enset (E. ventricosum)* could not be sustainable without cattle production (Table 49). They also disclosed that the existence of well-built interaction between *enset* and cattle production through generations which has a strong bond in determining the livelihoods of rural farming families of the zone. In the absence of cattle in this system, it is impossible to realize production and sustainability of *enset*. In any aspect of degree of dependence on *enset* in dietary intake, cattle play a critical role in *enset* system in maintaining soil fertility and agricultural sustainability. In low input farming systems, *enset* production is strongly dependent on cattle production thereby on the amount of cattle manure produced. In this farming system, cattle manure is the only source of nutrient input and is crucial for the productivity of *enset* garden.

The use of inorganic fertilizers is impossible to be used in *enset* production because of its high cost and limited availability. As a result, cattle manure is a locally available low cost substitute for the majority of resource poor farmers. Therefore, cattle are highly valued by HHs of the study area because of its various functions and long-term benefits. The perceptions of the interviewed HHs of current study on the essentiality of cattle in determining production and productivity of *enset* agreed with the work of Risse *et al*. (2006) and Maryo *et al*. (2014), who pointed out that in the absence of cattle in *enset* production system, the sustainability of *enset* production definitely be disadvantaged. Limiting the number of cattle per HH also limits the availability of manure to fertilize *enset* plant, which in turn affects *enset* farming.

On the other hand, about 15.8% of interviewed HHs from both *dega* and *weinadega* agroecologies have perceived that even though leaf and leaf midribs of *enset* served as a source of feed for cattle, it is possible to make sustainable the production and productivity of cattle without *enset* production if land for production of crops, forage development and grazing become available adequately (Table 49). However, majority (84.2%) of sample HHs revealed that in the existing fragmented land holding which doesn't give opportunity of producing grasses, improved forage crops and crop residues enough for cattle feeding, it is paramount important to practice *enset* cultivation without which sustainability in cattle production and productivity cannot be achieved.

In generalizing the interactive effect of cattle and *enset* production, the HHs who participated in the interview revealed that *enset* (*E. ventricosum*) is not only the major source of feed of cattle during normal seasons of the year but also it has potential of keeping the life of cattle and other livestock during drought period which aggravates the feed shortage and problems of livestock health. The HHs also disclosed that without cattle, sustainability of *enset* production cannot be successful as well as without *enset* production, cattle rearing will be under question. Therefore, in this production system each and every endeavour should be focused on realizing integrative development on *enset* and cattle and without which sustainability of this production system cannot be applicable.

Table 49: Interdependence of cattle & *enset* production in study areas of Gurage zone (%)

Agroecology	Do cattle size affect *enset*?		Do *enset* size affects cattle?	
	Yes	No	Yes	No
Dega (n = 180)	100	0.0	86.1	13.9
Weinadega (n = 180)	100	0.0	82.2	17.8
Over all (N = 360)	100	0.0	84.2	15.8

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

4.4.7. Years needed for *enset (E. ventricosum)* to mature

As indicated in Figure 6, the number of years needed for *enset (E. ventricosum)* to mature and prepared in to *kocho* and *bulla* was different based on agroecologies of the study areas. And the years needed in *dega* agroecology was longer than in the *weinadega* agroecology. In *weinadega* areas, about 50% of the respondent HHs disclosed that 7-8 years of growing time was needed whereas the remaining 50% of sample HHs of the same agroecology reported the necessity of 9-10 growing years for *enset* to mature, harvest and prepare in to *kocho* and *bulla*. Around 77.8% of HHs in *dega* agroecology reported the requirement of 9-10 growing years, however 22.2% of HHs indicated the need of greater than 10 years period for maturation of *enset* plant.

The differences observed in the number of years of maturation of *enset* plant among HHs of the same agroecology could most probably be due to differences on the ability and method of HHs in *enset* management (season of plowing, mulching, weeding, season of leaf and leaf sheaths cutting), planting space of either too narrow or too wide, the type of *enset* landraces (clones) used by individual farmers and differences in soil fertility. As to the perception of the respondent HHs of both agroecologies, manure application has a greatest share in determining the rate of growth of *enset* crop. Other than the aforementioned differences on management practices of HHs, variations in temperature could also bring alteration in number of years needed for maturation of *enset* plant between *dega* and *weinadega* agroecologies.

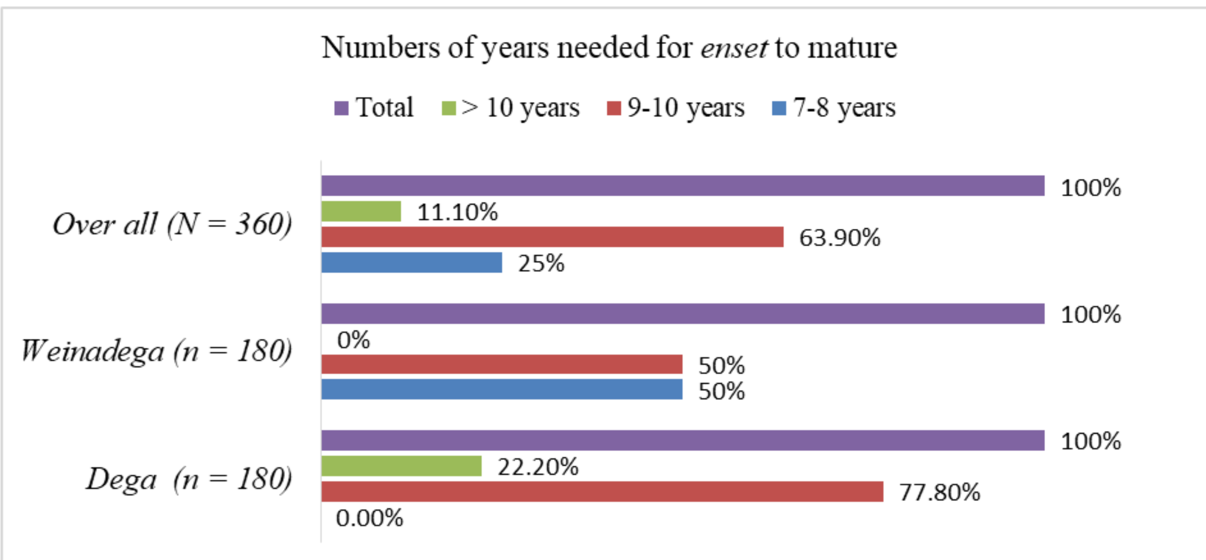


Figure 6: Number of years needed for *enset* to mature in the Gurage zone

4.4.8. Medicinal use of *Enset* and cattle products

Apart from what was described about the various uses of *enset*, HHs in the study areas also reported that some landraces (clones) of *enset* (*E. ventricosum*) such as *Astara, Guarye, Derye, Kibnar, Charkima, Oret, Ameratye, Ashektye, Demwenejat* are mainly used as traditional medicine for human being and animals towards healing broken and fractured bones of legs and arms, curing wounds and pains of spinal cord, provide strength to the bones and muscles, shorten the convalescence and used for other medicinal purposes. Most of the aforementioned *enset* landraces (clones) provide medicinal uses for human and livestock in common. About 67.7% of HHs participated in the study, realized that they have used some *enset* landraces for medicinal purposes to improve the health status and providing healing (curing) of different illness (sickness) of both human and animals.

According to the perceptions of HH respondents and cultural health practitioners (*Wegesha* in Amharic and *Kene* in Guragigna), landraces of *enset* including *Guarye, Derye, Oret, Ameratye* and *Kibnar* have played a significant role in curing bone fracture, curing broken bones, used in shortening of convalescence, important in curing back ache and cure wounds & pains of the body (Table 50). The three *enset* landraces of *Guarye, Derye and Oret, on the other hand,* take the greatest share in providing heal for the above-mentioned illnesses/sicknesses. The *Oret enset* clone also has played positive role in discharging delayed/retained placenta in human being but it is not advisable to eat the boiled corm of the *Oret enset* landrace by the pregnant woman that can cause abortion.

Astara enset landrace is known to avoid or minimize illness or pain, used in discharging the retained placenta, avoid the dead cells and secretions from damaged internal body parts of human being and animals in the form of pus, help in regeneration of the damaged body parts, shorten the convalescence, soften the broken, fractured bones and other damaged body parts of human and animals and makes the cultural therapeutic practices easy to manipulate (operate) without or with minimum pain. The *enset* clone known as *Kibnar*, on the other hand, may replace/take the function of *Astara* at its early stage of growth when there is no opportunity of getting *Astara enset* landrace. The *enset* landrace known as *Ashektye* has its own advantage in providing back-ache healing for both animals and human being. As to the perception of HHs and cultural health practitioners (*Wegesha*), *enset* clone known as *Demwenejat* is only used by animals in discharging retained or delayed placenta, used in preventing excessive bleeding after calving, help in birth giving or dead calf expelling and generally it has an abortifacient effect when utilized by pregnant animals.

The HH respondents and cultural health practitioners of the study areas reported also that the boiled corms of all the aforementioned *enset* landraces having medicinal value for human being cannot be eaten without products of cattle mainly milk soon after milking, yoghurt, *ayib*, butter or whey depending on the type of *enset* landraces under use and the type of illness or sickness to be threaten. Therefore, *enset* landraces used in healing or curing of the damaged body parts of human being must be eaten with products of cattle to provide medicinal value which also indicates the existence of interdependence among *enset* and cattle in keeping and providing of health of human being

The result of current study in relation to the medicinal use of some *enset* land races is in agreement with Worku (1996), who reported that particular landraces or clones of *enset* are used medicinally for both humans and livestock to cure bone fracture, broken bones, child birth problems (i.e., assisting to discharge placenta), diarrhea, birth control (abortifacient), to cure jaundice, back-ache and heart diseases. And the whole socio-economic activities of the farmers in the study areas of Gurage zone mainly depend on *enset* which satisfies many of their essential needs. By way of calling attention to the high supporting capacity and resourcefulness of *enset*, the rural house heads of Gurage referred *enset* as "*Yeseb -Teram Yafeya Guardera*", which means *enset* is "the corner stone for the life of human being and cattle". William (1966) stated that "the Gurages depend on *enset* not only for food, but also for other necessities of life. The use of *enset* seems endless in Gurages' "culture" which is in agreement with results of current study.

Table 50: Responses of HHs on some *enset* landraces used as traditional medicine in the study areas of Gurage zone (%)

Did you use *enset* in traditional medicine	Percent respondents per study *Woreda* (n = 90)				Over all N = 360
	Ezia	*Muhir & Aklil*	*Cheha*	*Enemor & Aner*	
Yes	77.8	62.2	64.4	64.4	67.2
No	22.2	37.8	35.6	35.6	32.8

Woreda = districts, n = number of sample HHs/*Woreda*, N = total sample HHs of the study.

4.5. Manure Utilization

In *enset* farming system of Gurage zone, cattle manure is the principal source of organic matter, nutrient input and crucial for the productivity of the system. The use of inorganic fertilizers is impossible for *enset* crop because of its high cost and limited availability. Households of the study area have given greater attention to produce farm yard manure to satisfy their requirement of nutrients to *enset* production since manure is regarded as essential by the HHs of the area for sustainable productivity of *enset* crop.

Cattle in the study area produce large quantity of manure every day and each farm HH uses cattle dung for manuring of his garden which is essential for improving soil fertility. Cattle manure is the basis for increasing production and productivity of crops particularly of *enset* plant in *enset*-based dairy cattle production system of Gurage zone. Manure improves nutrient restoration in the soils.

According to the result obtained in the current study, 100% of HH respondents in the study areas of Gurage zone revealed that the only purpose of cattle manure production was to be used manure as fertilizer. There was no use of cattle dung as fuel or dung cake for sale in this area (Table 51). The percent utilization of cattle manure for different crop production in the study areas was studied and its utilization level was different based on the type of crop produced.

According to the perception of HHs of the study areas, 91.3% of manure produced was utilized for the production of *enset* (*E. ventricosum*) whereas 3% of produced manure was used for fertilization of vegetables and root crops while the remaining 5.7% of manure was utilized for the production of fruits, coffee and chat in both agroecologies of *dega* and *weinadega* areas.

Table 51: Uses of cattle manure and percentage of manure used for different crops in the study areas of Gurage zone (%).

Study *woreda*	Uses of cattle manure		Manure used for different crops		
	Used as fertilizer	Used as fuel	*Enset crop*	Vegetables & root crops	Khat, coffee & fruits
Ezia (n = 90)	100	0.0	92.0	3.0	5.0
Muhir & Aklil (n = 90)	100	0.0	90.0	4.0	6.0
Cheha (n = 90)	100	0.0	93.0	2.0	5.0
Enemor & Aner (n = 90)	100	0.0	90.0	3.0	7.0
Over all (N = 360)	100	0.0	91.3	3.0	5.7

Woreda = districts, n = sample HHs per *woreda*, N = total sample HHs of the study.

4.5.1. Chemical composition of cattle manure

The result of chemical composition of manure collected from sample HHs in the study areas of Gurage zone is indicated in Table 52. Manure samples used in the study had a total nitrogen content of 2.68% in *dega* and 2.24% in *weinadega* with overall average percentage of 2.46% (on dry weight basis) and a C: N ratio of 11:1 for *dega*, 12:1 for *weinadega* and 11.5:1 for overall average. The composition of organic matter found in the manure sample analyzed in current study was 51.89% and 44.82% from manure samples taken in *dega* and *weinadega* agroecology, respectively, which is significantly important to assure the sustainability of the system.

Similarly, the main plant nutrients that have incorporated in the cattle manure was analyzed and the gram of nitrogen, phosphorus and potassium per kg DM of manure, respectively, were 26.8g/kg, 16.5g/kg and 1.6g/kg in *dega* as well as it was 22.4g/kg, 12.6g/kg and 1.2g/kg for *weinadega* agroecology. The observed differences in total nitrogen, organic carbon, carbon to nitrogen ratio and on the percentage of organic matter among the study areas of *dega* and *weinadega* agroecologies could mainly attributed to differences in environmental conditions of climate, soil, chemical content of the feeds consumed by cattle such as crop residues of different type, variation in composition of legumes in natural pastures, leaf and leaf midribs of different *enset* verities available for cattle feeding and so on.

Table 52: Cattle manure chemical composition in the study area of Gurage zone

Agroecology	Chemical composition of cattle manure							
	Nitrogen		Phosphorus		Potassium		OC	OM
	%	(g/kg DM)	%	(g/kg DM)	%	(g/kg DM)	%	%
Dega	2.68	26.8	1.65	16.5	0.16	1.6	30.1	51.89
Weinadega	2.24	22.4	1.26	12.6	0.12	1.2	26	44.82
overall	2.46	24.6	1.45	14.55	0.14	1.4	28.05	48.35

Source = laboratory analysis of sample collected (2017), *Dega* = highland, *Weinadega* = midaltitude, OC = organic carbon, OM = organic matter, DM = dry matter.

4.5.2. Households' potential of producing cattle manure

The result of current study revealed the declining of HHs' potential to produce cattle manure to fertilize *enset* or other crop garden. It is indicated in Table 53 that from HHs participated in the interview, about 77.8% from *dega* agroecology and 76.7% from *weinadega* agroecology reported the inability of having potential to produce cattle manure enough to fertilize crop garden particularly *enset*. According to the perceptions of the interviewed HHs, there are number of reasons for the reduced potential of farmers in producing enough manure. Increase in human population was one of the reasons of lowering manure production. Increases in human population has enhanced the fragmentation of hectarage of land distributed to individual farmer. The smallest land size allocated to individual HH gave rise to the reduction of the capacity of farmer to produce forage enough to feed his cattle, thereby minimizing the amount of manure produced and utilized.

The second reason for declining farmer's potential in manure production was the reduction of cattle number. The reduction in the size of cattle was resulted from inability of HHs to produce forage to feed their cattle. The fragmentation of land in the study areas exacerbated the bottlenecks associated with forage development. The production of low amount of livestock feed that couldn't support the maintenance and production requirements of cattle has called for the reduced amount of manure produced per animal. On the other hand, HHs of the study area urged to reduce the number of cattle owned due to incapability of producing feed to support the existed livestock population.

Land fragmentation not only put pressure on the households' potential to produce lesser amount of forage and to reduce the number of cattle owned but also negatively affect the households' potential to produce enough food to fulfill the annual food demand of family members. This reduce in the production of food items was mainly due to the reduced amount of manure production to fertilize *enset* garden that determines the production and productivity of *enset* in general and products of *enset* per household in particular.

Table 53: Potential of HHs on producing manure enough to fertilize *enset* garden in the study areas of Gurage zone (%).

Responses of households	Study *woreda* (n = 90)				Agroecologies		Over all (N=360)
	Ezia	*Muhir & Aklil*	*Cheha*	*Enemor & Aner*	*Dega* (n = 180)	*Weinadega* (n = 180)	
Yes	26.7	21.1	24.4	18.9	22.2	23.3	22.8
No	73.3	78.9	75.6	81.1	77.8	76.7	77.2

Woreda = districts, *Dega* = highland, *Weinadega* = midaltitude, HHs = households, n = sample HHs per *woreda* and agroecology, N = total sample HHs of the study.

4.5.3. Households' perception on the importance of manure

In *enset* farming system, cattle manure is the principal source of organic matter and nutrient input and is crucial for the productivity of the system. Hundred percent (100%) of HHs participated in the interview responded that sustainability of production and productivity of *enset* cannot be achieved without the application of cattle manure. In the absence of cattle in this system, the sustainability of *enset* production could definitely be affected. Limiting the number of cattle per HHs also limits the availability of manure to fertilize the *enset* garden which in turn affects *enset* farming system. On the other hand, 96.7% of HH respondents in both *dega* and *weinadega agroecologies,* reported that cattle manure has played a significant role in keeping sustainability of soil fertility and reducing soil erosion. Based on manure's low cost and manure's easily availability when compared with inorganic fertilizer, cattle manure was chosen by 94.4% and 92.5% HHs of both agroecologies, respectively (Table 54).

Table 54: Perception of HHs on cattle manure on *enset* production and productivity in the study areas of Gurage zone (%).

Households response	Study woreda (n = 90)				Overall (N=360)
	Ezia	*Muhir and Aklil*	*Cheha*	*Enemor and*	
Sustainable production & productivity	100	100	100	100	100
Low costly than inorganic fertilizer	96.7	87.8	94.4	98.9	94.4
Sustain soil fertility & reduce erosion	95.6	92.2	98.9	100	96.7
Easily availability	94.4	94.4	87.8	93.3	92..5

Woreda = districts, n = sample HHs per *woreda*, N = total sample HHs of the study.

4.6. Role of Cattle in Household's Food Security in *Enset* Based Agriculture

In this chapter, the contribution of cattle production to HH food security in *enset* production system, categorization of sample HHs in food secured and food insecure, perception of community about cattle and *enset* production and factors affecting HH food security status were analyzed and briefly discussed. In this section, the researcher employed the three major components of food security structures (food availability, food access, and food utilization) to see the contribution of *enset* based cattle production to HH food security.

4.6.1. Food availability

Food availability is the physical presence of food in the area of concern through all forms of domestic production, commercial imports and food aid. Food availability also refers to adequate availability of food in line with current population and demographic growth. Based on reviewed literature at this regard, besides the direct contribution of cattle to food availability, *enset*-based cattle production play a tremendous role in food availability through improvement in *enset* and other crop production by providing manure to fertilize crop garden. Improvement in soil fertility through application of cattle manure open the opportunity for higher productivity per plot of land and make sustainable the production of *enset* food items that can be harvested at any time and stage of growth.

4.6.1.1. Productivity of land in *enset*-cattle production system

Average land holding, production and productivity of *enset* (*E.ventricosum*) in the study area of Gurage zone were studied and the result was indicated in Table 55. Accordingly, the average cultivated land for *enset* production was 0.37 hectare, the average mature *enset* harvested per year per plot of cultivated *enset* land was 72 in number, the average production of *kocho* and *bulla* harvested per mature *enset*, respectively, was 51.8 and 1.88 kilogram. The result of *kocho* production per mature *enset* in the current study has lied between the ranges of 38 kg to 80kg with the average production of 51.8kg.

Variation observed in current study on kilogram of *kocho* yield per mature *enset* could be associated with landraces of *enset*, differences in soil fertility, management practices of individual HH and level of manure application as well as differences in agroclimate mostly temperature. Among *enset* based foods, *kocho* pre-dominates other *enset* food products such as *bulla* in its quantity of production. Consequently, quantification of *enset* yield mostly considers the yield of *kocho* production. The average yield of *bulla* produced per mature *enset* reported in the current study is 1.88 kilograms.

Based on the results of current study, about 195 mature *enset*, 10,101kg (101.01quintals) of *kocho* and 366.6kg (3.66 quintals) of *bulla* can be harvested per hectare of land per year. Average productivity of cereal grains in the study areas as per the results obtained from survey reports of HHs and Woreda Offices of Agriculture and Natural Resource Development (2016/2017) was 2079.5kg (20.8quintals) per hectare. To compare the differences in dry weight and caloric productivity of *enset* and cereal grains, the researcher used cereal equivalents (CE) to convert these products.

The cereal equivalent (CE) conversion of the yield or weight value of a food to the proportion of 3500 kilo calories per kilogram equivalents of cereals of *kocho* and *bulla* is 0.54 and 0.57, respectively, (Shank and Entiro 1996). Thus the total dry weight yield of *kocho* per hectare is 0.54 x 10,101kg (5454.54kg/ha) and the cereal equivalent weight of *kocho*/ha is equal to 0.54 x 5454.54kg/ha (2,945.45kg/ha). Dry and cereal equivalent weight of *bulla*, respectively, equal to 0.57 x 366.6kg/ha (208.96kg/ha) and 0.57 x 208.96kg/ha (119.11kg/ha). The total cereal equivalent weight (CE) of *kocho* and *bulla* produced per hectare is 2945.45kg +119.11kg (3064.56kg). The kilo calorie of *kocho* and *bulla* produced per hectare was calculated as (3064.56 x 3500 = 10,725,960kcal.

Conversely, average dry weight yield of cereals per hectare in study areas of Gurage Zone of current study was 2079.5kg and amount of energy produced in kilocalories was 2079.5kg x 3500kcal/kg = 7,278,250kcal. Comparing the productivity differences among *enset* and cereal grain, *enset* surpassed (exceeded) by 985.06 kg in dry weight and 3,447,710 kcal in energy (32.14%) per hectare of land and this value was enough to feed 4.50 persons for 365 days by consuming medically recommended daily intake of 2100 kcal energy per day. Therefore, *enset* can feed additional 4.50 persons adequately per hectare per year as compared with cereals grains produced per hectare of land. Having the aforementioned information at hand, the production and productivity of *enset* and the creation of chance to have food secured farming families in the study area was due to direct and indirect positive influences of cattle production which provides manure to fertilize the *enset* garden with every necessary nutrient for normal growth of *enset*.

Table 55: Average land holdings for *enset* production and productivity of *enset* in the study area of Gurage zone

Descriptions	Sum	Mean	Minimum	Maximum
Land allocation for *enset* per HH (ha)	134.37	0.37	0.11	1.20
Mature *enset* harvested per year/ha	25971.00	72.00	15.00	210.00
Kocho produced per mature *enset* (kg)	18645.00	51.80	38.00	80.00
Kocho produced per HH (kg)	1289100.00	3580.8	690.0	9450.0
Bulla produced per mature *enset* (kg)	675.30	1.88	1.00	3.00
Bulla produced per HH (kg)	46856.90	130.16	15.00	416.00

Source = own survey data (2017), ha = hectare

4.6.1.2. Adequacy of available food for consumption

Households participated in current study were interviewed on the amount of available food for consumption. Out of a total of 360 sample HHs, about 64.2% were perceived that the amount of available food for consumption was adequate to sustain their family members need while the remaining 35.8% HHs were said no. Conversely, there was great difference on the adequacy of available food and consumption between HHs of wealthy, medium and poor (HHs with different number of cattle owner ship). Accordingly, about 80.8% of wealthy and 64.2% of medium wealth group farmers indicated the presence of adequate food for consumption to lead normal life of their family.

Only 47.5% of poor wealth group HHs were reported the availability of adequate food to feed their family members but the remaining 52.5% of poor HHs were revealed that the amount of food available for consumption was not enough to lead normal life of their families (Table 56). The Pearson chi-square test also indicated the existence of significance association ($P<0.05$) among the number of cattle ownership by the HH as well as on the amount of available food and level of food consumption by individual HH. The Pearson chi square test of association indicated that HHs with greater number of cattle have better chance to produce and consume more food. Hence, cattle production has a great contribution to words the production of adequate food and on the amount of food available for consumption by farm HHs of *enset* growing areas of Gurage zone.

Table 56: Responses of HHs of different wealth groups on adequacy of available food for consumption of family members in the study area of Gurage zone (%)

Responses of HHs	Households of different wealth groups			
	Poor (n = 120)	Medium (n = 120)	Wealthy (n = 120)	Total (N= 360)
Yes	47.5	64.2	80.8	64.2
No	52.5	35.8	19.2	35.8
Total	100	100	100	100
Chi-Square	Value = 28.99, level of significance = 0.000***			

Poor = HHs with cattle size of 1-3, Medium = HHs with cattle size of 4-5, Wealthy = HHs with cattle size of ≥ 6, n = number of HHs in each wealth group, N = total HHs of the study.

4.6.1.3. Food self-sufficiency from own production

Differences were recorded on the level of food self-sufficiency between HHs having different cattle size (wealthy, medium, and poor). Accordingly, 87.5% wealthy, 72.5% medium and 60.8% poor HHs were self-sufficient in their own production (Table 57). To realize the existence of association between food self-sufficiency and differences in cattle ownership, a Pearson chi-square test was carried out. The result of the Pearson chi-square test indicated the existence of significance association ($P<0.05$) between the level of food self-sufficiency and number of cattle owned by HHs. This revealed the presence of well-built interaction between HH's food self-sufficiency from own production and number of cattle owned by HH of *enset* based cattle production system.

Table 57: Responses of HHs of different wealth groups on food self-sufficiency from own production in the study area of Gurage zone (%).

Households' response	Households of different wealth groups			
	Poor (n = 120)	Medium (n=120)	Wealthy (n=120)	Total (N=360)
Yes	60.8	72.5	87.5	73.6
No	39.2	27.5	12.5	26.4
Total	100	100	100	100
Chi-square value = 22.08, level of significance = 0.000***				

Poor = HHs with cattle size of 1-3, Medium = HHs with cattle size of 4-5, Wealthy = HHs with cattle size of ≥ 6, n = number of HHs in each wealth group, N = total HHs of the study.

4.6.2. Food access

Food access refers to individuals having adequate resource entitlements for acquiring appropriate foods for a nutritious diet. It depends on the amount of income available to the HH, on the distribution of income within the HH and on the price of food. It also depends on market, social and institutional entitlement and rights to which individual have access. Simply, making food available is not enough, one must also be able to purchase it, especially the low income HHs (Obamiro *et al.*, 2003). Thus, accessibility is viewed from perspective of purchasing power of the people and the physical accessibility to the sources of food. Cattle support this pillar from income generation point of view (through sale of cattle products and creation of livelihoods) and playing a major role in improving production and productivity of *enset* as well as keeping sustainability of *enset* (*E.ventricosum*) which is the staple food in the study area of Gurage zone.

4.6.2.1. Income generation from cattle and cattle products

Data collected from sample HH survey and focus group discussion suggested that the benefits of cattle production to the HH's economy are immense. Cattle are not only used as direct source of food (meat, milk, cheese and butter) for HHs but also used as a source of income through sale of the cattle and their products as well as they have played significant role in the creation of employment in the study area. Income generated by sample HHs from direct sale of cattle and their products from 2016, December to 2017, November was shown in (Table 58). The average income obtained by sample HHs from direct sale of cattle and their products was 808.28 ETB. Majority, 68.89% sample HHs were obtained annual income of 0-500 Birr whereas 20.83% were gained annual income of 501-2000 Birr. Around 6.67% HHs obtained an annual income of 2001-4000 Birr and the rest of 3.61% were gained an annual income of above 4000 Birr. These incomes, therefore, created an access to food directly or indirectly.

As indicated in Table 58, the annual income obtained from sale of cattle and cattle products accounted for about 17.5% of aggregate annual income of HHs in the study areas of Gurage zone. Besides this, differences in the percentage of income generation from cattle and cattle products were observed among HHs of the study PAs and agroecologies. Households found in all studied PAs of *dega* agroecology: *Shamene*, *Achene*, *Moche* and *Agata* accounted for greater percentage of annual income from sale of cattle and cattle products when compared with the overall average income of 17.15% than HHs found in all studied PAs of *weinadega* agroecology: *Shehremo*, *Wukiye*, *Yeferezye* and *Kochira*.

Table 58: Income from cattle and cattle products in the study areas of Gurage zone

PAs of the study	Range and percent annual income of HHs in birr (2016/2017)						
	0-500	501-2000	2001-4000	> 4000	Total	Mean	% income
Shamene (n =45)	34	7	3	1	45	1100.4	23.87
Achene(n =45)	37	5	2	1	45	1021.0	23.10
Moche(n =45)	33	9	3	0	45	822.2	17.8
Agata(n =45)	36	5	3	1	45	894.9	19.95
Shehremo(n =45)	29	12	2	2	45	503.6	10.43
Wukiye(n =45)	27	13	3	2	45	671.8	13.19
Yeferezye(n =45)	31	10	2	2	45	846.4	17.03
Kochira(n =45)	21	14	6	4	45	605.3	12.96
Overall (N = 360)	68.89	20.83	6.67	3.61	100	808.28	17.15

Source = own survey data (2017), Percentage of annual income = mean annual income from cattle (Table 62) divided by average annual aggregate income (Table 63).

4.6.2.2. Aggregate income of the respondent households

The aggregate income of the respondent HHs of the study areas of Gurage zone obtained from different income sources was ranged from 1800 to 13,500 Birr (Table 59) whereas the average aggregate income of the sample HHs was 4,712.69 Birr with standard deviation of 1,294.90. Majority of sample HHs, 82.8% have earned annual aggregate income of between 2,501-6,000 Birr while about 14.2% and 3%, respectively, were earned annual aggregate income of above 6000 and less than 2501 Birr between 2016, December and 2017, November. Within the study PAs, *Wukiye* PA from *Muhir and Aklil Woreda* earned better average aggregate income when compared with the rest of studied PAs that primarily related with the possibility of having relatively high Khat (*Catha edulis)* production potential of HHs found in *Wukiye* PA which is a major cash crop in this PA.

Table 59: Annual minimum, maximum and mean aggregate income of HHs in the study area of Gurage zone

Annual aggregate income in Birr	Number of respondents in each study peasant association								Total	(%)
	Shamene	*Achene*	*Moche*	*Agata*	*Shehremo*	*Wukiye*	*Yeferezye*	*Kochira*		
1800-2500	3	4	0	4	0	0	0	0	11	3.0
2501-4000	18	18	13	16	16	4	6	7	98	27.2
4001-6000	19	22	24	21	23	34	32	25	200	55.6
6001-8000	5	1	7	4	6	7	7	10	47	13.1
Above 8000	0	0	1	0	0	0	0	3	4	1.1
Minimum	1800	2100	2650	1800	3200	3200	2100	2350	1800	--
Maximum	7000	10000	13500	8000	7300	9000	8500	7600	13500	--
Mean	4610.67	4423.33	4619.11	4485.56	4827.33	5093.11	4970.44	4672.00	4712.69	--
Std. Deviation	1091.69	1455.27	1635.27	1303.6	871.54	1204.02	1378.94	1223.93	1294.90	--

Source = own survey data (2016/17), ETB = Ethiopian birr (currency).

4.6.3. Food utilization

Food utilization is defined as the means by which individuals reach a state of nutritional well-being where all physiological needs are met. This refers to HHs' use of the food to which they have access and individuals' ability to absorb and metabolize the nutrients. These ideas highlight the importance of non-food inputs into food security including knowledge of dietary needs and their potential impact on human health. According to Obamiro *et al* (2003), building knowledge of dietary needs and their potential impact on human health means, investing in complementary resources such as nutrition education, health care, provision of safe water and better sanitation practices. In this study whereas, food utilization was discussed using HH responses on number of meals consumed/day and dietary diversity of consumed food.

4.6.3.1. Number of meals per day

In the study area, the number of meals consumed per day was one of important indicators of HH wealth status and level of production. Thus, the number of meals per day for each sample HH was assessed and indicated in Table 60. The number of meals under normal situation in current study ranged from 1 to 3 times per day. Out of a total of 360 sample HHs, 5.6%, 33.4% and 61% of them were grouped under 1time, 2 times and 3 times eating in a day, respectively. Greater part (61%) of sample HHs of the area had the opportunity of getting normal number of meals per day (*i.e.*, 3 meals per day).

Table 60: HHs' response on number of meals/day in study areas of Gurage zone (%)

Number of eat/day	Study *woreda* (n = 90)				Agroecologies		Over all (N =360)
	Ezia	*Muhir & Aklil*	*Cheha*	*Enemor & Aner*	*Dega* (n = 180)	*Weinadega* (n = 180)	
1 time	2.2	2.2	4.4	4.4	3.4	7.8	5.6
2 times	35.6	31.1	31.1	42.2	29.6	37.2	33.4
3 times	62.2	66.7	64.4	53.3	67.0	55.0	61.0
Total	100	100	100	100	100	100	100

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

When HH's ability of providing enough food to be eaten by family members per day was clustered and analyzed based on level of cattle ownership (wealth groups), there is a clear differences in capability of food production and number of eating per day. From 120 sample HHs of each wealth group, about 82.5% wealthy and 60% medium wealth group HHs ate normal number of meal (3times) in a day. In the case of poor wealth group HHs, on the other hand, only 40.8% of them had the opportunity of 3times eating a day and majority (52.5%) of poor HHs ate only two times per day. From all sample HHs of the study, only about 61% of HHs had normal meals (3times eat) per day (Table 61). At the same time, the statistical Pearson chi-square test also revealed the existence of significant association (*P*<0.05) between number of cattle owned and number of food eats that the sample HHs acquire per day. That means, the greater the size of cattle owned by individual HH, the higher could be the opportunity of HH to have better number of food eating per day.

Table 61: Responses of HHs of different wealth groups on number of food eating per day in the study area of Gurage zone (%)

Number of eating per day	Responses of households			
	Poor (n = 120)	Medium (n =120)	Wealthy (n =120)	Total (N=360)
One time	6.7	5.8	4.2	5.6
Two times	52.5	34.2	13.3	33.4
Three times	40.8	60.0	82.5	61.0
Overall (%)	100	100	100	100
Chi-square test	Value = 34.07, level of significance = 0.000***			

Source = own survey data (2017), Poor = HHs having 1-3cattle, Medium= HHs having 4-5cattle, Wealthy = HHs having ≥6 cattle, HHs = Households.

4.6.3.2. Food diversity

Having highly diversified diet is greatly interrelated with productive and healthy life, getting adequate calorie and protein, capability on level of production and wealth status of HHs. Sample HHs were asked whether their family members consume nutritious and balanced food sufficient to lead their healthy life in the previous year as per their perception. Of a total of 360 sample HHs, about 48.6% of them replied that their family members consume the required/diversified diet, however, 38.9% of the HHs replied no and the remaining 12.5% didn't know whether their family members have eaten diversified food or not (Table 62). On the other hand, based on the result of the current study as shown in Table 66, out of 175 HHs who had opportunity for eating diversified food about 36.7%, 48.3% and 60.8%, respectively, were poor, medium and wealthy HHs. The statistical Pearson chi-square test also revealed the presence of significant association ($P<0.05$) between HHs owing different number of cattle and getting opportunity of eating diversified food necessary for normal life.

This indicated that HHs with higher number of cattle had better opportunity to get more diversified food to eat by the members of their family than those HHs having lesser number of cattle. This could be due to the fact that greater number of cattle ownership creates access to consume different (diversified) food items like meat, milk, butter and cheese as well as through nature of cattle interaction with production of *enset*, legumes, vegetables and other crops. In addition, annual income obtained from sale of cattle and cattle products could enhance the purchasing power of HHs thereby creating chance for diversifying food items eaten by the family members.

According to information gathered from interviewed HHs, cattle products of milk, milk products, meat as well as vegetables and pulses were commonly consumed with *kocho*. It is well known that cattle products are high in protein, vitamins and mineral contents which have created good chance of having better feeding status of family members who are dependent on consumption of *kocho*. At the same time, HHs with greater number of cattle can produce products with higher nutritive quality such as meat, milk, butter and cheese relatively in larger quantity that can be eaten together with *kocho*, hence improving the nutritional status of *kocho* used in human nutrition.

Table 62: Perceptions of HHs on diversified food eating by their family in the study areas of Gurage zone (%).

Response of households	Households of different Wealth groups			
	Poor (n=20)	Medium (n =120)	Wealthy (n=120)	Total(N=360)
Yes	36.7	48.3	60.8	48.6
No	48.3	39.2	29.2	38.9
Not known	15.0	12.5	10.0	12.5
Overall (%)	100	100	100	100
Chi-square test Value = 14.08, level of significance = 0.007**				

Source = own survey data (2017), Poor = HHs having 1-3 cattle, Medium= HHs having 4-5 cattle, Wealthy = HHs having ≥6 cattle, HHs = Households.

4.7. Classification of Food Secure and Food Insecure Households

Household food balance model (HFBM) described in methods of data analysis was used to quantify the available food for the sample HHs to determine per capita calorie consumption and through which the sample HHs classified in to food secured and food insecure. The data used for the computation were generated through field survey except for the estimates given for total post-harvest losses of food crops. As per estimates made by Degefa (2002), the post-harvest losses for the food crops in current study were estimated as 10% of total yield produced by the HH. However, losses for cattle products were not considered in this study due to lack of reliable data. The quantity of *enset* products, grains and cattle products produced by HH was calculated and converted in to daily dietary calorie equivalent (Table 63) separately on the basis of 1968-1997 Ethiopian health and nutrition research institute (EHNRI) food composition table (Appendix 6).

As indicated in EHNRI food composition table of Appendix 6, the calorie equivalent of *kocho*, *bulla,* grains and cattle products have varied depending on the type and kind of the end products prepared for consumption. Therefore, the average value of the major end products were taken for the consideration of conversion processes to obtain the total dietary energy available from each food sources. Moreover, a conversion of weight value of a food in to the proportion of standard 3,500 kcal/kg of cereal equivalents (CE) which is 0.54 and 0.57 for *kocho* and *bulla*, respectively, (Shank and

Entiro,, 1996) were utilized. The HH food balance assessment covered a period of one year from December 2016 to November 2017.

The types of food stuffs produced by sample HHs and the amount of food items available to feed the family members in the study areas of Gurage zone was indicated in Table 63. The proportion of calorie of individual products of *enset (kocho and bulla)*, grain and cattle products from the total was calculated to look into the contribution of each product to the dietary calorie supply of the HHs in the study area. The contribution of each food source in to the value of total dietary energy supply was indicated in Table 63 and out of the total dietary energy supply of the available food, about 65% dietary energy come from *kocho* and *bulla*, 24.8% was achieved from grains and 10.2% obtained from cattle products

Though the dietary energy produced from *kocho* and *bulla* was higher than from any products available for human consumption, the sample HHs of the study areas perceived that the production and productivity of *enset* as well as the amount of dietary energy produced from *enset* products were basically the direct effect of cattle production and number of cattle owned by HHs. The larger the number of cattle owned by individual HH, the more will be production and productivity of *enset* garden and the more could be the amount of dietary energy come from *enset* to feed family members which mainly associated with the cattle manure produced per HH to fertilize *enset* garden.

At the same time, most of HHs with smaller number of cattle ownership, have encountered with lower production and productivity of *enset* crop and reduced amount of dietary energy production to feed their family members. Accordingly, the number of cattle (either large or small number) owned by the individual HH in the study area of Gurage zone, has determining factor on the quantity and quality of *enset* products, on the total amount of dietary energy produced as well as putting influences on households' capability of being food secure or not.

Table 63: Food and dietary energy sources in the study area of Gurage zone

Food Sources	food types and level of kcal per kilogram	Available food in kilogram	Dietary energy equivalent (kcal)	Dietary energy contribution (%)
Enset	Kocho = (0.54x3500)	1160190	2192759100	
	Bulla = (0.57x3500)	42171.21	84131563.95	
	Total		2276890663.95	65%
Grains	Barley = (2672)	105030	280640160	
	Wheat = (2370.75)	57182.4	135565174.8	
	Maize = (1927.5)	104911.2	202216338	
	Teff = (1822)	82706.4	150691060.8	
	Pulses = (2904.85)	33868.8	98383783.68	
	Total		867496517.28	24.8%
Cattle	Milk & milk product = (77.925)	328354.32	25587010.39	
	Meat = (2080)	157772.85	328167528	
	Total =		353754538.39	10.2%
Over all			3498141719.62	100%

Source = own survey data (2016/2017), kcal = kilo calorie, kg = kilo gram.

4.7.1. Kilocalories of available daily dietary energy

The distribution of available dietary energy was considered based on the amount of dietary energy available and its distribution on the number of family members of individual HH in relation to the medically recommended minimum daily intake of 2100 kcal/person/day. Out of a total of 360 sample HHs, about 71.39% and 28.61%, respectively, have got daily kilo calorie greater and less than 2100 kcal (Table 64). Furthermore, to distinguish the level of variation on dietary energy produced between wealth groups (level of cattle ownership) and to understand the contribution of cattle in food security, distribution of available daily dietary energy per HH was measured.

Consequently, 92.5% wealthy, 73.33% medium and 48.33% poor HH members have got daily dietary energy of ≥ 2100kcal. When comparing HHs of different wealth groups based on the level of available daily average dietary energy, those HHs having large number of cattle (wealthy HHs) were in a position to produce greater amount (6057.32) of average daily kilocalories of energy per person. This is above the recommended average daily energy intake of 2100 kcal/person/day and greater than two folds of the average daily available dietary energy of 2812.04kcal per person produced by those HHs having small number of cattle (Table 64).

Based on the result of current study on available daily dietary energy intake, those HHs who had been consuming below medically recommended minimum daily dietary energy requirement of 2100kcal sorted out as food insecure and those whose daily kilocalories consumption was equivalent or above medically recommended minimum kilocalories of 2100kcal grouped as food secure. Therefore, the daily dietary energy resulted in current research work as indicated in Table 64, has demonstrated that out of a total of 360 sample HHs, 71.39% were food secure while 28.61% HHs were food insecure.

The situation of food security was also described based on the HH's level of cattle production. And out of a total of 120 wealthy households, about 92.5% were found to be food secure and the remaining 7.5% were food insecure. On the other hand, out of a total of 120 poor HHs, only 48.33% were found to be food secure and most (51.67%) were found to be food insecure. Similarly, from a total of 120 medium HHs included in this research work, 73.33% and 26.67% were found to be food secure and food insecure, respectively.

The statistical Chi-square test was also undertaken to identify the existence of association between the number of cattle owned by the HHs and the condition of HHs of different wealth groups on being food secure or not. The result of the Chi-square test revealed the occurrence of significant association ($P< 0.05$) between HHs of owing different number of cattle and on the level of gaining required amount of dietary kilocalories of energy per day per person (Table 64). This indicated that differences in the ownership of either large or small cattle number could affect the capacity of HH in realizing the HHs' food security.

Table 64: Daily kilocalorie energy consumption per family members of HH of different wealth groups in the study area of Gurage zone

Dietary energy consumption/ head/day(kcal)	Household members of different wealth groups							
	Wealthy		Medium		Poor		Total	
	Count	%	Count	%	Count	%	Count	%
1000-1499	5	4.17	13	10.83	37	30.83	55	15.28
1500-2099	4	3.33	19	15.83	25	20.83	48	13.33
2100-3099	7	5.83	13	10.83	13	10.83	33	9.16
3100-4000	10	8.33	19	15.83	17	14.17	46	12.78
4001-5000	23	19.17	23	19.17	13	10.83	59	16.39
5001-7000	36	30.00	17	14.17	11	9.17	64	17.78
> 7000	35	29.17	16	13.34	4	3.33	55	15.28
Total	120	100	120	100	120	100	360	100
Mean	6057.32	-	4221.7	-	2812.04	-	4799.19	-
Std. D	2997.82	-	2649.39	-	1758.37	-	3133.07	-
	Chi-square test value = 28.62,level of significance = 000***							

Source = own survey data (2016/2017), Poor = HHs having 1-3cattle, Medium= HHs having 4-5 cattle, Wealthy = HHs having ≥6 cattle, HHs = households.

4.7.2. Major sources of income to fulfill food shortage gap

It is commonly known that sources of income differs from one HH to the other and from one area to another depending on different factors of nature, culture, farming system and other related socioeconomic conditions. According to the results of the current study indicated in Figure 7, the three major source of HH income to fulfill seasonal food shortage gap on both agroecologies of the study areas of Gurage zone were identified. Based on this, off-farm activities provided 33.3% of income while selling of other assets and selling of grains represent, respectively, 27.3% and 15% income sources to fulfil food shortage gap in *dega*. In the *weinadega* agroecology, on the other hand, selling of Khat *(Catha edulis),* Off-farm activities and selling of other assets accounted for 28.3%, 22.2% and 22.2% income source of HH to fulfill seasonal food shortage gap, respectively.

Households in the study area also used alternative sources of income to avert food shortage gap. In *dega* agroecology selling of livestock 13.3%, *enset* and *enset* products selling 8.9% and gift from relatives 2.2% were another source of income to bridge the food shortage gap whereas in *weinadega* agroecology selling of livestock 7.8%, selling of *enset* and *enset* products 7.8%, gift from relatives 6.1% and grain selling 5.6% were additional sources of income reported by the HHs to fill seasonal food shortage gap. As shown from the result of current study on Figure 7, in both agroecologies of *dega* and *weinadega* study areas, income from selling of livestock as well as from *enset* and *enset* products were not the primer source of income to fulfill the food shortage gap.

Unless unexpected and extreme causes of natural or manmade disasters were encountered, HHs in the study areas never engaged in selling of cattle and *enset* and *enset* products to fulfill the food shortage gap. Instead, majority of HHs in this system had the experience of taking measures to bridge the food shortage gap through allowing the stored *kocho* to be eaten by the family if there any and giving permition to harvest and process *enset* plant in to *kocho* and other products. Households who have no capacity to produce enough *enset* and *enset* products, other annual crops and have no potential of storing products of any type for future use, on the other hand, have tried to alleviate the encountered food shortage gap by selling livestock particularly small ruminants, selling of labor, selling other assets such as eucalyptus tree and ask aid from relatives.

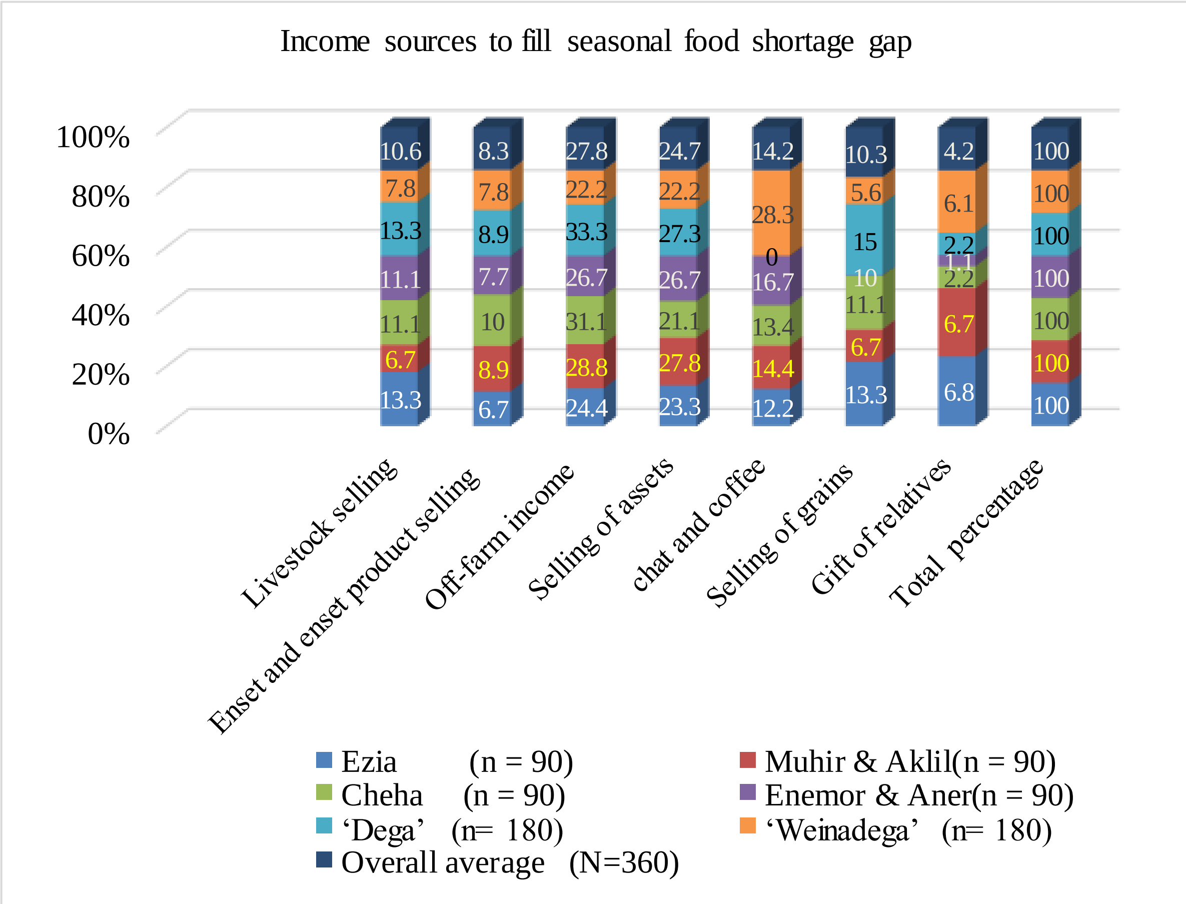


Figure 7: Income sources to fill seasonal food shortage gap in Gurage zone.

4.8. Months of the Year in Which the HHs Consume *Enset* Products

The result obtained from HH's response on the amount of *kocho* produced and the length of time within a year in which the family members of HH consume *kocho* in the study areas of Gurage zone was indicated in Table 65. According to the perceptions of the HHs participated in the current study, almost all of the house heads in both *dega* and *weinadega* agroecologies confirmed that they have primarily depended on *kocho* consumption throughout the year. Similarly, HHs found in both *dega* and *weinadega* areas were asked to verify whether the harvested *kocho* was enough for year round consumption or not. Out of 180 HHs of *dega* agroecology, 72.78% were confirmed that the amount of *kocho* produced was enough to feed members of their family and the rest of 27.22% were not in a position to produce enough *kocho* to fulfill the year round consumption need of their family. Similarly, from 180 HHs of *weinadega* areas, about 82.22% were approved that the quantity of *kocho* produced was enough to feed their family members whereas around 17.78% of the farmers did not produce enough *kocho* to feed their family members year round. In general the number of HHs who had potential of producing *kocho* enough for annual food requirements of their family members in both agroecologies of Gurage zone were accounted for about 77.5% (Table 65).

Table 65: Households' response on the amount of kocho produced and months in which the family members consume kocho in the study areas of Gurage zone

Agroecologies	Do HHs produce enough *kocho* for annual consumption		Months of the year in which *kocho* is consumed by family members
	Yes	No	
Dega (n = 180)	72.78%	27.22%	Year round
Weinadega (n = 180	82.22%	17.78%	Year round
Overall (N = 360)	77.5%	22.5%	Year round

Source: own field survey data (2016/2017), *Dega* = highland, *Weinadega* = midaltitude, n = number of sample HHs per agroecology, N = total sample HHs of the study.

5. DISCUSSION

5.1. Characterization of Enset-Based Dairy Cattle Production Systems

5.1.1. Socioeconomic characteristics of households

The observation on HH characteristics showed that the percentage of female headed HHs of 25.6% in *weinadega* agroecology is greater as compared to that of 7.2% in *dega* agroecology (Table 1). However, the average male HHs of 83.6% in both agroecologies more exceeded than 16.4% of the female HHs. The result obtained in the current study was comparable with the values of 88.89 % male and 11.11% female headed HHs reported by Samuel (2014), in Shebedino and Dale districts of southern Ethiopia. Whereas it was different from the results of 67% male and 33% female headed HHs reported by Azage (2004), in Addis Ababa; 52.3% male and 47.7% female headed HHs reported by Haile *et al.*(2012) for Hawassa town; 75.9% male and 24.1 % female-headed HHs reported by Belay and Janssens (2016) in Jimma town, Oromiya region of Ethiopia; 56.7% males and 43.3% female HHs by Asrat *et al.* *(*2016) reported in and around Wolayta Sodo town of southern Ethiopia. The differences observed in the percentage of male headed HHs among *weinadega* and *dega* rural areas of Gurage zone in particular (Table 1) could probably be attributed to the greater rate of evacuation of males from *weinadega* areas to the cities and towns found in different parts of Ethiopia in search of job opportunity leaving the rural HHs' business to their wives. On the other hand, differences observed on average number of male and female HHs in current study area of Gurage zone in general might be associated with cultural issues forcing females to get married and/or pushing aside females from being having power of bargaining on economic motives (FGD).

The results of current study in the study areas of Gurage zone showed that 61.1% of the sample HHs had the opportunities of getting different level of education (Table 1) was similar to 59.4% reported by Asrat *et al.* (2016) but higher than the result of 56.3% reported by Selamawit *et al.* (2017) in north Achefer district of Amhara region. The level of education of HHs reported in current study, on the other hand, was lower than 82.2% reported by Samuel (2014), 90% reported by Beriso *et al.* (2015) and

95.8% reported by Belay and Janssens (2016). The differences observed in level of education between the study areas of Gurage zone and HHs found in other parts of the country could be attributed to differences in access to schools. Group discussion was made to know the opinions of groups on whether education has advantage on performing different agricultural activities of HHs or not. The members of group discussion disclosed the importance of education as an instrument to improve the farmer's capability to acquire information, to recognize, understand and respond on adoption of new technologies that are helpful in increasing production and productivity. The report made by the group discussants is in agreement with the results of Ekwe and Nwachukwu (2006), Ofukou *et al.* (2009) and Belay and Janssens (2016) who reported farmers with education back ground adopt usually new technologies more rapidly and easily than uneducated farmers to ensure good results. Mulugeta (2005), on the other hand, indicated that HHs with low level of educational back ground can have negative impact on the transfer of agricultural technologies and participation in development. The group discussants also disclosed that in most cases, educated HHs are very eager to accept extension services and other income generating activities which enable them to enhance their productivity and production level. Asrat *et al.* (2016) also indicated that dairy cattle owners with good level of literacy can improve the current traditional dairy production systems using good extension and training. Similarly, Beriso *et al.* (2015) disclosed that HHs with better educational background have better ability to implement improved agricultural practices and wise use of scarce agricultural resources and it can be considered as good opportunity to facilitate extension services for rural development and transferring technology which all are in line with the result of current study.

The average number of family members of 7.71 per HH across the agroecologies of studied areas (Table 2) was similar to the country average family size of 7.50 persons per HH reported by Berhanu et *al*. (2007) and 7.54 persons per HH reported by Kassa *et al.* (2015) from Awassa but lower than reported average family size of 9.92 from Adami Tullu Jiddo Kombolcha district of east Showa zone of Oromiya region by Dawit *et al*. (2013). However it is higher than the national average of 5.2 reported by CSA (2003); the average family size of 6.2 by Ahmed (2006) from highland and midaltitude of Basona worana woreda of north Shoa; 7.05 by Beriso *et al* (2015) from

Aleta Chukko woreda of Sidama zone in southern Ethiopia; 6.46 and 7.17 reported by Kassa *et al*. (2015), respectively, from Ambo and Bako Tibe; 6.02 reported by Belay and Janssens (2016) from Jimma area, 6.51 reported by Asrat *et al*. (2016) from in and around Wolayta Sodo town of southern Ethiopia and 6.6 reported by Selamawit *et al.* (2017) from north Achefer district in Amhara region. The observation of relatively larger average family size in the study areas of Gurage zone could probably be related with agricultural activities of *enset* cultivation which is relatively labor intensive. The age of the respondents ranged from 30 - 78 years with an average age of 48.94 years. The average number of family members in age category of ≤ 14 and > 65 per HH was higher (P<0.05) for *weinadega* than *dega* areas and the difference could be associated with greater number of children per HH.

The proportion of crossbred cattle 4.45% as indicated in Table 3, was in line with the proportion of crossbred cattle 4.4% reported by Beriso *et al.* (2015) at Aleta Chukko District of Southern Ethiopia. But it was different from the report of Tsehay (2001) and CSA (2008), reported that about 99% of cattle population of Ethiopia are indigenous which are adapted to feed and water shortages, disease challenges and harsh climates. The study area of Gurage zone is low cereal crop producing area. Around 88.05% of livestock owners in these areas engaged mainly in the production of cattle aiming mainly on the production of milk to support *enset* based food to lead the healthy life and manure to fertilize crop garden which is in agreement with the result of Beriso *et al.* (2015) who reported that cattle was important component of the mixed-farming system and a primary purpose of cattle rearing in Aleta Chukko District of Southern Ethiopia was for milk production (72%). Moreover, in the study areas of Gurage zone, the majority (83.4%) of cattle population represented female cows, heifers and calves of both sexes. The oxen and bulls in current study areas accounted for 16.6% of the total cattle population which disagreed with the work of Gryseels and Goe (1984) who reported that most farmers in the central highlands of Ethiopia own two oxen, a cow, few sheep and a donkey. The result of current work also disagreed with report made by ILCA (1990), indicated that in mixed production systems where animals are used for draught and transport, the proportion of mature oxen or donkeys in herds tends to be relatively high.

The average land holding per HH in *weinadega* agroecology was 2.08ha while it was 1.44ha for *dega* agroecology. The overall average land holding in the study area, was 1.75ha which was in agreement with the result of 1.72ha reported by Kassa *et al*. (2015) from Awassa but less than the results of 3.3ha reported by Yitaye *et al.* (2007) in the highland areas of Amhara region; 2.5ha reported by Yeshitila (2008) in southern Ethiopia at Alaba district; 4.25ha from Humbo village and 2.75ha Dembi village of Diga Woreda in east Wollega Zone of Oromiya Region reported by Dereje *et al*. (2014); 2.34ha reported by Misgana *et al*. (2015) from selected districts of east Wollega Zone of Oromiya Region; 5.41ha from Ambo and 3.84ha from Bako Tibe of Oromiya Region reported by Kassa *et al*. (2015) and 2.18ha reported by Selamawit *et al.*(2017) from north Achefer district in Amhara Region.

Types of housing used for livestock in the study areas of Gurage zone were 100% family living house with separate partition (barn) paved with stone floor (Table 6). As the perception of the interviewed HHs the reason for housing the livestock in the family house was because of fear of thieves, to protect animals from extreme environmental conditions and for ease of husbandry practices of feeding, watering, milking, waste management. This result was much comparable with the result of Beriso *et al.* (2015) at Aleta Chukko District of Southern Ethiopia, who reported that 89% of HHs kept their cattle alongside with farm house heads under the same shed in the separate room (barn). The result of current study on livestock housing, on the other hand, was different from reports made by Zewdie (2010) in the highland and central rift valley of Ethiopia, Misgana *et al.* (2015) in Selected Districts of East Wollega Zone of Ethiopia and Selamawit *et al*. (2017) in watersheds of North Achefer District in Amhara Region of Ethiopia who reported majority of HHs housed their cattle in separate house having different housing structures.

Water sources of livestock in the study areas were identified and 100% of HHs in three PAs in *dega* agroecology as well as most (82.78%) of livestock keepers in both agroecologies of study areas relied on rivers as major water sources for their livestock (Table 7). The result of current study varies with the report of Belete (2006) in Fogera district who indicated about 48.75% of house heads use water for their cattle from ground wells, 47.2% from rivers, and 5.29% from Lake Tana and ponds. Similarly, Selamawit *et al.* (2017) reported that major source of water for livestock during dry season in watersheds of north Achefer district of Amhara Region was 49.6% well, 37.5% spring and 12.9% river water which was different from the result of current study. As indicated in Table 8, in both agroecologies of the study areas, only 17.5% of HHs were in a position to get water for their animals at a distance of 1-2km, however, 36.94% and 45.56% of HHs traveled a distance of 2-4 km and more than 4 km far to get water, respectively. In the drier season of the year, majority (86.4%) of HHs provided water to their livestock once a day which did not correspond with the result of Selamawit *et al.* (2017) who reported that 66.11% of house heads practiced watering of their livestock two times a day during dry season. The HHs and group discussants participated in the study indicated that watering frequency decreased as distance to water accessing point increased and livestock mostly encountered with weight loss and reduces potential of water drinking due to weakening and this was corresponded with the report of Kassahun *et al*. (2008), who reported that watering frequency decreased as distance to water accessing point increased and Girma *et al*. (2009), reported that animals consumed less water when they traveled further to water sources.

Cattle ownership varies depending on the type of agroecology, wealth status and overall farm production objectives. The average cattle holding (in TLU) per HH in *dega* and *weinadega* agroecologies of the study areas of Gurage zone, respectively, was 3.34 and 3.37 with over all mean of 3.35 which was comparable with the results of 3.31 for highland and lesser than 4.59 for midaltitude areas reported by Dereje (2009) in three *enset* (*E. ventricosum*) growing regions of Ethiopia. The result of current study also was much lesser than 7.57 for highland and 6.54 for midaltitude areas reported by Abera *et al.* (2018) in selected districts of Sidama Zone, Southern Ethiopia. Whereas the average cattle owned (in number) per HH of *dega* and *weinadega* agroecology, respectively, was 4.86 and 4.88. There was no significant difference ($P > 0.05$) on the average cattle holding per HH in both agroecologies. The overall average number of cattle per HH for current study was 4.87 and it was a bit higher than the average cattle number of 4 at Akaki and Lemu, central Ethiopia reported by Bayush *et al*. (2008), however, was tremendously lesser than 7.1 in north west Shewa zones, 15.5 in mixed crop livestock production system of Central Rift

Valley, 17.9 around Debrebirhan, 19.4 around Ziway Central Rift Valley and 8.27 at Adami Tullu Jiddo Kombolcha district in Oromiya Region, respectively, reported by Agajie *et al.* (2002), Lemma *et al.* (2005), Ahmed (2006), Zewdie (2010) and Dawit *et al*. (2013).

5.1.2. Measures of Productive and reproductive performance of cattle

In the study areas of Gurage zone, 95.5% of cattle breeds owned by HHs are typically of mixed indigenous breeds of central Ethiopia, which are characterized by low milk yield and small in size whereas 4.5% were crossbred of varied blood level. The overall estimated daily milk yield obtained in the current study was about 1.53 kg/day/cow with the mean difference of 0.22 kg as indicated in Table 17/18. The overall average milk yield reported in current study was 1.53 kg/day/cow which is in line with the result of 1.51 kg/day/cow reported by Abera *et al.* (2018) from selected districts of Sidama Zone, Southern Ethiopia but higher than the average daily milk yield of 1.26 kg/day/cow reported by Mulugeta and Belayeneh (2013) in Chacha town and nearby selected kebeles in north shewa zone of Amhara Region, Ethiopia and the average milk yield of 1.11 kg/day/cow reported by Kumar *et al.* (2014) at Gondar, northern Ethiopia. Similarly, the average milk yield of current study was found to be higher than the results of 1.0 kg/day/cow for Arsi zebu breed, 1.2 kg/day/cow for local zebu breed at Meiso district, 1.2 kg/day/cow for local zebu cows, and 1.35 kg/day/cow country average reported, respectively, by Lemma *et al.* (2005), Kedija (2007), Mulugeta *et al*. (2009) and CSA (2016). However, the average milk yield of current study 1.53 kg/day/cow was lower than the results of 2.1 kg/day/cow for Sheko breed in Bench Maji zone (Stein *et al*., 2006), 2.2 kg/day/cow for Boran breed in Borana Zone (Adugna and Aster, 2007) and 1.63 kg/day/cow for local zebu cattle at Aleta Chukko district of southern Ethiopia (Beriso *et al.,* 2015).

The overall estimated mean lactation length of cows obtained in the current study for both agroecologies was 217 days and greater than the average lactation length of 204.33 days for indigenous cows at Gondar, northern Ethiopia reported by Kumar *et al.* (2014) and the average lactation period of 180 days (6 months) reported by CSA (2016). The result of current study, on the other hand, was comparable with the reported lactation length of 219 days for local zebu breed at Meiso district by Kedija,

(2007) but shorter than lactation length of 305 days as defined by Foley *et al*. (1972) for highlands of local breeds of Ethiopia, 330 days of lactation lengths reported by Fekadu (1994) for local breeds; 285 days for Arsi zebu breed by Lemma *et al.* (2005); 264 days for Sheko breed in Bench Maji zone by Stein *et al*. (2006), 249 days for Boran breed in Borana Zone by Adugna and Aster (2007), 298 days for indigenous zebu cattle in Aleta Chukko district of southern Ethiopia by Beriso *et al.* (2015) and 246 days for local dairy cows in selected districts of Sidama Zone, southern Ethiopia reported by Abera *et al.* (2018).

The overall estimated mean age at first service for heifers of the study areas was indicated in Table 18. The overall estimated mean age of heifers at first conception for the current study was 53.44 months. This result was similar with reported average age of heifers at first service of 53 months for highland Zebu in different parts of Ethiopia reported by Mukassa-Mugrewa (1989), 55 months for Horro cattle by Mulugeta *et al.*, (1991) but it was higher than reported value of 34.4 months for Ogaden cattle by Getinet (2005) and 38.16 months reported by Mulugeta and Belayeneh (2013) in Chacha town and nearby selected kebeles in north Shoa Zone of Amhara Region, Ethiopia. Estimated mean ages at first service were significantly ($P<0.05$) longer for cows specially owned by HHs in PAs of *Yeferezye*, *Wukiye* and *Kochira* which all are found in *weinadega* agroecology.

Similarly overall estimated mean age at first calving for heifers of the study areas was indicated in Table 18. The range of age of 60-64months at first calving for heifers in the current study did not agree with the reported range of age at first calving of 35-62 months for Ethiopian cattle by Kiwuwa *et al*. (1983) but similar with the report of Mukassa-Mugrewa *et al.* (1991) and Mulugeta *et al.* (1991). The average age of 62 months at first calving in the current study also was not in agreement with the estimated mean of age at first calving 30.1 months reported by Kelay (2002), 47.16 months reported by Mulugeta and Belayeneh (2013) and 51.24 months reported by Beriso *et al.* (2015). The overall estimated mean age of heifers at first caving for the current study also was much higher than 51.9 months of age at first calving reported by Debir (2016) for local cattle in Sidama Zone, Southern Ethiopia and 52.3 months reported by Abera *et al.* (2018) for local dairy cows in selected districts of Sidama Zone, southern Ethiopia.

Extended length of days open between caving and conception affects lifetime production, generation interval and influences profitability of the dairy production hence, should not exceed 80 to 85 days, if a calving interval of 12 months is to be achieved (De Vries and Risco, 2005). Nutritional deficiencies coupled with heavy internal and external parasite load under extensive systems and allowing calves to suckle their dams may all interfere with ovarian function, thereby prolonging the days open (Hafez, 1993 and Gebreegziabher *et al.* 2005). The average length of days open for the current study for both agroecologies of Gurage zone was nearly about 7 months (211.44days) that was extremely longer than the reports of De Vries and Risco (2005).

The overall estimated mean of caving interval for the current study was 481.44days (16months) which is comparable with 16.01 months reported by Kedija (2007) for local cattle at Meiso district, Oromiya Region of Ethiopia and 472 days (15.7 months) reported by Zewdie (2010) in the highlands and central rift valley of Ethiopia. However, it was lower than the reported value of 24.94 months by Mulugeta and Belayeneh (2013) for Chacha town and nearby selected kebeles in north Shoa zone of Amhara Region of Ethiopia, 19.93months reported by Beriso *et al.* (2015) for local breed cows in Aleta Chukko district of southern Ethiopia, 20.08 months reported by Abera *et al.* (2018) for local dairy cows in selected districts of Sidama zone, southern Ethiopia. Range of caving interval observed in the current study 474.67- 487.11.days (15.8-16.2months) was within the ranged estimates of 12.2 to 26.6 months of calving interval in zebu cattle of Ethiopia reported by Mukassa-Mugrewa (1989).

5.1.3. Major constraints of dairy production

As indicated in Table 19, about 68.1% of HHs in the study areas indicated feed shortage as the first major constraint in affecting cattle production and productivity. This is mainly due to shortage of land for grazing and fodder production as the result of expansion of crop agriculture in the expense of grazing land. The result of current study corresponds with the result of Beriso *et al*. (2015) from Aleta Chukko district of southern Ethiopia; Selamawit *et al*. (2017) from watersheds of north Achefer district of Amhara region and Abera *et al*. (2018) in selected districts of Sidama zone, southern Ethiopia who reported that feed shortage was one of the major challenges which affect productive and reproductive performance of local dairy cows

Moreover, absence or inadequate forage seeds availability and extension service rendered to this regard was almost insignificant which aggravated the shortage of livestock/cattle feed in the study area. As the result, farmers of the study areas have mainly focused on production of *enset (E. ventricosum*) which provides not only food for human being but also it is a source for huge amount of feed (1169.36 tons) which accounted for 50.77% of TDM available per year particularly for cattle feeding (Table 38). During the study period, group discussion was made and they disclosed that the main reason of farmers to focus on *enset* production is due to reduced available land for grazing and crop cultivation as well as lack of appropriate farm inputs to produce food crops enough to feed the family and crop residues that can support their livestock. The report made by the groups agreed with the repot of Risse *et al*. (2006), who reported that in *enset* production systems there is a shortage of grazing as well as arable land, which in turn tends to limit production of annual pastures and/or crops that contributed to shortage of livestock feed resources.

About 58.9% of the HH respondents reported that low performance of local cattle was other important problem of dairy development which took the second rank (Table 19). The respondent HHs were emphasized that these indigenous cattle were generally characterized by small size, low milk yield, have slow growth rate and remain unproductive for longer period. The amount of average milk obtained per cow/day was not more than 1.5 kg and insufficient to satisfy the milk consumption need of the family which agreed with the result of Beriso *et al*. (2015) in Aleta Chukko district of southern Ethiopia and Abera *et al*. (2018) in selected districts of Sidama zone, southern Ethiopia. Group discussion on nature of dairying was made and the group discussants revealed that AI activities have been started since two decades aiming on improving productive performance of local cattle. However, due to encountered technical and managerial problems such as poor heat detection skill by the owners of the cow and AI technicians, inconsistency on AI input and service provision, lack of interest of both inseminators and experts of livestock due to lack of motivation made the AI program inefficient. The report of group discussion agreed with the reports of Samre *et al*. (2015) in and around Alamata district in Tigray region of Ethiopia and Fentaye and Wubshet (2018) from Essera woreda of Dawuro zone in southern Ethiopia. The results of focus group discussion also corresponded with the report of Philipson *et al*. (2011), who indicated that the activities of AI has failed in many situations in developing countries because of lack of infrastructure and the costs involved on transportation and liquid nitrogen for storage of semen, this is because the breeding program has not been designed to be sustainable.

As indicated in Table 19 water shortage was reported as the third major constraint during the dry season by 51.7% of HHs of both agroecologies. On the other hand, about 82.78% of livestock keepers have relied on rivers as major water sources for their livestock in both agroecologies of the study areas of Gurage Zone (Table 7). The result of current study varies with the report of Belete (2006) who reported 48.75% of house heads in Fogera district use water for their cattle from ground wells, 47.20% from rivers, and 5.29% from Lake Tana and ponds. Similarly, Selamawit *et al.* (2017) reported the major water source for livestock during dry season in watersheds of north Achefer district of Amhara region was 49.6% well, 37.5% spring and 12.9% river water which was not in agreement with the result of the current study. In both agroecologies of the study areas, only 17.5% of HHs (N = 360) were in a position to get water for their animals at a distance of 1-2km, however, 36.94% and 45.56% of HHs traveled a distance of 2-4 km and greater than 4 km, respectively. In the drier season of the year, the majority (86.4%) of HHs (N = 360) provided water to their livestock once a day which did not correspond with the result of 66.11% house heads practiced watering of their livestock two times a day during dry season reported by Selamawit *et al.* (2017). Group discussion on livestock water sources and its accessibility was made and they suggested that moving livestock to distant places in search of drinking water is time taking, tedious work and causes energy loss and it needs intervention on the use of different water harvesting techniques such as harvesting the runoff in wet season to partially solve the problem, construction of appropriate water harvesting structures of shallow to deep wells as well as pond construction by making common theme among government, non-government organizations and the community based on agroecologies. The respondent HHs and group discussants participated in the study also indicated that watering frequency decreased as distance to water accessing point increased. They also disclosed that livestock traveled long distance in search of water mostly encountered with weight loss and reduces potential of water drinking because of weakening which was corresponded with the report of Kassahun *et al*. (2008), who reported that watering frequency decreased as the distance to water accessing point increased and Girma *et al*. (2009) who reported that animals consume less water if they have traveled further to the water sources.

Animal disease was the fourth constraint (N = 360) prioritized by 46.4% of the participants (Table 19). The prevalent diseases of the study area include: Anthrax, Blackleg, Foot and Mouth Disease (FMD), Bovine Pasteurollosis, Lump Skin Disease (LSD), External and internal parasites. Because of inability of HHs to get drugs and vaccines with required amount and in a scheduled manner (in time), livestock owners in the study area were forced to buy and utilize some drugs and vaccines delivered by illegal traders which were not good enough to heal sick animals and to protect the animals from being infected. The result obtained in the current study in relation to problems associated with livestock disease outbreak and the mechanism of preventions under taken agreed with the results reported by Beriso *et al*. (2015) and Selamawit *et al.* (2017), who reported that inadequate veterinary service to handle diseases outbreak was the prevailing constraints of dairy production.

As reported by the group discussants in the study areas, in most of the cases measures of disease prevention and control have been undertaken by the regional and local government bodies and it is in line with the report of MoARD (2008), that revealed those vaccines and medicines required for handling of livestock diseases were typically provided on a highly subsidized basis by the Veterinary Department of the Regional Agricultural Bureau and sometimes through Project Finance. Groups participated in the discussion also indicated the existence of complaints on low preventive capability of (LSD) vaccine which is the only imported and free of charge. The constraints of livestock production identified in current study in general corresponds with the results made by Berhanu et *al.* (2009), Negassa *et al*. (2011), Getahun (2012), Dawit *et al.* (2013) and Dereje *et al.* (2014) who reported that the inadequacy of feed, water scarcity, high disease prevalence, low productivity of local breeding stock are the main dairy cattle production constraints in different parts of Ethiopia. Azage *et al.* (2013) in their report revealed also that dairy production in Ethiopia has been hampered by multi-faced, production system-specific constraints related to genotype, feed resources and feeding systems, access to services and inputs, low adoption of improved technologies, marketing and absence of clear policy support to the sector which is in line with the report of current study.

5.1.4. Mating systems of dairy cattle

About 83.6% of the respondents in the study areas of both agroecologies used natural mating system using local bulls as indicated in Table 22 and 15.3% of farmers were used combined mating system of AI and bull mating for their dairy cattle. The Use of AI services as the only option to improve the genetic makeup of cattle by HHs of the study area was almost nil and it was 1.1%. The result of current study was more comparable with the result of Beriso *et al.* (2015), who reported that 91% of HHs practiced natural mating system using bull available in the area, some (7%) of the farmers used both natural and AI while 2% of them used AI only. The result of current study, however, did not agree with report of Asrat *et al.* (2016), who reported that in rural production system about 68.9% use natural mating using local bulls, 28.9% of the HHs use AI and the rest 2.2% use both natural mating and AI service. Group discussion and personal communication with elite members of the community was made to realize the responses given by HHs on mating system and they disclosed that AI services designed to be delivered in regular program (conventional AI service) has collapsed since 2002 following structural decentralization strategy of government offices.

The discussants also indicated that structural linkage between service delivery offices of study areas and national artificial insemination center (NAIC) has become extremely loosen. There is neither collaboration nor regular communication between NAIC and AI service providers. The AI technicians have lost their interest in the area of insemination due to lack of attention by government bodies. The absence or shortage of provision of consumables and equipment used in AI service delivery including sheath, gloves, apron, inseminating gun, containers of liquid nitrogen, motor cycle were mentioned as serious bottlenecks by group discussants for recorded lower performance and loss of working interest of the AI technicians. In addition, the system has encountered with lack of frozen semen and liquid nitrogen. Everyone in areas of development has focused mainly on crop production leaving livestock/cattle rearing activities aside. Because of the above mentioned bottlenecks and similar reasons, most of AI technicians with good experience and skill in providing AI cervices changed their working area of livestock sub sector either by leaving the occupation or by changing their area of study (FGD and Dirsha D., Personal Communication).

Even in the areas where there is opportunity for AI services delivery, the inseminated cows have never conceived at once and have come in to heat repeatedly, that might be associated with problem of heat detection, time of insemination, use of proper insemination technique, semen quality and technical efficiency of AI technicians that was in line with the results reported by Samre *et al*. (2015) in and around Alamata district in Tigray region of Ethiopia and Fentaye and Wubshet (2018) from Essera woreda in Dawuro zone of southern Ethiopia. The results obtained from HH interview, focus group discussion and personal communication in current study was also corresponds with the report of Philipsson *et al*. (2011), who indicated that the use of AI has failed in many situations in developing countries because of lack of infrastructure and the costs involved, such as transportation and liquid nitrogen for storage of semen this is because the breeding program has not been designed to be sustainable.

The result of current study is also in line with the report of Desalegn (2008), who reported the proportion of AI users in regional sites of Ethiopia was lower. The same author also indicated that major constraints associated with AI in Ethiopia include loose structural linkage between NAIC and service giving units, absence of collaboration and regular communication between NAIC and stakeholders, lack of proper and functional breeding policy and herd recording system, inadequate resources availability in terms of inputs and facilities, absence of incentives and rewards to motivate AI technicians. Similarly, Minale and Yilkal (2015), in their study reported that the owner of cattle had a problem of getting AI services through which they can upgrade the genetic makeup of their low producing dairy animals due to difficulties encountered in input provision as well as different technical and administrative problems. Most cattle owners in the study areas of Gurage zone especially those who are living far from towns of each *Woreda* Administration, have no opportunity of getting AI services and cross breeding activity is almost non-existent which has agreed with the report made by Azage *et al*. (2013), who reported that the number of crossbred cows in rural areas is very low and is mainly concentrated in and around major urban and peri-urban centers.

Estrus synchronization coupled with AI service provision has started since 2011, and the campaign has continued for the last six years. The activities practiced using this program, however, has encountered a number of technical and administrative problems that associated with low performances. Although reasons for this low performance have not well studied and no solutions have given, the campaign of estrus synchronization and AI services provision has continued. When estrus synchronization and cow's insemination is compared with conventional system of AI service delivery, the campaign has provided better opportunity of cattle owners in getting AI services in scheduled approach at their dwellings and relatively with better results of crosses of 4.5% as reported in the current study than the reported value of about 1% crossbred cattle population at national level (Tsehay, 2001; CSA, 2008; CSA, 2016).

According to the report of group discussion, there are different constraints that have urged to use natural mating using local bulls by HHs in the area. These constraints include knowledge on selection criteria of cows for AI, access and cost of AI service, ease of getting preferred service of either AI or breeding bull, number of services required per conception, skill of estrus detection and insemination. When the aforementioned constraints are well addressed, almost 97% of HHs in the study area of Gurage zone prefer AI and breeding bull services to improve genetic potential of their cattle. In order to respond to high milk demand in this *enset*-based production system and to exploit potentials and resources available there, provision of genetically superior dairy cattle or good breeding services delivery as per the needs of cattle owners is one of the prerequisites for development of dairying. Provision of well-organized and scheduled estrus synchronization and AI service provision is a good option to reach the cattle owners living at distant areas from towns of each *woreda* Administration of the study areas. Hence, to make the program successful and the HH users profitable, technical and managerial problems associated with implementation of estrus synchronization and cow's insemination should be avoided, more attentions must be given for the improvements of cattle feeding and health care services (FGD).

5.1.5. Seasonality of feed resources

In the study areas of Gurage zone leaf and leaf midribs of *enset (E. ventricosum)*, crop residues and natural pasture were the major feed resources for livestock feeding in different seasons. The feeds available at different months of a year for both *dega* and *weinadega* agroecologies of the study areas are strongly influenced by season of the year which is similar to the findings on the seasonal availability of feed resources reported by Gryseels (1988a) and Gashaw (1992) in the central highlands of Ethiopia. The amount and the proportions of dry matter produced from *enset* leaf and leaf midribs was much higher than any of feed resources available, which was 506.4 tons (52.73%) in *dega* and 662.96 tons (49.36%) in *weinadega* agroecology (Table 38). The *In vitro* dry matter digestibility (IVDMD) in the leaf and leaf midribs of *enset* was 58.18% for *dega* and 60.45% for *weinadega* agroecology, which has vital advantages in the digestibility and intake during cattle feeding. The amount of DM produced from crop residues and its percentage from the total available livestock feed in *dega* agroecology was 312.33 tons (32.52%) and it was 472.83tons (35.2%) in *weinadega* agroecology. The amount of dry matter produced from natural pasture was 141.62 tons (14.75%) and 207.33tons (15.44%) for *dega* and *weinadega* areas, respectively. In all aspects of measurements under taken to determine the DM, DCP and ME content of available livestock feed in the study areas of Gurage zone, leaf and leaf midribs of *enset* represented the greatest share of 50.77% TDM, 70.86% TDCP and 54.81% TME available for cattle feeding (Table 38) and therefore, *enset* leaves and midribs are the major source of feed to feed and safeguard the life of animals. The results obtained in the current study is in agreement with the reports of Dereje (1996), who reported chemical composition and the rumen degradability suggest that *enset* leaf has a potential to be used in cattle feeding to an increasing extent. Dereje (2009), also reported that HHs fed *enset* leaf to their cattle from December to May, when there is limitation of feed in quality and quantity.

Brandt *et al*. (1997), also reported that following harvest, crop residues are given to the cattle and among all *enset* growing groups *enset* leaves form an integral part of the dry season cattle diet and they may be used for as long as 7 to 8 months depending on area and ethnic group. Menbere (2014), on his report indicated that during dry season of the year cattle in *enset* growing areas are substantially dependent on parts of *enset* not normally eaten by humans particularly leaf and upper parts of the leaf (midribs). Similarly, Jimma *et al*. (2016) reported that about 94.3% of HHs in the Kembata Tembaro and Wolayta Zones in one or another way used leaf and pseudo stem of *enset* in feeding their cattle during the drier season of the year particularly when other feed resources became in scarce, which is also in line with the result of current study. On the other hand, there is a definite time to utilize grazing land in the study area and it is dominantly utilized in the wet season of the year, mainly between the months of late August to December. Crop residues were also used as main feed during both dry and rainy seasons of the year (December to August) that corresponds with the report of Alemayehu (2004), Tolera *et al.* (2012), Dereje *et al*. (2014) and Selamawit *et al.* (2017), who stated natural pasture and crop residues to be major feed resources in different areas of Ethiopia at different seasons of the year.

5.1.6. Composition of natural pastures and feeding priority of cattle

Measurement was made on the potential biomass yield and DM yield of natural pasture species. Grasses species represented 89% and 86% whereas legumes represented for 4.2% and 3.1% DM biomass yields from *dega* and *weinadega* agroecology, respectively (Table 26). The higher share of grasses species observed in the current study agreed with the reports of Sisay (2006) and Teshome (2007). The lower proportion of legumes monitored in the study areas might probably be due to sprawling nature of growth of the legumes which make them more susceptible to be lost through grazing. Variation in biomass composition of legumes in current study could also be related with altitudinal differences in elevation of *dega* and *weinadega* that corresponds with the report of Alemu (1990) and Alemayehu (2005), who reported that the proportion of legumes tends to increase with increasing altitude and particularly above 2,200 masl and at lower altitudes native legumes are less abundant.

Feeding strategy depends on the nature of the farming system, objective of herding animals and the availability of feed resources in specific area which is to be affordable by the farmers. In line with this, farmers were ranked feeding priority of available feeds and supplements to their cattle. From a total of 360 HHs participated in the study, about 42.5% of HHs had given the first feeding priority to lactating cows whereas around 35% HHs of the study areas gave their priority of feeding to calves. The rest of 12.8% and 9.7% of HHs, respectively, gave priority of feeding for weak animal and plowing oxen (Table 29). Mode of feeding priority in the current study area gave more attention to the lactating cows than the plowing oxen which was different from the report made by Mekuanint and Girma (2017), in Gasera and Ginnir districts in Bale zone of Oromiya region.

5.1.7. Feeds, feeding and length of grazing

In both *dega* and *weinadega* agroecologies of Gurage zone, livestock production system is dominated by extensive system of production where most of the time farmers depend largely on feeding of their livestock with leaf and leaf midribs of *enset* (*E. ventricosum*), natural pasture and crop residues that corresponds with the report made by Yigrem *et al*. (2008) and Asrat *et al*. (2016). Households in the study areas of Gurage zone used different feeding practices of cattle including cut and carry, grazing along roadsides or tethering and grazing of cattle in the backyard area (Table 28). The result of current study was in line with the report of Asrat *et al.* (2013) and Asrat et *al*. (2016), respectively, in Humbo woreda and in and around Wolayta Sodo town. The estimated average grazing hours were 6.27hrs/day in *dega* and 8.11hrs/day in *weinadega* agroecologies. The overall average grazing hours were 7.19/day ranged between 5-10hrs (Table 30). Herders in the *dega* agroecology brought their cattle back to home from grazing field earlier which contributed to the shorter grazing period as compared to cattle found in *weinadega* agroecology of the study areas. The maximum grazing hour recorded in current study corresponds with the work of

McDonald *et al*. (1995) who reported that animals normally graze about 8 hours per day but some times as long as 10 hours per day.

5.1.8. Milk consumption, processing, marketing and calf rearing

All HH respondents in the study areas of both agroecologies of Gurage Zone practiced hand milking and 100% of the HHs milk their cows twice a day; at 6-8am in the morning and 7-9 pm in the evening (Table 31). The result of current study corresponds with the result of Yigrem *et al*. (2008) who reported that in Shashemene and Dilla areas, only about 3.3% of farmers milk their cows thrice a day while 96.7% of house heads milk their cows twice a day. However, the result of current study disagreed with report made by Asrat *et.al.* (2016), who indicated that majority (95.3%) of the HHs in and around rural areas of Sodo town of Wolayta zone milk their cows thrice a day; at 6-7am in the morning, 3-4pm in the afternoon and 8-9pm in the evening. Consumption pattern of produced milk and milk products varies depending upon the amount of milk produced per HH, season of the year and fasting period particularly in areas where the followers of Orthodox Christian are found. Fresh and fermented milk, *Ayib* and butter are the most common products produced and consumed by HHs in both agroecologies of the study areas which was in line with the report made by Zewdie (2010) from central rift valley of Ethiopia. Marketing of raw milk is not common in this *enset*-based dairy production system of all study sites of Gurage Zone and mostly consumed at home with *kocho* which is in agreement with the report of Getachew (2003), who indicated that most of milk produced in rural dairy system is retained for home consumption and it is non-market oriented. The main reason for the absence of raw milk selling in the study area was not the existence of cultural reasons and/or taboos that forbid the selling of raw milk but it was due to low milk produced by individual HH.

Churning of milk was practiced by all HHs found in study PAs and in most cases, the process of butter making in current study areas of Gurage Zone was similar to churning process observed in most parts of the country as reported by Fekadu (1994), in southern Ethiopia, Zelalem and Inger (2000), around Holetta and Debre Zeit areas and Zewdie (2010) in Central Rift Valley. Collecting of milk for churning practiced in two ways. The first method of collecting milk for churning is common practice that has been done in most areas of Ethiopia by collecting some days (2-4 days) milk produced by individual HH and let the milk to sour and the sour milk is allowed to be churned which was similar to the report of Zelalem and Inger (2000), and Zewdie (2010). The second method of collecting milk for churning is practiced by collecting of measurable amount of milk using local milk measuring equipment of glass, jog and mud made equipment in *Guragigna* called *Jerr, Enjaba*, etc. from a group made by HHs wives of neighborhood, ruled by bylaws established by group members of HHs wives.

The method of milk collection by forming groups from neighboring HH wives in *Guragigna* known as *Wujo* and mainly performed by those HHs' wives who have small number of milking cow(s) and/or possessing milking cow(s) with low potential of milk production. Group discussion made by milk group members revealed that making group to collect milk for churning through *Wujo* helped the members in providing opportunity for collecting and bringing small amount of milk produced by individual group member which could not be considered for churning (FGD). The equipment commonly used in churning is clay pot. Some members in the area might use a stick with four (common) to six finger-like projections at one end (*Mesbekia* in Amharic and *shirmet* in Guragigna) to mix and steer the sour milk before the commencement of churning. Milking is performed two times (morning and evening) per day and soon after milking, the milk is transferred in to a clay pot (in Guragigna called *Yeb Egujet*) until enough sour milk is collected for churning.

Usually the quality of the formed curdle of sour milk is visually evaluated and its readiness is determined by the female member of the HH who has long experience on doing so. The sour milk is transferred to another clean and smoked churning clay pot (*Yeb Wosher* in *Guragigna*) after checking its readiness to be churned. The mouth or opening of the churn is sealed using dried but well prepared, unteared and well soaked *enset* leaf sheaths (internal surface of the sheath, in *Guragigna* called *Eniwa*) and tied it firmly using jute rope made of decorticated pseudo stem of *enset* (locally called *Kacha*). At the middle part of the neck of the churning pot, a small hole *(Fifwet* in Guragigna) is made for releasing the developed gas during churning and to visualize the completion of churning process without opening the mouth of the churning pot. The process of churning may take 1:00 to 1:30 hours depending on the temperature of the day and the amount of sour milk under churning. Based on the perception of focus group discussants, lower environmental temperature and smaller amount of sour milk can help to shorten the process of churning which is in line with the report of Zewdie (2010). Butter formation visually determined by checking the presence or absence of granules of fat (*Firye in Guragigna*) by over flowing of small amount of sour milk under churning process through *Fifwet* and if granules of fat (*Firye)* are observed, the process of churning will continue.

The major marketable milk products in the study areas are butter and *Ayib*. These products are marketed mainly through informal marketing systems where producers sell the products of milk to direct consumer, unlicensed traders or retailers directly either on homestead or open local market. The selling and buying price of the milk products in the study area was usually set through negotiation between the seller and the buyer. The price for locally processed products of milk (butter and *Ayib)* was highest in the long dry season (Late of October to Mid of February) in both *dega* and *weinadega* agroecologies and, respectively, were 167.14 and 170.02 Birr for butter and 56.01 and 62.22 Birr for *Ayib*. There was variation ($P<0.05$) in prices of the salable milk products between agroecologies and price for butter and *ayib* was highest at *weinadega* agroecology than the *dega* agroecology.

Price variations for butter and *ayib* among agroecologies could be attributed to proximity of the study PAs of *weinadega* agroecology to towns where demand for both products is high. Price variations for butter and *ayib* among agroecologies could also be attributed relatively to lower production of these products in the *weinadega* than the *dega* PAs of the study areas. The highest average price of 167.14 Birr for butter and 59.11 Birr for *Ayib* was reported in long dry season (Late of October to Mid of February) and the lowest average price of 136.31 Birr for butter and 43.19 Birr for *Ayib* (Table 34) was in short rainy season (Late of February to May) and this result was in line with the result of Zewdie (2010) in the highlands and central rift valley areas of Ethiopia.

All of the HH respondents of the study areas of Gurage zone were practiced free colostrum feeding of calves for about 6 to10 days after calving (Table 35). Herders were well aware of the use of colostrum feeding for the newly born animals and understand the beneficial effect on health of the young. In addition to the colostrum feeding partial suckling of calves prior to milking was also common practices. The result of this study was in line with the reports of Asrat *et al.* (2013) in Humbo woreda, Beriso *et al.* (2015) in Aleta Chukko district of southern Ethiopia, and Asrat *et al*. (2016) in and surrounding rural area of Sodo town, who reported, respectively, that 80%, 100% and 94.1% of HHs were practiced colostrum feeding and partial suckling of calf before milking. Coppock (1994) reported a weaning age of calf ranged between 7-12 months for Boran calves in Ethiopia which was similar to the range of calf weaning age of 6-12months in the current study. The overall average age of calf weaning in the current study was about 9 months which was longer than the calf weaning age of 7.83 months reported by Beriso *et al*. (2015). Weaning process in the study areas of Gurage zone dependent on factors such as when the dam became pregnant, when there is feed availability for the weaned calves, when the cow becomes aggressive or when she reduced in milk yield for the calf and when the dam becomes dry off that was in agreement with the report made by Asrat *et al.* (2016).

5.1.9. Gender labor division for cattle related activities

About 66.4% of milking was handled by HH wives or adult females whereas 22.5% of milking was done by both sexes and the rest 11.1% of the milking activities were done by males (figure 4/a). The result of the current study is in agreement with Belete (2006), he reported that in Fogera district of Amhara Region milking was primary handled by women and similar report was made by Beriso *et al.* (2015) in Aleta Chukko district of southern Ethiopia that 80% of milking of dairy animal is done by women but it differs from the result of Yigrem *et al*, (2008), who reported in Shashemene and Dilla areas milking was entirely performed by adult males and husbands. At the same time, 100% of marketing of milk products in the study areas was practiced by adult females (figure 4/b) which was not in agreement with the report of Beriso *et al*. (2015), who reported that only 58% of marketing activities of milk products was done by females. Around 56.7% of activities related to calf rearing (figure 4/c) were associated with the female members of the HH and it was different from 38% reported by Beriso *et al*. (2015) in Aleta Chukko District of southern Ethiopia. The remaining 37.5% and 5.8% of the activities of calf rearing was practiced, respectively, by both sexes and male members of the family. On the other hand, 51.7%, 17.5% and 30.8% of cattle herding (figure 4/d) was practiced, respectively, by adult males, females and both sexes of the family members and it was different from the result of Beriso *et al*. (2015), who reported that 62% of activities related with cattle herding was performed by children. The frequency of barn cleaning varies between seasons and the number of animals owned by individual HHs, especially based on number of cattle owned. About 76.67% of barn cleaning activity in the study areas of Gurage zone was done by females whereas the remaining 8.33% and 15% of barn cleaning done, respectively, by male members and by both sexes (figure 4/e) which was not in agreement with the result of Beriso *et al.* (2015), who reported only 50% of barn cleaning activity was done by females. For about 72.5% of activities related to herd feeding and watering was carried out by males and 18.3% was done by both sexes (figure 4/f) which agreed with the report of Beriso *et al.* (2015) at Aleta Chukko district and Zewdie (2010) at Sebeta and Jimma areas but different from the report of Zewdie (2010) at Debrebirhan area. Major (76.1%) of activities related with cattle feed collection were the task of males in all study areas of Gurage zone (figure 4/g) which was in line with the report of Zewdie (2010) at highlands and central rift valley of Ethiopia. In generalizing the activities related to cattle management, there was sharing of responsibilities between men and women members of family for different husbandry activities (figure 4/h) and women played as significant role as men which was 38.18% and 39.35%, respectively.

5.2. Chemical Composition and Nutritive Value of Feedstuffs

Chemical composition and nutritive value of the major feedstuffs utilized for livestock feeding in the study areas of Gurage zone was analyzed (Table 36) and DM content of the feeds available for livestock feeding in both *dega* and *weinadega* agroecologies was above 90%, which corresponds with reported results of different scholars in different parts of the country (Ahmed, 2006; Sisay 2006). Ash content of major cereal crop residues in current study ranged from 6.49% to 9.32% for straws and from 4.23% to 9.81% for stubbles. Wheat straw had the highest ash content of 9.32% in *weinadega agroecology*, followed by 9.02% in barely straw on *dega* agroecology. The value of ash content for barely straw reported in this study was lower than the value 14.6% reported by Yitaye (1999) and 19.7% by Solomon (2004) but comparable with the value of 9.11% reported by Mekuanint and Girma (2017).

On the other hand, the value of ash content for wheat straw 9.32% was similar with 9.34% reported by Mekuanint and Girma (2017) but higher than 8.94%, 8.22% and 8.8% reported, respectively, by Alemu *et al*. (1989), Solomon (2004) and Chalchissa *et al*. (2014). The ash content of maize stover recorded in this work (9.98%) is greater than 7% reported by Yitaye (1999) and 9.29% reported by Chalchissa *et al.* (2014). The variations observed on ash contents of crop residues of cereal crops could be associated with environmental factors of rain fall, soil character, temperature and contamination of residues by other external factors. The ash content of leaf and leaf midribs of *enset* (*E. ventricosum*) reported in this study in *dega* and *weinadega* agroecologies, respectively, were 7.12% and 7.31% with overall average of 7.22 % (Table 36), which is lower than the reported value of 16.8% by Mohammed *et al.,* (2013). The ash content of native pastures was 10.88% for *dega* and 11.97% for *weinadega* agroecology. The variation observed on ash content of native pastures could possibly be due to variation in agroecology of study areas that corresponds with the report of Little (1982), who stated that the ash content of natural pastures increase as elevation in altitude decreases and such variations could possibly arise from difference in climate and soil types. However, Mekuanint and Girma (2017) reported 10.99% ash content of native grasses from *dega* and 9.89% from *weinadega* which disagreed with the statement made by Little (1982) and the results reported in the current study.

The CP content of crop straws varied from 2.63% barley to 5.54% field pea. Lower CP value for barley straw reported in this study agrees with the report of Yitaye (1999), Solomon (2004) and Ahmed (2006). In general the percentage of CP obtained from crop straws that are considered as available feed resources for livestock feeding in the study areas is much lower than that set as a minimum level of 7% CP to limit intake (Milford and Minson, 1966; Van Soest, 1982). There are findings that crop stubbles have lower leaf to stem ratio than the corresponding straws that limits the CP contents of the stubbles to minimum level (Ørskov 1988), however, the content of CP found in stubbles of barely, wheat, field pea and faba bean reported in current study had higher CP content than that of their corresponding straws (Table 36). This may be associated with the presence of grasses and other species of legumes that were grown on crop fields and left aside with stubbles of crops on crop grown fields during harvest. Though the stubbles of barely, wheat, field pea and faba bean in the study areas had higher CP content than that of their corresponding straws, the CP content reported in current study from all residues of crops was at lower level to fulfill the optimum CP requirement of livestock. The report made by current study agreed with the general statement made by Preston and Leng (1984), who indicated that all cereal crop residues have low nitrogen or CP content and are composed of cell wall components with little soluble cell contents.

Natural pastures from *dega* and *weinadega* agroecologies of the study areas, respectively, had CP content of 8.23% and 6.34%. The value for CP content of pastures from *dega* agroecology was higher than that of *weinadega* area. Such differences may be associated with reduction in the proportion of legumes in the pasture with a decrease in altitude and this is in line with the finding of Alemayehu (1985) and Mekuanint and Girma (2017). The CP values from natural pastures are closer to the minimum value reported by Milford and Minson (1966) and Van Soest (1982), required for optimum rumen microbial function, hence, can support maintenance requirement of ruminants with slight supplementation. Conversely, the amount of CP contents found in the leaf and leaf midribs of *enset* reported in current study were 11.39% in *dega* and 9.34% in *weinadega* agroecology with overall average of 10.37%, which were lesser than the average CP value of 14.6% reported by Dereje (2009) and 13.15% reported by Mohammed *et al.*, (2013). However, the CP content of leaf and leaf midribs of *enset* far exceeded from all available livestock feeds in the study areas of Gurage Zone as well as the minimum value of 7% required for optimum rumen microbial function reported by Milford and Minson (1966) and Van Soest (1982). Therefore, *enset* leaf can be used as a supplemental feed resource to back up the short fall and can support maintenance requirement of ruminants. The report on CP content of leaf and leaf midribs of *enset (E.ventricosum)* in current study was compatible with the report of Brandt *et al*. (1997), who stated that protein content and total amount of protein are greater in the portion of *enset* not eaten by humans. The same authors indicated that by comparison, the stems and any remaining leaves of cereals and other tuber crops that are left for animal feed are usually of low protein value than the leaf and the leaf midribs of *enset* used as cattle feeds. Woodward *et al*. (2011), also reported that e*nset* leaf as one of the highest protein concentrated feed from available fodder resources during the dry season and *enset* leaf protein concentration is much higher than for example timothy hay.

The NDF content of straws of cereal crops in current study was between 69.4% in *teff* to 48.94% in barley. As indicated in Table 36, stubbles of most cereal crops had slightly lower NDF contents than their corresponding straws. Sisay (2006) reported greater than 70% average NDF contents for cereal crop residues. Similar results of 79.4% and 72.98% were reported for the straws of cereal crops, respectively, by Alemu *et al*. (1989) and Solomon (2004). The NDF content of 78.6%, 81.5% and 82.13%, respectively, for wheat straw, *teff* straw and maize stover were reported by Chalchissa *et al.* (2014). Solomon (2004), also reported 79.7% NDF content for cereal crops stubbles. The NDF content of straws of field pea, faba bean and barley as well as all crop stubbles identified in current study ranged between 45% - 65%. The NDF content of leaf and leaf midribs of *enset* was 64.92% for *dega* and 61.26% for *weinadega* agroecology which is much lower than the average NDF value of 69.6% in *enset* leaf reported by Dereje (2009).

Those feed resources of livestock of the current study with the reported NDF values ranging between 45%-65% could be classified udder medium quality feed and may not impose drawbacks on animal performance as indicated by Singh and Oosting (1992). The NDF content of 68.8% recorded for maize stover in the current study was much lesser than 82.13% NDF content of maize stover reported by Chalchissa *et al.* (2014). The NDF content of native pasture (74.1%) reported in current study in *dega* and 75.54% in *weinadega* were closer to the values reported by Solomon (2004) and Ahmed (2006). The higher NDF content could be a limiting factor on feed intake, since voluntary feed intake and NDF content are negatively correlated (Ensminger *et al*. 1990) and therefore, feeds with NDF content of greater than 65% in current study could be classified as low quality roughages, which could impose drawbacks on feed intake and animal production.

The ADF content of crop straws varied from 47.2% in faba bean to 66% in wheat whereas the ADF content of crop stubbles were ranged from 35.2% in barley to 65.6% in field pea. The ADF content for both crop straws and stubbles are within the range reported by Solomon (2004), Ahmed (2006) and Solomon *et al.* (2008a). Conversely, the ADF content for native pastures for *dega* and *weinadega* agroecologies, respectively, was 40.01% and 41.08%. Kellems and Church (1998) categorized roughages with less than 40% ADF as high quality and above 40% as low quality. The results of ADF content of feeds in current study was higher than the ADF values reported by Yitaye (1999) which was 39.45% for barley straw, 29.98% for native pastures and 44.22% for maize stover. Variation in ADF content could be attributed to differences in temperature, crop management and soil type.

The ADF content of maize stover 51.72% reported by Chalchissa *et al.* (2014) was higher than the reported ADF value of 47.6% in current study. The ADF content of 46.8% for *teff* straw and 58.1% for wheat straw reported by Chalchissa *et al.* (2014) was lower than the results of current study as indicated in Table 36. The ADF value reported for leaf and leaf midribs of *enset* (*E. ventricosum*) in the current study was as low as 38.34% in *dega* and 39.18% in *weinadega* and lower than 42.1% ADF content of *enset* leaf reported by Dereje (2009) in the three *enset* growing regions of Ethiopia. The ADF content of leaf and leaf midribs of *enset* in current study also lower than the higher limit category (40%) of ADF for high quality roughages reported by Kellems and Church (1998) and the leaf and leaf midribs of *enset* in the study areas can be grouped under high quality roughages and used in livestock particularly in cattle feeding.

The ADL contained in different crop residues found in the study areas ranged from 6.95% to 14.44%. The highest concentration of lignin (14.44%) was found in field pea straw followed by (12.62%) in faba bean straw. The lignin content of field pea and faba bean straws found in current study was comparable with the results of 13.64% for field pea and 12.72% for faba bean straws reported by Mekuanint and

Girma (2017). However, ADL contents of 16.37% for field pea and 13.21% for faba bean straws reported by Solomon (2004) and 15. 85% for field pea and 15.42% for faba bean straws reported by Ahmed (2006), were higher than the results reported in current study. The percentage of lignin in crop stubbles reported in the current study also varied between 6.95% in *teff* stubble to 13.31% in field pea stubble. The highest lignin percentage was observed in the stubbles of field pea, which is also in line with the ADL content of field pea stubbles of 15.82% reported by Ahmed (2006).

The ADL content of 14.44 and 12.62 for field pea and faba bean straw as well as 13.31% and 11.02% for stubbles of field pea and faba bean recorded in this study, respectively, were imperatively higher than the maximum level of 7% that limits DM intake and livestock production (Reed *et al*., 1986). This indicated existence of greater differences in lignification between crop residues of cereals (monocotyledons) and legumes (dicotyledons). The level of IVDMD and ME produced from residues of legumes of the current study, however, were much better than those residues from cereal crops of non-legume origin (monocots) that could be associated with intrinsic nature of these two crop families. As it was reported in current study, non-legumes (monocots) have much higher fiber (NDF and ADF) concentrations than legumes species (dicots) and, on the other hand, monocots have lower concentration of readily digestible cell contents. The result of current study well comparable with the report of Buxton and Russell (1988), who reported that the most important difference existed between grasses (monocots) and legumes (dicots) is in the concentration of fiber and hence differences in the concentration of IVDMD and ME.

Even though lignin has a negative impact on the fiber digestibility of legumes, legumes contain much lesser fiber (NDF and ADF) than grasses which lessens the impact of lignin on overall digestible energy concentration. For these reason, lignin concentration is not a good indicator of digestible energy when making comparisons between grass species and legumes (Buxton and Russell (1988). The lignin concentration in maize stover of the study area was found to be 10.59% and native pastures of *dega* and *weinadega* agroecologies, respectively, were 7.69% and 7.87%, which were greater than limiting lignin content of 7%. The ADL content of leaf and leaf midribs of *enset* (*E. ventricosum*) in the current study was 6.37% for *dega* and

6.31% for *weinadega* agroecology with overall average lignin content of 6.34% for both agroecologies and was higher than the average ADL content of 3.26% reported by Mohammed *et al*. (2013), however it was lower than 7% maximum lignin content to affects rumen activities and feed intake reported by (Reed *et al*., 1986) and average ADL content of 8.54% reported by Dereje (2009) from three *enset* growing regions of southern Ethiopia. Variations observed in ADL composition of *enset* leaf and midribs could be associated with differences in stage of growth of the *enset* plant, landraces (varieties) of *enset* plant used, method of sample taking, edaphic and agro climatic differences encountered.

The IVDMD for maize stover reported in current study was 49.93% and lower than the reported value 58.65% by Chalchissa *et al.* (2014). The level of IVDMD from leaf and leaf midribs of *enset* in current study was about 58.18% and 60.45% whereas it was 55.91% and 54.35% for natural pastures in *dega* and *weinadega* agroecologies, respectively. The IVDMD of straws of cereal crops ranged from 40.74% to 55.5% in which the faba bean straw had the highest (55.5%) content followed by field pea straw (52.64%). The IVDMD value of 40.74% reported for wheat straw in current work (Table 36) was lower than from all reported values for the straws of cereal crops of current study but it was similar to the results of 41.92% reported from Gassera district and 42.22% reported from Ginnir districts in Bale zone of Oromiya region by Mekuanint and Girma (2017). Similarly, IVDMD content of corresponding cereal crop stubbles were ranged from 35.68% to 48.23%. The highest value was recorded for faba bean stubble (48.23%) and the lowest value recorded for wheat stubble (35.68%). From crop residues utilized for livestock feeding in the study areas, greater value of IVDMD was recorded for those straws and stubbles of legume origin. The results of the current study on IVDMD of crop residues was in line with the report of Buxton and Russell (1988) and Seyoum and Fekede (2008), reported that cereal crop residues are normally characterized by low digestibility and energy value, which are both inherent in their chemical composition.

The average ME contents of crop straws and stubbles in current study were within the range reported by Solomon (2004) and Yitaye (1999) but average ME recorded in current study as indicated in Table 36 was much higher than the ME content of 5.96

MJ/kg DM for wheat straw reported by Chalchissa *et al.* (2014). The energy content of native pasture in current study was 8.39 MJ/kg DM in *dega* and 8.15 MJ/kg DM in *weinadega* agroecology, which is comparable with 8.19 MJ/kg DM reported by Zinash *et al*. (1995) and 8.17 MJ/kg DM reported by Yitaye (1999). The energy content of maize stover in the study area (7.49 MJ/kg DM) was comparable with the report of Yitaye (1999) which was 7.33 MJ/kg DM but lower than 8.79 MJ/kg DM reported by Chalchissa *et al.* (2014). The ME value contained in leaf and leaf midribs of *enset* (*E. ventricosum*) from *dega* and *weinadega* agroecologies, respectively, were 8.73 MJ/kg DM and 9.0MJ/kg DM (Table 41) and variations on energy content of leaf and leaf midribs of *enset* among agroecologies of the study areas could probably be associated with differences in the agroclimatic conditions as well as the type of *enset* landraces (clones) grown in each agroecology.

Calcium and phosphorus are the two determining minerals in both function and amount in the production and productivity of livestock. A concentration of Ca in majority of feeds in the study areas except those pastures and stubbles of (faba bean, barley and *teff*) were at normal range. Conversely, P concentrations of nearly all feeds in the study areas were low (Table 36) when compared with the recommendations of < 2 g/kg DM low, between 2-3.5 g/kg DM normal and > 4 g/kg DM high, for both Ca and P minerals made by McDonald *et al.* (1995) and Kellems and Church (1998). According to McDowell and Conrad (1977), on the other hand, the critical level of calcium and phosphorus needed in livestock production under grazing management practice was 3 g/kg DM and 2.5 g/kg DM, respectively. The average Ca and P concentration obtained in current study from leaf and leaf midribs of *enset*, respectively, were 3.64 g/kg DM and 1.19 g/kg DM which were much higher than the reported value of 2.18 g/kg DM of Ca and 0.18 g/kg DM of P by Mohammed *et al.* (2013) and 1.07 g/kg DM Ca and 0.22 g/kg DM P reported by Dereje (2009) from southern Ethiopia. The difference observed in chemical composition and nutritive value of *enset* leaf could be associated with differences in farming practices of HHs in different areas, agroecology, soil fertility, nature of manure application, the stage of growth and the landraces of *ense*t used from which the leaf and leaf midribs were taken for the analysis.

5.3. Livestock Feed Balance

The amount of DM produced from leaf and leaf midribs of *enset* reported in current study is in line with reports of Brandt *et al*. (1997), who stated that among all *enset* growing groups *enset* leaves form an integral part of the dry season cattle diet and may be used for as long as 7 to 8 months a year. Similar statement was made by Dereje (1996) and Menbere (2014), who reported that *enset* leaves are major source of feed, during the dry season cattle are substantially dependent on parts of *enset* not normally eaten by humans, particularly the leaf and leaf sheaths (midribs). On the same way, DM production from crop straws of barley, wheat and field pea in *dega* and maize stover, *teff* and wheat straws in *weinadega* agroecology represented the largest share of DM produced and used primarily as dry season feed which agreed with the report of Dereje *et al*. (2014) from Diga *Woreda* of east Wollega zone indicated that crop residues are used as major sources of livestock feed during dry season.

Wheat straw in the study areas of both agroecologies (Table 38) has provided huge amount of DM, however, hardly utilized when there was enough feed to sustain the animals. The wheat straw was stored together with other crop residues as feed reserve and provided it to the livestock when HHs were encountered in feed shortage and similar report was recorded by Mekuanint and Girma (2017) from Gassera and Diga districts of Bale zone in Oromiya region. Use of improved fodder trees and those of agro industrial byproducts in the study areas were negligible which is in agreement with the report of Alemayehu (2005), who reported that the production of improved pasture and forages in most parts of Ethiopia is insignificant and the contribution of agro industrial by products is also minimal and restricted to some urban and peri urban farms. Dereje *et al*. (2014) also indicated that fodder crops are important livestock feed, but farmers in the Humbo, Dapo and Dembi villages of Diga *Woreda* in east Wollega Zone hardly grow improved forages and extension service to support forage development in the area appears to be weak and non-functional.

The annual available feed reported in the current study was compared with the annual requirements of the livestock population in the study areas. The overall estimated feed supply in the study area met only for 76.81% of DM and 69.9% of DCP daily maintenance requirement of livestock, however, total estimate of ME was 1.67% in surplus per year which was estimated based on the recommendations for DM, DCP and ME made by Kearl (1982) and McCarthy (1986) per TLU. Estimates on the amount of available feed supply and demand per year per agroecology of *dega* and *weinadega* were also made separately and in *dega* agroecology the available feed supply met only about 64.98% DM, 66.24% DCP and 85.66% ME of the maintenance requirement of livestock per farm per year. On the other hand, in *weinadega* agroecology, the available feed supply satisfied about 88.31% DM, 73.46% DCP maintenance requirement of livestock and the total ME estimates were 17.22% in surplus per year (Table 42).

In *Moche* PA of *dega* agroecology, on the other hand, the available feed on year round basis satisfied about 97.18% DM and 96.08% DCP maintenance requirement and the estimated ME was 28.84% in surplus. On the rest of three PAs of *dega* agroecology (*Shamene*, *Achene and Agata)*, however, livestock were in serious negative feed balance (Table 42). The reason for betterment of available livestock feed in *weinadega* agroecology might be associated relatively with better availability of land for grazing, cropping and production of *enset* (*E. ventricosum*). It was indicated in Table 42 that the total estimated annual feed supply in the study area of Gurage zone met only about 76.81% DM and 69.9% DCP maintenance requirement of livestock. The feed deficit encountered in the study areas might be associated with lower amount of feed production, poor quality roughages produced and absence of agroidustrial by products and improved forages to supplement.

The observed negative feed balance in DM requirement in the current study agreed with earlier work of Adugna and Said, (1994) reported for different areas in the country; DM deficit reported by Yeshitila (2008) in Alaba District of southern Ethiopia; Firew and Getnet (2010) reported from different parts of Amhara Regional State; Zewdie (2010) reported from central rift valley around Ziway in Oromiya Region; Dawit *et al.* (2013) from selected kebeles of Adami Tullu Jiddo Kombolcha district of East Shewa Zone in Oromiya Region and feed deficit reported by Selamawit *et al.* (2017) from north Achefer district in Amhara Region. However, it disagreed with the report of Sisay (2006) reported surplus DM supply than the total annual livestock requirement in North Gondar Zone of Ethiopia.

5.4. Interaction of Cattle and *Enset* Production

Livestock particularly cattle comprised a major and integral component of farming system in the study area of Gurage Zone and there was close interaction between cattle and *enset* (*E. ventricosum*) production. Based on results of group discussions and interviewed HHs, cattle production is one of the essential and integral components in *enset* culture both interms of supplying farm yard manure and provision of milk, milk products and meat without which consumption of *kocho* would be difficult. Around 88.05% of livestock owners (Table 4) in these areas engaged mainly in production of cattle majorly aiming on the production of milk to support *enset*-based food to lead healthy life and manure production to fertilize crop garden which is in agreement with the result of Beriso *et al.* (2015) who reported that cattle were important component of the mixed-farming system that they provide, milk, fertilizer, income and used as saving to the farmers. The number of mature *enset* harvested by the farmer is directly related to the number of cattle owned by HHs. In the same way, *enset* production is very important in production of cattle in that *enset* provides leaf and the leaf midribs to feed animals for the entire period of 7-8 months in a year, which is in line with the report of Brandt *et al*. (1997), who reported that among all *enset* growing groups *enset* leaves form an integral part of the dry season cattle feed and may be used for as long as 7 to 8 months of the dry season of a year. Similarly, Nurfeta *et al.* (2008) reported that *enset* leaves (leaf blades and leaf stalks of *enset*) are not used as food for humans but are used as fodder for livestock.

During droughts, *enset* leaves along with its midribs cut off from *enset* plant and sliced in to minimum size using the leaf and leaf midribs slicing knife in Guragigna known as *Muriya* and given to animals particularly to cattle. Thus, *enset* leaves are especially important as fodder resource when grasslands and annual crops fail due to extended and unpredictable droughts. The CP content of leaf and leaf midribs of *enset* reported in the current study was higher than the content of CP contained in any of feeds available for livestock in both *dega* and *weinadega* agroecologies (Table 36) of the study areas which corresponds with the general fact that more proteins are found in the leaves of *enset* than in the stems or roots of *enset* plants (Brandt *et al*., 1997). Households in both agroecologies of the study areas substantially depend on leaf and leaf midribs of *enset* (*E. ventricosum*) to feed their cattle. The amount of DM produced from *enset* parts in both agroecologies of the study areas accounted for 1169.36 tons (50.77%) from a TDM of 2303.47 tons produced in a year which is greater than half of TDM produced and available for livestock feeding in the area (Table 38). The result of current study is in agreement with reports made by Dereje (1996), Mulugeta (1996) and Menbere (2014), who reported that *enset* leaves are the major source of feed to the cattle. During dry seasons, cattle are substantially dependent on parts of *enset* not normally eaten by humans, particularly the leaf, and leaf sheaths (midribs).

According to the results of current study, the trend of *enset (E. ventricosum)* farm size per HH was decreasing from time to time in the last five years (Table 46). About 61.7% of HHs from both agroecologies reported that *enset* farm size per HH has shown decreasing trend due to fragmentation of land between the HH members of adult hood but the area coverage is still increasing. As the result of fragmented and small land holdings to produce annual crops enough to accommodate the year round food requirements of family members, HHs of the study areas urged to shift their annual crop production to *enset* cultivation. The reason of change in the mode of production of cereals to *enset* was due to the ability of *enset* plant to produce more products of *kocho* and *bulla* to support annual caloric requirement of farming family within that small holding (Table 45).

Though HHs of the study areas tried every endeavour to improve production and productivity of *enset* crop using his own cultural management practices, attention given by concerned bodies of government and research institutions was insignificant. More attention was given to production of annual crops, the importance of which was immaterial when comparing them with the importance of *enset* in saving the lives of the farming families of the study areas. This result was in agreement with the report of William (1966), who reported that "The Gurages have a vital interest in *enset* locally called '*asset*'. They depend on it for many of the necessities of life. The uses of ‘*asset*’ seem endless and all parts of ‘*asset*’ are consumed in one way or another, this increases considerably the importance of ‘*asset*’ in Gurage culture”. But, in the Gurage area, *enset* has not received considerable attention due to undermining its potential (lack of consideration) of contribution to livelihoods and food security of farm HHs and there is an idea and practices of replacing *enset* by annual crops (William, 1966). Similar to trends observed decline in *enset* farm size, the trend of cattle ownership in the study areas of both agroecologies of Gurage zone has declined at HH level due to shortage of land for forage production and grazing which was resulted from land fragmentation and division of land holdings of HH (father or mother) between adult members of family during marriage.

Cattle have played a critical role in *enset* system in maintaining soil fertility and agricultural sustainability. Based on the perception of HHs and results of group discussion, in the absence of cattle in this system, sustainability of *enset* production could definitely and negatively be affected. Reducing the number of cattle per HH mean, reduction in the availability of manure to fertilize *enset* garden that negatively affects *enset* production. The result of current study agreed with the report of Brandt *et al. (*1997) and Maryo *et al*. (2014), who indicated that different factors contribute to the progressive downward spiral in the cattle sub sector of the rural economy. This decline in cattle size affects level of manure production and decreases in cattle manure causes reductions in long-term sustainability of *enset* systems. It could also have an impact on human nutrition. All (100%) of HHs participated in the interview confirmed that cattle manure is a major and locally available source of nutrient input in *enset* farming and is crucial for the productivity of their *enset* farm which agreed with the report of Risse *et al*., (2006), who reported that cattle manure is a locally available low cost substitute of inorganic fertilizer for majority of resource poor farmers and cattle manure is highly valued by farmers because of its multiple roles and long-term benefits. Similar conclusion was made by Maryo *et al*. (2014), who indicated that decline in the number of cattle will call for decline in cattle manure production which cause reductions in long-term sustainability of *enset* production and productivity.

On the other hand, about 84.2% of sample HHs in the study areas of Gurage zone (Table 49), revealed that in the existed situation of fragmented land holding which doesn't give opportunity of producing grasses, improved forage crops and crop residues enough to feed cattle, it is paramount important to practice *enset* cultivation without which cattle production cannot be in practice. Leaf and leaf midribs of *enset* (*E. ventricosum*) is used as feed source of cattle and has potential of keeping the life of cattle and other livestock during drought period that aggravates the feed shortage and livestock health problems. The results of current study is corresponded with the work of Dereje (1996) and Menbere (2014),who reported that due to the encroachment of crop at the expense of grazing lands, the system is dependent on cut and carry system for its cattle feed. During dry season, cattle are substantially dependent on parts of *enset* not normally eaten by humans, particularly the leaf and the upper parts of the leaf sheaths/midribs. Dereje (2009) also indicated that by considering the chemical composition of *enset* and its mineral content, *enset* leaf can be used as a supplemental feed resource by the cattle owners to support the short fall encountered due to limitation of feed in quality and quantity during dry period of the year. Mohammed *et al*. (2013) also stated that *enset* leaves can give space to realize the sustainable feeding in cattle production and are generally suitable feed for cattle. Jimma *et al*. (2016) from Kembata Tembaro and Wolayta zones reported that about 94.3% of HHs of the area in one or another way used the leaf and the pseudo stem of *enset* in feeding their cattle during the drier season of the year particularly when other feed resources became in scarce, which are in line with the result of current study.

The number of years needed for *enset* to mature was longer in *dega* agroecology than in *weinadega* agroecology and in the most of the cases it was in the raged between 7 to 10 years. The result of current study on the number of years needed for *enset* to mature is not in agreement with Brandt *et al*. (1997) and Mulugeta (1996) who reported that *enset* is usually harvested at onset of flowering between 5 to 8 years after planting. On the other hand, Tesfaye (2005) reported that in the high altitudes of 2300-3100 masl where mean temperature drops to 10-15^{o}C, *enset* takes 8-10 years and sometimes up to16 years to mature which is in line with the result of current study. The HH respondents and the group discussants of the study revealed that the differences observed on the number of years of maturation for *enset* plant in the same agroecology could be associated with differences on the ability and method of HHs in the *enset* management, differences in *enset* landraces used by individual farmers and majorly on manure application. Furthermore, differences in temperature between *dega* and *weinadega* agroecologies could also bring variation in number of years needed for maturation of *enset* plant. The report of current study agreed with the report made by Risse *et al*. (2006), who indicated that in *enset* farming system, cattle manure is the principal source of organic matter and nutrient input and is crucial for the productivity and rate of growth of *enset* plant.

5.5. Manure Utilization and Chemical Composition

In *enset* farming system of Gurage zone, cattle manure is the principal source of organic matter and nutrient input and is crucial for the productivity of the system. The use of inorganic fertilizers is limited for *enset* crop because of its high cost and limited availability. Households involved in the cattle rearing in the study areas of Gurage zone (Table 51) revealed that the primary and the only purpose (100%) of cattle manure production was to be used as fertilizer and there is no practices of using cattle dung as fuel or dung cake for sale. The result of current study is in line with the report of Snijders *et al.,* (2009), who reported that manure is an important source of nutrients for many smallholder farmers in East Africa, with cattle manure being the dominant type. In the same way, Muhereza *et al. (*2014), reported that 100% of farmers in central Uganda utilized cattle manure to their crop garden. The results of the current study also corresponded with the report of Risse *et al*. (2006), who stated cattle manure as an excellent source of plant nutrients such as nitrogen, phosphorus and potassium as well as the secondary nutrients that plants require. The same authors also noted that the application of cattle manure increases the level of soil organic matter.

The result of current study, on the other hand, is not in agreement with report of Alemayehu, (2004), who reported that manure production is considered important by most crop/livestock and agro-pastoralist farmers in Ethiopia, but as secondary rather than a primary purpose. The result of this research work also is not in line with the report made by Mekonnen and Köhlin (2008), who reported that in highlands of Ethiopia where sedentary agriculture is practiced, most of the manure produced is used as fuel, especially in central and northern part of Ethiopia and only a very small fraction is used as manuring the soil and its use as manure is generally limited to small area of land around homestead or nearby farms. The same authors revealed also that each farm HH in central and northern part of the country uses dung for his HH energy requirement essential for cooking and heating. The result of current study is not agreed with the report of Lupwayi *et al.* (1999) who reported that manure collected from farms in Deneba area had significantly greater contents of N, P, K, but due to scarcity of fuel wood, farmers in Deneba use manure for fuel in domestic cooking and heating instead of applying it to soil. The result of current study also disagreed with the result reported by Yilma, (2001), from Sidama zone of southern Ethiopia indicated, around 20% of livestock dung is used as a source of fuel and the rest 80% is used for farm yard manure.

Manure used in the analysis of current study had a total nitrogen content of 2.68% in *dega* and 2.24% in *weinadega* agroecologies with overall average of 2.46% on dry weight basis which is in agreement with the report of Snijders *et al.* (2009) who indicated that the total nitrogen content of manure on a dry matter basis ranges from below 0.5% to over 4%. At the same time the carbon to nitrogen ratio of manure for both agroecologies was assessed and the C: N ratio of 11:1 was for *dega*, 12:1 for *weinadega* with overall average result of 11.5:1. The results obtained in current study on the percentage of total nitrogen and carbon to nitrogen ratio from cattle manure, however, was different from the result reported by Ferew (2012), who found that manure used in his study had total nitrogen of 1.89% on dry weight basis and a C: N ratio of 18:1 (Table 52). On the other hand, the moisture content of cattle manure at different agroecology of *dega* and *weinadega* differed each other and it was about 29.4% for *dega* and 25.3% for *weinadega* agroecology.

The difference in total nitrogen, organic carbon and carbon to nitrogen ratio among sample manure taken from the study areas in particular and in cattle manure in general could mainly be attributed to differences in environmental conditions of climate, soil, chemical composition of the feeds consumed by cattle (crop residues of different type, variation in legumes to grass composition, leaf and leaf midribs of *enset* available to cattle feeding) and so on which is in agreement with the report of Lupwayi *et al.*

(1999), who stated that manures collected from experimental stations contained significantly more N, P, K, than the manures from smallholder farms, probably due to differences in the type and quality of available feed and other factors. Snijders *et al.* (2009) on their report also indicated the existence of large variation in nitrogen, phosphorus, potassium and carbon contents of cattle manures. The same authors also indicated that manure quality strongly varies, due to variation in feed supply and intake, ration quality, addition of organic material to excreta, losses during collection and storage and contamination with soil.

The composition of organic matter found in manure sample in the current study was 51.89% and 44.82% for sample manure taken in *dega* and *weinadega* agroecology, respectively, which is significantly important for sustainability of the system. Similarly, the main plant nutrients that have incorporated in cattle manure was identified and the amount of nitrogen, phosphorus and potassium (gram of N, P and K per kg DM of manure), respectively, were 26.8 g/kg, 16.5 g/kg and 1.6 g/kg in the cases of *dega* and 22.4 g/kg, 12.6 g/kg and1.2 g/kg in *weinadega* agroecology. The contents minerals found in manure samples of the current study are much higher in *dega* than in *weinadega*. This report was in agreement with the repot made by Snijders *et al.*, (2009) who indicated that contents in farm yard manure particularly the nitrogen from temperate countries are often higher, probably due to higher protein contents in feed rations, more favorable collection and storage conditions, including lower temperatures. The amount (gm/kg DM) of nitrogen, phosphorus reported in current study was also much higher than the result of 18.9gm N/kg and 6gm P/kg DM of manure reported by Ferew (2012) and the average result of 18.3gm N/kg and 4.5gm P/kg of manure on dry matter basis reported by Lupwayi *et al.* (1999). However, amount of potassium reported in current study was extremely lower than the reported potassium value of 21.3 gm kg^{-1} DM by Lupwayi *et al.* (1999) which needs special attention in the future.

As to the HHs' potential in producing cattle manure, about 77.8% from *dega* agroecology and 76.7% HHs from *weinadega* agroecology with overall average of 77.25% HHs responded the inability of having potential to produce enough amount of cattle manure to fertilize crop garden particularly *enset* (Table 53). The reasons for

HHs' inability to produce cattle manure enough to fertilize crop garden were increasing number of human population which put pressure on land availability thereby reducing the ability of HHs to produce and to feed forage enough to his livestock. The reduction in the size of cattle due to reduced forage production also reduces manure production. Increase in human population and decreases in land holding directly affect number of cattle and by its turn can affect the production of food items mainly due to reduced amount of manure production to fertilize crop garden. The result of current study agreed with the result of Muhereza *et al. (*2014) who reported that farmers from central Uganda indicated that cattle manure was not adequate to fertilize the whole farm in a single cropping season because of small herd size as well as lack of supplementary feeding and inadequate fodder production due to limitation in land availability, therefore, farmers were fertilized portions of their farm on a rotational basis according to perceived soil nutrient deficiency. The result of current study also corresponds with the report of Maryo *et al. (*2014), who stated that the absence/reduced number of cattle due to different reasons can cause reduction in manure production which certainly and negatively affect sustainability of *enset* production.

Households and group discussants participated in the study have perceived that in the absence of cattle manure in this system, the sustainability of *enset* production could negatively be affected which agreed with the report of Brandt *et al. (*1997) and Maryo *et al*. (2014), who indicated that different factors contribute to the progressive downward spiral in the production of cattle subsector of the rural economy. This decline in cattle size affects the level of manure production and decreases in cattle manure causes reductions in the long-term sustainability of *enset* production. It could also have an impact on human nutrition. The HHs and group discussants also emphasized that cattle manure is the principal source of organic matter and mechanism of nutrient delivery for *enset* production that determines the productivity of the *enset* garden which also agreed with the report of Tadesse (2013), who reported that manure plays a vital role in improving crop yields, allowing sustainable productivity and has ability of changing soil microclimate condition and restoration of ecological balance. Snijders *et al.* (2009) also stated that manure is an important source of nutrients for many smallholder farmers in East Africa, with cattle manure being the dominant type which was in agreement with the result of current study.

The HHs participated in the interview of current study were asked the significance of manure over chemical fertilizer in respect to provision of production sustainability, in keeping soil fertility, reducing soil erosion, on ease of availability and low cost and so on. And 100% of HHs who participated in the study indicated that sustainability of production and productivity of *enset* cannot be achieved without the application of cattle manure. On the other hand, about 96.7% of the respondent HHs in all study areas of both *dega* and *weinadega agroecologies*, concluded that cattle manure played a significant role in keeping soil fertility and in reducing soil erosion. Based on manure's low cost and manure's easily availability when compared with inorganic fertilizer, cattle manure was chosen, respectively, by 94.4% and 92.5% HHs of both agroecologies (Table 54). The result obtained in this study well corresponded with the report of Muhereza *et al. (*2014), who reported that the major benefits obtained from the use of cattle manure include increased crop yields, disease reduction, easily availability and low cost of cattle manure purchasing than inorganic fertilizer.

5.6. Role of Cattle in HH Food Security in *Enset* Based Agriculture

Food security of HHs in the current study areas was affected by several determinants including HHs' family size, farm land holding, number of cattle holding and number of mature *enset* harvested per year and these all have significant effect on determining food security of HH. Among these food security determinant factors, size of farm land, number of cattle holding and number of mature *enset* harvested are supply-side factors whereas the HHs' family size is demand-side factor (Shiferaw *et al*., 2003). The result of current study was in line with the report made by Degefa (2002), Kidane *et al.* (2005) and Tefera (2009) who indicated in their report that farm land size, livestock ownership, family size and level of technology application of HHs were some out of various determinants of HHs' food security.

Enset based cattle production can contribute to food availability through income generation, interaction with *enset* and other crop production by providing manure to fertilize crop garden. Cattle production open the opportunity for higher productivity per plot of land and make sustainable the production and productivity of *enset* food items that can be harvested at any time and stage of growth allowing HHs to balance period of food shortage which is in line with the report made by Brandt *et al*. (1997), who stated that *enset* is usually grown with generations of plants mixed, thus being a reliable food source overtime. However, the number of years required for *enset* to mature reported in current study ranged between 7-10 years (Figure 6), which is different from the report of Brandt *et al*. (1997), who stated that *enset* is usually harvested at beginning of flowering between 5 to 8 years after planting. Conversely, Tesfaye (2005) reported that in the high altitudes of 2300-3100 masl where mean temperature drops to 10-15^{o}C, *enset* takes 8-10 years and sometimes up to16 years to mature which is in line with the result of current study. The difference observed on the years required for maturation of *enset* could be associated with the edaphic and climatic conditions, cultural practices and *enset* landraces used at different areas of current study as well as in the country.

The average cultivated land for *enset* production in current study was 0.37ha, the average number of mature *enset* harvested was 72 and the average *kocho* and *bulla* produced per mature *enset*, respectively, was 51.8 kg and 1.88 kg (Table 55). And the result of *kocho* per mature *enset* in current study was ranged between 38 kg to 80 kg with the average production of 51.8 kg. The average kilogram of *kocho* produced in current study was not in agreement with the nationwide survey report made by Taye (1984) and CSA (1998), who reported 19.04 kg/*enset* (11.9 tons/ ha/year) and 30.2 kg/mature *enset*, respectively. The average kilogram of *kocho* produced in the study areas per mature *enset* laid within the range of *kocho* produced per mature *enset* reported by Shank and Entiro (1996) which was 19.7 to 84.6 kg/*enset* but higher than the report of Admasu (2002), who reported a maximum yield of 42.02 kg/*enset* (26.26tons/ha/year). Among *enset* based foods, *kocho* predominates other *enset* food product such as *bulla* in its quantity. Consequently, quantification of *enset* yield mostly considers the yield of *kocho* production. The average yield of *bulla* produced per mature *enset* reported in current study was 1.88 kg which is much higher than the national survey report of 1kg average *bulla* per mature *enset* (CSA, 1998).

The quantity of *enset* products, grains and cattle products were calculated and converted in to daily dietary calorie equivalent (Table 63) separately based on Ethiopian Health and Nutrition Research Institute (EHNRI) food composition table of 1968-1997 (Appendix 6). The net available *kocho, bulla*, grains and cattle products for each sample HH were converted in to calories equivalent using the conversion factors (Shank and Entiro, 1996). The total proportion of calories produced from individual products of *kocho, bulla*, grains and cattle products were calculated to look in to the contribution of each product to the dietary calorie supply of the HHs in the study area. Out of total dietary energy supply of the available food, 65%, 24.8% and 10.2%, respectively, were obtained from *enset* products (*kocho* and *bulla*), grains and cattle products. The average dry weight yield of cereal grain per hectare in the current study was 2079.5 kg and the amount of energy produced in kilocalories was 2079.5kg x 3500kcal/kg (7,278,250kcal). Depending on cereal equivalent (CE) conversion of the yield or weight value of a food to the proportion of 3500 kcal per kilogram equivalents of cereals (Shank and Entiro, 1996), the total cereal equivalent weight (CE) of *kocho* and *bulla* produced per hectare is 2945.45kg +119.11kg (3064.56kg). The kilo calorie of *kocho* and *bulla* produced per hectare was 3064.56 x 3500 (10,725,960kcal). The total cereal equivalent yield of *enset* (*kocho* and *bulla*) per hectare was 3064.56kg. Hence *enset* surpassed by 985.06 kg in cereal equivalent weight and 3,447,710kcal in energy (32.14%) per hectare of land which is enough to serve 4.5 persons for 365 days with medically recommended minimum daily energy intake of 2100 kcal (FAO, 1998).

Enset plant can be harvested at any time and any stage of growth, allowing HHs to balance period of food shortage. *Enset* plant is relatively resistant crop for adverse environmental factors of seasonal drought, seasonal flooding, erratic and shortage of rain fall than other crops. *Enset* foods (*kocho* and *bulla*) can be stored for long-term uses and the storage ability of *kocho* and *bulla* for long periods with little storage loss provides HHs with a mechanism to smooth consumption during food shortage and reduces food insecurity which is in line with the report of FAO (2010), stated that Ethiopia, being a food insecure country and in protracted crisis, the country would be benefited from increased and improved use of *enset*. Kefale and Sandford (1994), reported that the primary strategic importance of *enset* in food security is that *enset* helps to prevent famine by surviving drought when other food crops fail. Once *enset* plants are established in areas of sufficient rainfall, they are able to tolerate occasional years of very low rainfall or a short rainy season. The same authors reported that *enset* gives higher yield of 1.3 to 3.5 times much more food energy per unit of cultivated land with the same management practices than other crops and supporting the densely populated areas in the country. Therefore, for HHs facing a shortage of land, the higher energy productivity of *enset* relative to cereals makes *enset* an important food security crop.

According to the reports of group discussion, all parts of *enset* have some economic importance. The corm and pseudo stem of *enset* are the most important sources of food. Some landraces of *enset* are used for traditional medicines. The leaves and leaf midribs of *enset* are used as cattle feed. The leaves of *enset* also used as wrapping for products of *enset* during preparation, storage and transportation, used as wrapping of khat (*Catha edulis*), used in bread baking and it also used as a source of cash. The fiber (*kacha*) extracted during *kocho* processing is locally used for making strings; ropes and other products of culturally accepted and value added traditional handicrafts which corresponds with the report of Mulugeta (1996), Brandt *et al*. (1997) and Nurfeta *et al*. (2008), who stated that *enset* is a multipurpose crop including human food, animal forage, fiber (industrial crop), construction materials and traditional medicines.

Negash and Niehof (2004), also reported that *enset* cultivation is a straight forward method to facilitate people to achieve independent livelihoods security. *Enset* can improve food security in drought prone areas where the climate is warm but not too hot, thus in much larger areas than where currently used. Mulugeta (1996) also reported that once *enset* plant is established, it can be utilized as a source of food all year round so long as it exists with reasonable size, thus it saved many lives in the past recurrent drought in the country. As reported by Shiferaw *et al*. (2003), HHs in cereals-*enset*-based systems are more likely to be food secure than those in cereal-based system because of better productivity, longer storability and flexible harvesting capability, drought tolerance and other desirable traits of *enset* plant. Brandt *et al*. (1997) also reported that *Enset* acts as a food store which can be used at any time of the year; it is relatively drought-resistant plant, the leaves along its midribs provide fodder for livestock. By its nature *enset* is considered as a 'drought security' and 'strategic' crop and in densely populated areas of southern Ethiopia, *enset* is regarded as a food security crop.

Based on perception of interviewed sample HHs and results from FGD, the production and productivity of *enset* and the amount of dietary energy produced from *enset* products basically dependent on the cattle production and on the number of cattle (large or small cattle size) owned by HH. The HH respondents and group discussants concluded that the holding of either larger or smaller number of cattle by individuals has determinant effect on the amount of manure production which directly affects the growth performance of *enset*, the quantity and quality of *enset* products, amount of dietary energy supply from *enset* and therefore, the HHs' capability of being food secure or food insecure.

By considering the average dietary energy reported from current study, 71.39% of HHs participated on the study were found to be food secure and those of 28.61% were food insecure (Table 64). To distinguish variation between wealth groups and to see contribution of cattle in food security, the distribution of available dietary energy based on the number of cattle ownership (wealth grouping) were measured. And 92.5% wealthy, 73.33% medium and 48.33% poor HHs got daily dietary energy ≥ 2100kcal (Table 64). Accordingly, those HHs who had been consuming < 2100kcal medically recommended daily dietary energy (FAO, 1998,) sorted out as food insecure groups, whereas those HHs consuming ≥ 2100 kcal of medically recommended daily dietary energy, grouped as food secure.

Households having large number of cattle (wealthy HHs) were in a position to produce greater amount of average daily dietary energy of 6057.32kcal per person which is above medically recommended minimum daily dietary energy requirement of 2100 kcal/person/day (FAO, 1998, Wikipedia, n.d.) and it is greater than twofold of average dietary energy of 2812.04 kcal per individual produced by those poor HHs owning small number of cattle (Table 64). Tefera (2009), also indicated that house heads who owned greater number of cattle have better food security status than those house heads with less number of cattle ownership and agreed with the result of current study. In the study areas of Gurage zone cattle not only influence the food security (energy consumption) of HHs through improving production and productivity of *kocho and bulla* but cattle also put their direct effect of 10.2% on energy supply from total energy produced in the area thereby influencing the HHs' food security status directly (Table 63).

Cattle in the study area have different functions ranging from supply of manure to fertilize *enset* and other garden crop production, involvement in direct food supply (milk, meat, butter and cheese) and cash generation through sale and have integration with other livelihoods of population. The result of current study is in agreement with the report of Ehui *et al*. (2002), who indicated that cattle are an important component of nearly all farming systems in Ethiopia and provide draught power, milk, meat, manure, hides and serve as a capital asset against risk. The same authors also reported that, cattle are important source of cash income and play an important role in ensuring food security and alleviating poverty. Gryseels (1988b), on his study indicated that income accumulated from sale of cattle, their products and by-products was wisely used to finance the purchase of HH commodities that support the food security status of the family such as grains, salt, coffee, tea, cooking oil, sugar, as well as meeting health expenses. Brandt *et al.* (1997) on their report stated that, because of increasing population and limited land, there may be a decline in total cattle numbers in general, and also there is a definite decline for individual HHs' ownership. This decline has an impact on manure production and it could also have an impact on human nutrition. The cycle of increasing impoverishment of the cattle component in this mixed crop-livestock system is a serious cause for concern.

Brandt *et al.* (1997) also comprehended that the multi-purposes of cattle cannot be replaced by fertilizers and sustainability of *enset* cultivation system is a result of the tight articulation of the *enset/*crop and cattle production systems. With an increasing population in an already densely populated area, it is likely that the negative trend in cattle population will continue with potentially severe impacts on *enset* production that can affect human food security. Shiferaw *et al*. (2003) reported that the wealth status of the HH is measured by the number of cattle owned since cattle is the most important indicator of wealth in rural Ethiopia. A HH's level of farm resources (e.g., livestock/cattle) can be expected to affect its ability to withstand abrupt changes in production, prices, income or unforeseen events that create the need for additional expenditures. Shiferaw *et al*. (2003) also indicated that particularly in Ethiopia where the incidence of crop failure frequently occurs due to shortage and erratic nature of rainfall, the level of one's cattle ownership is very important to combat those incidences. They also added that wealth as proxied by the livestock (cattle) size is significantly larger for the food secure than for the food insecure HHs, implying that it matters in predicting who would be food secure.

Risse *et al*. (2006) and Maryo *et al*. (2014) on their study indicated that decreases in cattle number causes reduction in manure production thereby reducing the long-term sustainability of *enset* systems. In the absence of cattle in this system, sustainability of *enset* production definitely becomes disadvantaged. Limiting number of cattle per HH also limits the availability of manure to fertilize *enset* plant, which in turn affects *enset* production. Furthermore, study made by Staal *et al*. (2008) showed that food secured HHs were associated with high livestock numbers, especially cattle asset ownership, indicating that increased cash incomes primarily came from these animals through the sale of live cattle, milk, meat, hides and skins. Tefera, (2009) also stated that the house heads who owned greater number of cattle have better food security status than those house heads with less number of cattle ownership. Group discussants in the study areas also concluded that *enset* has played different functions including as source of human food, livestock feed, in cash generations, as traditional medicine, material for construction, used in hand crafts and contributed a significant role in livelihoods of people in general. However, all these significantly important functions of *enset* can only be in place when there is interdependence between cattle and *enset* production. Based on perceptions of group discussants and HH participants of current study, measurers to be undertaken to realize food security in the area must be planned and brought in to action by interrelating *enset* and cattle production.

Family size also affects HH food consumption with regard to the number of consumers. This is because of larger family size put more pressure on HH food consumption and causes the available HHs' food to decrease per individual family member. And HHs with large number of family members in the current study are more prone to food insecurity than those HHs having smaller number of family size which agreed with the report of Omotesho *et al*. (2007) who reported that a HH tend to be poor/food insecure as his family member size increases. Similar result was reported by Shiferaw *et al*. (2003), who indicated that farm HHs in Ethiopia are small-scale semi-subsistence producers with limited participation in non-agricultural sector. Because resources are very limited, increasing family size may put much more pressure on consumption than it contributes to production and food requirements increase with increases number of persons within a HH. Correspondingly, Tefera (2009) also indicated that family size is negatively related with food security status of HHs, because as the family size increases the probability of HH to be food secured decreases.

Hectarage of land owned per individual HH in the study areas of both agroecologies has effect on food security status of farming families either positively or negatively which are under subsistence agriculture. Provision of adequate land for crop agriculture and cattle production, with no question can improve food security status of farmers and the results of current study realized this fact. Shiferaw *et al*. (2003), reported that the larger the farmland the HH owned, the higher the production level. Hence, it is expected that HHs with larger farmland are more likely to be food secure. Similar report was made by Kebreab *et al*. (2005*)* who reported that increasing human population coupled with diminishing land resources are creating a growing number of landless people who cannot produce their own subsistence, leading in to food insecurity in the HHs. Tefera (2009), also indicated that the size of land holding has either direct positive or negative impact with food security status of HHs. As the size of land holding per individual farmer decreases, the probability of HH to be food secure also be decreased and the food security status of HH increases when the size of land holding per HH increases which corresponds with the result of current study.

The three major source of HH income to fulfill seasonal food shortage gap at *dega* agroecology were off-farm activities (33.3%), selling other assets (27.3%) and selling grains (15%). Whereas, in midaltitude agroecology, selling of Khat *(Catha edulis)* and coffee (28.3%), Off-farm income (22.2%) and income from selling other assets

(22.2%) were used in filling HHs' seasonal food shortage gap. In both *dega* and *weinadega* agroecologies of the study areas, income from selling of livestock and *enset* and *enset* products were not the primer source of fulfilling the food shortage gap (Figure 7). The report of group discussion also confirmed that majority of HHs in the study areas of Gurage zone never engaged in selling cattle and *enset* and *enset* products to bridge food shortage gap except when unexpected natural or manmade calamities were encountered. When major means of income sources in both agroecologies of study areas were taken in aggregate, income from off-farm activities took the first place which corresponded with report of (Omotesho *et al*., 2007) who stated that Non-farm income is major determinant of poverty level. Households that have non-farm sources of income tend to easily get out of poverty than HHs who don't have other sources of income outside the farm.

6. CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion

The study was conducted in four Woreda of Gurage zone, situated at southwest of Addis Ababa. The objective of the study was to investigate trends of cattle and *enset* interdependence among smallholder farming families whose food security has been based on these resources through generations. Qualitative as well as quantitative data were obtained during the study period through sample households interview, group discussion, secondary and primary data review and personal observation. The collected data include family structure, farm size, land use pattern, herd size and structure, purpose of livestock raising, daily milk yield, market places, market price of cattle and milk products, measures of productive and reproductive performances of dairy cattle, mating systems, livestock feed types, gender related dairy production activities, livestock disease prevalence and health service rendered, types of livestock housing, *enset* and cattle interdependence, cattle manure production, utilization and analysis of manure composition, crop grain yield, methods of feed collection and feeding, major feed resources assessment, laboratory evaluation of chemical composition and nutritive value of major feed resources.

The overall estimated daily milk yield in the study areas of Gurage zone was found to be about 1.53 kg/day/cow. Marketing of fluid milk is not common in this *enset*-based dairy production system and most of it consumed at home with *kocho*. The reason for the absence of milk selling was not due to existence of taboos and/or cultural issues that prohibit selling of fluid milk but it is due to low milk production per individual HH. Because, almost all breeds of cattle maintained are indigenous zebu, amount of milk produced/day/cow was low and it never gave opportunity for selling liquid milk.

In both agroecologies of the study areas, about 95.55% of cattle owned by HHs were mixed indigenous breeds of central Ethiopia. Lack of advantages of getting AI and bull services were major bottle necks and uncertainties to improve production and productivity of cattle. About 83.6% of respondent HHs in both agroecologies used natural mating system using local bulls. Due to absence or shortage of consumables, inputs and equipment used in AI services negatively affected AI service provision and aggravated the loss of working interest of AI technicians. Estrus synchronization Campaign of cows and AI service delivery has started since 2011 in collaboration with Federal Ministry and Southern Ethiopia Regional Bureau of Agriculture and Natural Resources. The activities practiced using this program has encountered a number of technical and administrative problems which have called for lower performance which has not yet well studied but the campaign still has continued. When bottlenecks associated with access to preferred AI or bull service, improved rate of conception, improved estrus detection of AI technicians, access to feed and health services well addressed, about 97% of HHs in the study area of Gurage zone prefer AI and bull services to improve genetic potential of their cattle.

The nature of strong association of cattle with *enset* (*E. ventricosum*) production, HHs in the study areas urged to keep a number of cattle. The primary objective of rearing cattle in this area is the necessity for high demand of manure to fertilize *enset* fields and production of milk and milk products to supplement *kocho* which is low in protein. Households in *enset* based cattle production systems of Gurage zone utilized 100% of produced manure to fertilize crop/*enset* garden and no HH has utilized manure for fuel or dung cake for sale. In this low input farming system, *enset* is strongly dependent on the amount of cattle manure produced hence on the number of cattle owned. As manure is principal source of nutrient input and is crucial for *enset* productivity, HHs of the study area confirmed that in the absence of cattle manure *enset* production cannot be sustainable and impossible to realize their food security.

Hundred percent (100%) of HHs living in three study PAs of *dega* agroecology in particular and about 82.78% of farmers in both agroecologies in general depend on rivers as sources of water to save the life of their livestock. In spite of the greater contribution of rivers as sources water, shortage of water is critical problem during dry season of the year in PAs far away from rivers and where the rivers are not permanent, particularly for those HHs settled at *dega* agroecology.

It was also indicated during group discussion that prolonged dry period, erratic and uneven rainfall distribution could affect the growth performance of natural pasture and crop production hence crop residues. Moreover, absence of improved forage development activities and almost nonexistence of extension services rendering in forage development and utilization has aggravated the shortage of livestock feed. Household participants indicated that carrying capacity of grazing land is low when comparing it with number of animals grazed on it. Because of this imbalance, grazing lands are overgrazed and remaining with little ground cover favoring soil degradation.

From a total of feed produced in both *dega* and *weinadega* agroecologies of the study areas, leaf and leaf midribs of *enset (E. ventricosum)* took the greatest share in quantity and quality with overall production of 50.77% TDM, 71.02% TDCP and 54.94% TME which leads the champion from those natural pastures and crop residues. The available feed did not satisfy the maintenance requirements of livestock reared in the study area. The scarcity of feed was more serious in *dega* PAs and livestock in these areas faced in serious feed shortage particularly during dry season which causes in low productivity of livestock/cattle.

6.2. Recommendations

Therefore, based on the above conclusions the following recommendations are forwarded:

a) To achieve better results and to enhance HH’s benefit from cattle, activities related to genetic improvements like estrus synchronization and AI service provision should be harmonized with technical skill and provision of sufficient AI inputs.

b) Selection and development of dairy cattle suitable for the study area should be the focus area of future research work.

c) Detailed monitoring research is imperative for further investigation of the productive and reproductive performance of indigenous cattle.

d) Efficient animal health services focusing on preventive measures and scheduled delivery of drugs and chemicals with affordable price should be implemented.

e) Attention should be given on implementation of activities of making equilibrium between nutrient supply and demand of livestock through realizing development of productive and nutritious forage plants, empowering farmers to improve crop residues storage and utilization by realizing technical and material support.

f) Systemic replacement of less productive and unthrifty animals with fewer but more productive animals through negotiation with livestock keepers should be practiced to balance the system.

g) Intervention to mitigate dry season feed shortage through utilization of non-conventional feeds (brewery wet or dry grains) available in and around the study areas and establishment of appropriate agro processing firms that can provide alternative feeds with better quality protein, energy, vitamin and minerals should be carried out.

h) To alleviate water constraint during dry season based on agroecologies, different water harvesting structures of harvesting run-off, shallow or deep wells construction and pond construction through creation of common theme among government, non-government organizations and the community should be implemented.

i) Finally, the study result indicated that *enset* and cattle production have strong interaction and role on buffering HHs' food security. Farmers and FGDs articulated that *enset* and cattle are the basis of their life but received low attention by development ventures. In food security realization programs, everyone who have stake on development activities should take his own accountability & responsibility to improve agriculture, mainly *enset* & cattle production through provision of strong & continuous extension services and area specific research works. The development planners and political leaders should focus on improving production and productivity, understand the life securing abilities and do not undermine the economic and famine buffering potentials of *enset* and cattle. By considering multi-socio-economic use of *enset* crop, on the other hand, special attention should be given to hasten *enset* production throughout Ethiopia.

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8. APPENDICES

Appendix 1: Dairy products market price in birr in both agroecologies of Gurage zone in different seasons in birr.

Market price of dairy products	Agroecology (n =180)		
Butter	*Dega*	*Weinadega*	Average
Long dry season	165.73±0.65[b]	168.54±0.62[a]	167.14±0.46
Long rainy season	131.76±0.97[b]	140.86±1.10[a]	136.31±0.77
Short rainy season	148.00±0.83[b]	155.03±0.91[a]	151.51±0.64
Ayib			
Long dry season	43.03±0.69[b]	49.58±0.76[a]	46.31±0.54
Long rainy season	43.38±0.36[b]	45.93±0.40[a]	44.66±0.28
Short rainy season	56.77±0.49[b]	61.46±0.55[a]	59.11±0.39

a-b means with different letters of superscripts in the same row for *dega* and *weinadega* agroecology differ significantly ($P<0.05$) for market price of butter and *ayib* at different seasons of the year, n = number of respondents per agroecology, *Ayib* = homemade cheese.

Appendix 2: Dairy products market price in birr in the study woreda of Gurage zone in different seasons in birr.

Study Woreda	Market price of butter		Market price of Ayib	
(n = 90)	Dry season	Rainy season	Dry season	Rainy season
Ezia	165.83±.83	131.59±1.41[c]	43.36±1.06[b]	44.99±.45
Muhir & Aklil	166.03±.89	134.98±1.46[bc]	45.50±1.01[ba]	44.07±.58
Cheha	168.24±.96	139.74±1.68[a]	48.61±1.03[a]	44.56±.66
Enemor & Aner	168.44±.94	138.92±1.48[ba]	47.76±1.15[a]	45.01±.50
Average	167.14±.46	136.31±.77	46.31±.54	44.66±.28

a-b means with different letters of superscripts in the same column for studied districts differ significantly ($P<0.05$) for market price of butter and *ayib* at different seasons of the year n = number of respondents per district, Woreda = district, Ayib = homemade cheese.

Appendix 3: Specially designed milk collecting format for study areas of Gurage zone

Milking			Name of Household	Name of PA	Milking cows Number	Total kg of milk produced	Overall average per day
Phases	Month	Day					
1	January	1st					
1	January	16th					
1	January	30th					
Sum							
Mean							
2	May	1st					
2	May	16th					
2	May	30th					
Sum							
Mean							
3	September	1st					
3	September	16th					
3	September	30th					
Sum							
Mean							
Mean total							
Grand mean							

Milk yield data collecting questionnaire per household in three phases (January, May and September) of 2017, each phase having three milking days (1st, 16th and 30th) of January, May and September.

Appendix 4: Conversion factors of livestock number to tropical livestock unit (TLU)

Livestock species	TLU
Local oxen/bulls	1.1
Cross bred oxen/bulls	1.9
Local cows	0.8
Crossbred cows	1.8
Local heifers	0.5
Crossbred heifers	0.7
Local calves	0.2
Crossbred calves	0.4
Sheep	0.1
Goats	0.1
Horses	0.8
donkeys	0.5

Source: Gryseels (1988) and Bekele (1991), TLU=Total Livestock Unit.

Appendix 5: Total daily nutrient requirement of livestock per livestock species

Livestock species	DM (kg)	CP(g)	ME (MJ)
Oxen	4.8	361.3	33.0
Bulls	4.8	361.3	33.0
Cows	4.4	227.8	29.7
Heifers	3.3	232.0	21.7
Calves	1.9	144.0	13.0
Sheep	0.65	53.0	4.3
Goats	0.64	49.0	5.0
Horses	5.3	400.4	27.6
Donkeys	2.5	192.5	14.9

Source: Kearl (1982) and McCarthy (1986)

Appendix 6: Caloric content of the foods commonly consumed in the study Area

No	Food items		Food energy (Kcal/100 grams)
A	*Enset products*		
1	*Kocho*	*= Pan cake*	157
2	*Bulla*	*= Genfo*	105
		= Berabrat	413
3	*Amicho*	*= Boiled amicho*	131
B	Grains		
1	Teff	*= Injera*	175.20
		= Porridage	189.40
2	Wheat	*= Bread*	210.65
		= Porridage	146.65
		= Nifro (boiled)	198.10
		= Kollo(roasted)	392.90
3	Barely		142.5
	=Porridage/besso		392.40
		=Kollo (roasted)	
4	*Maize*	*=Kollo (roasted)*	186
		=Nifuro(boiled)	198
		=Bread/tirwoshe	207
5	Pea	*=Kik (watt)*	260.97
		=Kollo	320
	(roasted)		
C	Livestock product		
1	Milk	*=Raw mil*	73.70
		=Cheese	132.40
		=Sourmilk(ergo)	82.60
		=Aguat	23
2	Beef	*=Raw meat*	114.80
		=Key watt	177.40
		=Tibs	256.80
		=Kitfo	283.0
	Mutton	*=Key watt*	152.90
		=Tibs	201.10
	Goat	*=Key watt*	200.00
		=Tibs	212.80
3	Egg	*= kikile*	152.90
		= Tibs	295.10

Source: Ethiopian health and nutrition research institute (EHNRI) food composition table (1968-1997).

Appendix 7: Gender related cattle production activities in the study area of Gurage zone

Activities	Sex of family	Percentage & number of HHs/woreda (n = 90)				Average N = 360
		Ezia	Muhir & Aklil	Cheha	Enemor & Aner	
Milking	Male	8(8.9)	11(12.2)	11(12.2)	10(11.1)	40(11.1)
	Female	60(66.7)	59(65.6)	62(68.9)	58(64.4)	239(66.4)
	Both sexes	22(24.4)	20(22.2)	17(18.9)	22(24.4)	81(22.5)
Milk product marketing	Male	0(0)	0(0)	0(0)	0(0)	0(0)
	Female	90(100)	90(100)	90(100)	90(100)	360(100)
	Both sexes	0(0)	0(0)	0(0)	0(0)	0(0)
Calf rearing	Male	6(6.7)	4 (4.4)	6(6.7)	5(5.6)	21(5.8)
	Female	45(50)	53(58.9)	58(64.4)	48(53.3)	204(56.7)
	Both sexes	39(43.3)	33(36.7)	26(28.9)	37(41.1)	135(37.5)
Cattle herding	Male	50(55.6)	47(52.2)	49(54.4)	40(44.4)	186(51.7)
	Female	13(14.4)	15(16.7)	17(18.9)	18(20)	63(17.5)
	Both sexes	27(30.0)	28(31.1)	24(26.7)	32(35.6)	111(30.8)
Barn cleaning	Male	10(11.11)	7(7.78)	5(5.56)	8(8.89)	30(8.33)
	Female	65(72.22)	71(78.89)	74(82.22)	66(73.33)	276(76.67)
	Both sexes	15(16.67)	12(13.33)	11(12.22)	16(17.78)	54(15.00)
Herd feeding & watering	Male	69(76.6)	64(71.1)	62(68.9)	66(73.3)	261(72.5)
	Female	6(6.7)	14(15.6)	9(10)	4(4.5)	33(9.2)
	Both sexes	15(16.7)	12(13.3)	19(21.1)	20(22.2)	66(18.3)
Feed collection	Male	71(78.9)	65(72.2)	72(80)	66(73.3)	274(76.1)
	Female	4(4.4)	6(6.7)	7(7.8)	8(8.9)	25(7.0)
	Both sexes	15(16.7)	19(21.1)	11(12.2)	16(17.8)	61(16.9

Appendix 8: Income sources to fill seasonal food shortage gap in study areas of Gurage zone (%)

Major means of food security during food shortage	Study districts (n = 90)				Agroecology (n =180)		
	Ezia	*Muhir & Aklil*	*Cheha*	*Enemor & Aner*	HL	MA	Mean
Livestock selling	13.3	6.7	11.1	11.1	13.3	7.8	10.6
Enset & product	6.7	8.9	10.0	7.7	8.9	7.8	8.3
Off farm income	24.4	28.8	31.1	26.7	33.3	22.2	27.8
Other assets selling	23.3	27.8	21.1	26.7	27.3	22.2	24.7
Khat & coffee selling	12.2	14.4	13.4	16.7	0.0	28.3	14.2
Grain & pulse selling	13.3	6.7	11.1	10.0	15.0	5.6	10.3
Gift from relatives	6.8	6.7	2.2	1.1	2.2	6.1	4.2
Overall	100	100	100	100	100	100	100

HL = highland, MA = midaltitude

Appendix 9: Enset clones found in Gurage areas

Ranges and level of distribution	Names of *enset* (*E.ventricosum*) clones found in Gurage areas.
Distribution of *enset* clones in both *dega* and *weinadega* agroecologies of Gurage areas are dependent on household's interest & capability in relation to provision of inputs, on level of productivity of individual *enset* clone, on nature of *enset* clones to reach maturity and on nature of *enset* clones in terms of multiplication, etc.	*Abakite, Agade, Agewrare, Agorgur, Anchiro, Ameratye, Anqefuye, Anzana, Astara, Ashektye, Aychore, Aywegne, Badedet, Bazeriye, Benezhe, Beresiye, Bishaamerat, Bosere, Buaeche, Charkima, Chehuyet, Chifwod, Demwenejat, Denquinet, Derewetiye, Derye, Egendiye, Ehire, Emirye, Etquaqof, Fereziye, Forensic, Gaznar, Gezod, Gezwod, Gimbuwe, Ginjiwe, Guarye, Gufenwe, Gumbura, Helod, Hone, Iniba, Kanchiwe, Kembat, Kibnar, Kuashkuashiye, Kyekyeret, Lemat, Marde, Marye, Mishrat, Muyetiye, Nechiwe, Oret, Ousmail, Qyeswe, Sapara, Shertiye, Sinwot, Tegaded, Teriye, Wenadiye, Weqa, Weshmeja, Yawiare, Yederemaqinqe, Yegetiye, Yeshiraqinqe, Yiregiye, Zeguired, Zigeziwe, Zober.*

Source: Fetta (2007)

Appendix 10: Questionnaires used in data collection

Section I

1 Instruction to the Enumerator

Please, introduce yourself before starting to question about who you are; where you are working and for whom you are working and the purpose and objectives of the interview. Ask each question patiently until the household gets the point. For closed question, circle on it and for open questions fill the households' response precisely in the blank space where necessary.

Enumerator Name__________________________________ Date_________________

Section II

General Information

1. Region_____________ 2.Zone _____________

3.Woreda___________4.PA____________ 5. Household Name____________________________ 6. Sex ______ 7. Age______________

8. Level of education of household

a) Illiterate b) Grade 1-6 c) Grade 7-8 d) Grade 9-12 e) >12 grade.

9. Number of family members including the household head?

a) Male____ b) Female____ c) ≤ 14years____ d) ≥ 15-65 years____ e) > 65 years _____

Section III

Landholding and its use pattern

1) Total area of land owned by the household, _________________________________ha.

2) Allocation of land by household for different uses

a) Annual crop ______ha. b) Enset ______ha. c) Perennial crop _______ha. e) Grazing land _____ha. e) Forage crop _____ha. f) Forest ______ha. g) Fallow land _______ha

3. Allocation of land for major annual food crops.

a) Barley________ha. b) Wheat ______ha. c) Teff ______ha d) Fababean_________ha. e) Fieldpea_______ha. f) Maize_______ha. g) Chickpea_____ha. h) Sorghum______ha.

4. The yield obtained from annual grain crops in quintal?

a) Wheat________ b) Barley_______ c) *Teff* _________ d) Faba bean________

e) Field Pea _______ f) Maize ________ g) Chick pea ______ h) Sorghum ________

Section IV

Livestock production

1) Cattle herd structure	Total number of animals
Milking cows	
Dry cows	
Oxen	
Male calves	
Female calves	
Heifers	
Bulls	

2) Sheep and goats	Total number of animals
Adult sheep	
Lambs	
Adult goats	
Kids	
3) Equines	
Horses	
Donkey	
Mule	

4. Purpose of cattle keeping :- A) Traction only, B) Milk only, C) Milk and traction, D) Milk and Manure E) Savings only

5. Labor division of the family member in livestock/cattle management activities

Type of activities	Sex of individuals	Age of individuals
Milking		
Milk and milk product marketing		
Calf rearing		
Cattle Herding		
Barn cleaning		
Herd feeding/watering		
Feed collection		

Section V.

Dairy Cattle Production and Reproduction

1. Where did you get dairy cows initially?

a) bought from market b) from the respective agricultural offices c) bred at home d) other (specify), ____

2. How much do you cost (in ETB) for the crossbred:-

a) Dry cow__________. b) Milking cow___________. c) Pregnant cow____________. d) In-calf heifers_______________. e) Non-pregnant heifer_____________. f) Male calves________________. g) Female calf______________________.

3. How much do you cost (in ETB) for local breed: - a) Dry cow___________. b) Milking cow__________. c) Pregnant cow___________. d) In-calf heifers_________. e) Non-pregnant heifer________. f) Male calves_________. g) Female calf_________.

4. How much do you cost (in ETB) for pure exotic breed:-

a) Dry cow_________. b) Milking cow__________. c) Pregnant cow___________. d) In-calf heifers________. e) Non-pregnant heifer_______. f) Male calves___________. g) Female calf_________. h) Breeding bull__________. h) Male calf____________.

5. How many cattle do you have?

a) Local (______) b) Cross (_______) c/ Pure exotic breed (________)

6. How many milking cows do you have currently?

a) Local cows_________ b) Cross breed_________ c) pure exotic breed____________

7. Milking frequency per day a) once per day b) twice per day c) thrice per day

8. Milking times? a) Morning b) Midday c) Evening d) a & b e) a & c f) a, b & c

9. Total amount of milk yield per day (liter/day/cow)?

a) Local cows________ b) crossbred cows_________ c) Pure exotic cows___________.

10. Lactation length in days/months. a) Local cows ______ b) Crossbred ___________. c) Pure exotic cows______________ (underline days or month)

11. What is the at age first mating? a/ Local bred heifers ______________________ b) Crossbred heifers _________ c/ pure exotic bred heifers ______________________

12. Age at first calving in months/years a) for local heifers__________ b) for crossbred heifers____________ c) pure exotic breed heifers. _________ (underline month or years)

13. Calving interval in months/years a) For local bred cows_______ b) For crossbred

cows_________ c) For pure exotic bred cow ___________ (underline month or years)

14. Do you practice the isolation of new born calf from dam? a) Yes b) no

15 What is the calf weaning age in month? a) 6-8 b) 9-12 c) >12

16. How do you breed your dairy animals? a) Natural mating b) AI c) a and b

17. For what purpose do you use crossbred (purebred exotic) male calves?

a) Breeding b) Selling at early age c) Slaughtered at early age d) For traction

Section VI

Milking, Milk and milk products marketing

1. How milking is done? a) Hand milking b) Machine milking

2. Do you practice milk selling? a) Yes b) No

3. If yes where do you sell milk? a) Local market b) Home get c) milk collection center

7. Do you ever practice milk churning? a) Yes b) No

8. If yes, what types of equipment do you use to collect and churn the milk? Please specify:____

____

9. Do you ever collect milk for churning from your neighbors? a) Yes b) No

10 If yes, in what way do you collect? ____

11. For how long (days) do you collect the milk for churning a) From own milking cows _________________days b) From neighbors _______________________days

12. What is the liter of milk to be collected for churning per churn? _____________.

13. In what form do you process milk (multiple choices are possible in order of importance?

a) Butter b) Yoghurt c) Cheese d) Whey

14. At what season of the year do you get more milk? a) Dry b) Long rain c) Short rain

15. At what season of the year do you sell more amount of milk?

a) Dry season b) Long rainy season c) Short rain season

16. What is the price (ETB) per liter/kg of whole milk in birr during?

a) Dry season________ b) Long rainy season_________ c) Short rainy season________

17. What is the price (ETB) of butter in kg during?

a) Dry season________ b) Long rainy season________ c) Short rainy season________

18. What is the price (birr/ liter or kg) of yoghurt during?

a) Dry season_______ b) Long rainy season________ c) Short rainy season________

19. What is the price (birr/ kg) of homemade cheese during?

a) Dry season________ b) Long rainy season________ c) Short rainy season________

20. From which type of products of milk do you get better price

a) Whole milk b) Butter c) Cheese d) Yoghurt

21. Please put the summary of butter making (churning) & cheese making processes.

____

____

____

Section VII

Feeding Management of Animals

1. How do you feed your dairy animals?

a) Indoor feeding using individual feeding system b) Grazing & cut and carry c) Tethering, grazing and cut & carry d) Let to graze in a grazing land e/ Tethering & cut and carry

2. Do you have access to grazing land? a) Yes b) No

3. If you let your dairy cows to graze, for how long do they graze per day? ________hrs.

4. What is the size of your grazing land? ____________________________________ha.

6) Is the grazing land your own a) Yes b) No

7. Do you know the amount of each feed type given to them daily?

a) Yes b) No

8. If no, what is the major reason? ____

9. Do you believe that your cattle are getting sufficient feed? a) Yes b) No

10. If No, why?____

____

11. Is the grazing resource adequate to your animals? A) Yes b) No

12. If not what measures do you take to alleviate problems of feed shortage?

a) Purchase concentrate b) Purchase forage c) rent grazing land d) use crop residues

e) Reduction of stock f/ other (specify) _____________________________________

13. Do you practice giving different priority of feeding to your cattle? a) Yes b) No

14. At which season do you face feed shortages?

a) Short rainy season b) Long rainy season c) Short dry season d) Long dry season

15. Do you feed crop residues to your animals? a) Yes b) No

16. List the major types of crop residues you feed to your animals in your area? ____

____

17. What effects do you observe on you cattle due to feed shortage, mention in order of importance____

____

18. How do you store crop residues? a) Stacked outside b) stacked under shade c) baled outside d) baled under shade e) other (specify) ________________________

19. For how long do you store crop residue after collection before feeding?

a) Soon after collection b) One month c) Two months d) Over two months

20. In what form do you feed your crop residue? a) Whole b) Chopped c) Treated d) Mixed with other feeds e) other (specify) __________________________________

21. Do you collect all crop residues and preserve for the time of feed shortage without any loss in the field? a) Yes b) No

22. Indicate the type feed used for your animals at different months?

Grazing	Months feeding/grazing											
	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Own pasture												
Communal Pasture												
Crop residue												
Crop aftermath												
Zero grazing												
Weeds of crop												
Enset leaf												

23. What type of grazing system employed during dry season? a) Unherded b) Herded c) Paddock d) Tethered e) Zero grazing f) Cut and carry

24. What are major problems of hindering cattle production? Mention in order of importance____

____

25. What type of grazing system employed during wet season? a) Unherded b) Herded c) Paddock d) Tethered e) Zero grazing f) Cut and carry

26. Do you practice development of improved forage? a) Yes b) No

27. If it is no, what are the major reasons hindering development of improved forage?

a) Land shortage b) Improved seed Shortage c) Lack of knowledge d) Lack of finance

Section VIII

Watering Management of Animals

1. What are the sources of water to your animals?

a) River b) Pond c) Spring water d) Pipe water e/ dug well

2. What is the average distance travelled by livestock to water source during dry season?

a) Watered at home b) < 1km c) 1-5km D) 6-10km e) >10km

3. How frequently livestock/ cattle are watered during dry season per day?

a) Once b) Twice c) A*d libitum* d) Once in two days e) Once in three days

Section IX

Interdependence of *Enset* and Cattle Production

1. Is the product of *enset (kocho)* the staple food in your family? a) Yes b) No

2. Do you believe that product of *enset (kocho)* is sufficient in providing every nutrients necessary for normal life? a) Yes b) No

3. If no, which products do you choose/utilize mostly to be eaten along with *kocho*? Please indicate in order of importance

____

____

4. What are the other major uses of *enset* plant in the household? Please indicate in order ofimportance____

5. Do *enset* and cattle have interdependence one on the other? a) Yes b) No

6. If yes, please indicate their interdependence precisely? ___________________________

7. Indicate the major reasons to cultivate *enset* plant in your farm (please list in order of priority by putting A, B, C, D, etc. in front of the choice, A-representing the once most priority).

a) Resistance to natural hazard (drought, flood, frost, etc.) e) Its use as cattle feed

b) Its multipurpose nature (food, and other uses) d) Source of income

c) Its high yield per plot of land h) Used as money store

f) Its long period storability and steadiness potentials g) Medicinal use

8. Does *enset* used as cattle feed? a) Yes b) No

9. If yes, which parts of the *enset* are mostly used as cattle feed in order of importance?

10. At which season of the year *enset* parts are used as cattle feed?

a) Dry season b) Rainy season c) Year round.

11. Do you agree in the importance of cattle in the production and productivity of *enset*?

a) Yes b) No

12. If yes, mention the importance of cattle in the order of priority?

13. Does production and productivity of *enset* can be affected by the number of cattle that the household has owned? a) Yes b) No

14. If yes, please mention the reason why the increasing and/or decreasing number of cattle can affect production and productivity of *enset*

____

____

____

____

15. Can *enset* production and productivity be sustainable with the absence of cattle?

a) Yes b) No

16. if not, mention the reason clearly, please,

____

____

____

17. Can cattle production and productivity be sustainable with the absence of *enset* production? (Please clarify)____

____

18. How long does *enset* take to mature on your farm?

a) 5- 6years b) 7-8 years c) 9-10 years d) above 10 years.

19. How many mature *enset* do you harvest per annum in your *enset* farm? ___________.

20. Is it enough for your annual consumption comparing with your family size?

a) Yes b) No

21. If your answer is no, for how many month can it feed your family? ______________.

22. How much kg of kocho is produced per mature *enset* plant? ____________________.

23. When does your family mainly consume *enset* products?

a) Throughout the year b) At time of food shortage c) Other (specify) ___________.

24. For how long do you store kocho _______________ year/ months (underline)?

25. For how many years does kocho have the potential of storability? _______________.

26. What is your major means of security during season of food shortage? please list in order of priority by putting A, B, C, D, etc. in front of the choice, A-representing the once most priority. a) Domestic animals and their products selling. b) *Enset* and its products selling. c) Remittance from relatives. d) Khat, coffee, and fruits. e) Off farm income f) Grain & pulse selling g) Selling other assets

27. How is the trend in the size of livestock/cattle during the last 5 years?

a) Increasing b) Declining c) No change

28. If your answer is declining, what are the main reasons? Please list in order of priority by putting A, B, C, D, etc. in front of the choice, A-representing the once most priority.

a) Feed shortage b) Disease c) Drought d) Others (specify) ____.

29. How is the trend in the size of *enset* during the last 5 years?

a) Increasing b) Declining c) No change

30. If your answer is declining, what are the main reasons? Please list in order of priority by putting A, B, C, D, etc. in front of the choice, A-representing the once most priority.

a) Lack of manure b) Disease c) Drought d) Wild life e) Decline of soil fertility f) Others (specify) ____.

31. What is your opinion towards cattle production regarding to livelihood and food security? a) Has advantages b) Has no advantage

<u>Section X</u>

Manure use, utilization and extension services

1. Does cattle manure have importance in production and productivity of *enset* and other crops? a) Yes b) No

2. If yes, what are major importance of manure? Please clarify____

____

____

3. Do you have enough potential of providing of manure for your garden? a) Yes b) No

4. If not, what are the main reasons not to produce enough manure for your garden?

____

____

5. For what main purposes does manure produced utilized in the household (in %)?

a) Manuring garden crops (___ %) b) Used as fuel/cooking food and heating (____ %)

6. For which crop do you give more attention in manure utilization (in %)? a) *Enset* (____ %) b) Vegetables (___ %) c) Cereal crops (____ %) d) Fruit crops (___ %).

7. Do you ever utilize inorganic fertilizers for *enset* production? a) Yes b) No

8. If no, mention the reason why you didn't utilize it, ______________________________

____

____

9. If not, what do you use to fertilize *enset*? a) Manure b) Compost c) Other (specify) ____

10. Have you ever compared the advantage and/or disadvantage of manure and fertilizer uses in *enset* production? a) Yes b) No

11. If yes, please, mention the advantage and/or disadvantage of manure and fertilizer uses____

____

<u>Section XI</u>

Household's Food Security

1. Do you meet the all-year round food requirement of your household members from own production? a. Yes b. No

2. If your response is No, from where did you fill food shortage gap?

a. Purchase from the market b. Borrow from relatives c. Gift from relatives

d. Other specify____

3. What is the source of income to fulfill food shortage gap by purchase?

a/ Selling of livestock b/ Selling of enset products c/ Loan d/ selling of other asset

e/ off-farm income sources f/ others______________________________.

4. How many times your family members eat per day?

a/ One time b) Two times c) Three times. d) Four times

5. According to your own opinion is your household?

a/ Food secured b/ Food insecure c/ Varies from year to year

d. Varies from season to season. e. Do not known

6. If your household/family is food insecure, what are the main reasons for being food insecure?____

____

7. If the response for question 5 is food secure, what do you think about the contribution of livestock/cattle in yours' HH food security? a) High b) Medium c) Low

8. Do cattle have role in improving the households' food security? a) Yes b) No

9. If your answer is yes, please mention the role played by cattle in improving food security____

____

____

10. Do you use *enset* as a traditional medicine to treat sickness/illness? a) Yes b/ No

11. If yes, mention the *enset* types having medicinal advantage for human being and animals, type of sickness/illness and the type of *enset* verities used in medication of respectivesickness/illness.____

____

____

____

____