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**INTERCONNECTIONS BETWEEN LIVESTOCK HUSBANDRY PRACTICES, FEED
RESOURCES, CLIMATE VARIABILITY AND METHANE EMISSION IN MIXED
FARMING AREAS OF BALE HIGHLANDS, 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

June, 2018

Bishoftu, Ethiopia

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RESOURCES, CLIMATE VARIABILITY AND METHANE EMISSION IN MIXED
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A Dissertation Submitted to College of Veterinary Medicine and Agriculture, Addis
Ababa University for Fulfillment of the Requirement of Degree of Doctor of Philosophy
in Animal Production

By

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As members of the examination board of the final PhD open defense, we certify that we have read and evaluated the dissertation prepared by **Mr. Girma Defar** entitled **“Interconnections between Livestock Husbandry Practices, Feed Resources, Climate Variability and Methane Emission in Mixed Farming Areas of Bale Highlands, Ethiopia”** and recommended that it be accepted as fulfilling of the dissertation requirement for the Degree of Doctor of Philosophy in Animal Production.

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DEDICATION

I dedicate this work to my beloved grandmother Bafena Biratu for nursing me with affection and her further immeasurable sacrifices from my childhood which is impossible without a mother, but Bafena realized it.

STATEMENT OF AUTHOR

I, first declare that this dissertation is my own work and that all sources of materials used for this dissertation have been duly acknowledged. This dissertation has been submitted for fulfillment of the requirement 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 the rules of the library. I solemnly declare that this dissertation 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 was born in January 1979 in Ginnir District of Bale Zone. He passed early school ages at Jafera Elementary, Delo Junior, and Ginnir Secondary and High Schools. After his High School education completion, he joined the then Mekelle University College in September 2000 where he studied Animal and Range Sciences and graduated in July 2003. Soon after graduation, he was employed by the Ministry of Agriculture Department of Agricultural Technical and Vocational Educational Training (ATVET) as junior instructor at Agarfa ATVET College and in the same year, he joined Bako Agricultural Research Center as a Junior Researcher in Animal Production Division. Again, in October 2004 he was employed by the Ministry of Agriculture, Department of ATVET as an instructor at Bako ATVET College where he served for seven years.

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ABBREVIATIONS

ADF	Acid detergent fiber
ADL	Acid detergent lignin
ANOVA	Analysis of variance
AOAC	Association of official analytical chemists
ADMY	Average daily milk yield
BoFED	Bureau of finance and economic development
CBPP	Contagious bovine pleuropneumonia
CCPP	Contagious caprine pleuropneumonia
CDR	Community development research
CH ₄	Methane
CO ₂ -e	Carbon dioxide equivalent
CP	Crude protein
CRGE	Climate resilient green economy
CSA	Central statistical agency
DCP	Digestible crude protein
DM	Dry matter
EF	Emission factor
EPA	Environmental protection agency
ESAFF	Eastern and southern African small scale farmers' forum
FAO	Food and agricultural organization of the United Nations
FDRE	Federal democratic republic of Ethiopia
FGD	Focus group discussion
GDP	Gross domestic product
GEI	Gross energy intake
GHG	Greenhouse gas
GWP	Global warming potential
HH	Household
HMC	Homemade concentrate
IGAD	Intergovernmental authority on development

ABBREVIATIONS (*Continued*)

ILCA	International livestock centre for Africa
IVDOMD	<i>In vitro</i> digestible organic matter in the dry matter
ILRI	International livestock research institute
IPCC	Intergovernmental panel for climate change
IUCN	International union for conservation of nature
ME	Metabolizable energy
MJ	Mega joule
MoA	Ministry of Agriculture
N ₂ O	Nitrous oxide
NDF	Neutral detergent fiber
NMA	National metrological agency
ONRS	Oromia National Regional State
TLU	Tropical livestock unit
WISP	World initiative for sustainable pastoralist
X ²	Chi-square

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ABSTRACT

The study was conducted in the potential mixed farming areas of Bale highland to investigate interconnections between livestock husbandry practices, available feed resources, climate variability and methane emission. Using multi-stage purposive sampling, 156 households of the three wealth groups [better (≥ 4.25 hectare land, >15 TLU); medium (2.25-4.25 hectare land, >5 and ≤ 15 TLU), and low (≤ 2.25 hectare land, ≤ 5 TLU)] were selected. Structured questionnaires, focus group discussions, key informants interview, field visits and feed samples chemical analysis were the employed methods during the study. Secondary data were used from different offices and organization reports, and literature. The nutrient balance was estimated based on the demand and supply while the livestock methane emissions were estimated according to the IPCC guidelines. Descriptive statistics, chi-square and one-way ANOVA tests were used to analyze the data. Indices were computed to obtain the aggregate rank of considered variables. The mean land holding was significantly ($P < 0.001$) different between wealth groups. The mean land allocated for cultivation was 81.47, 84.51 and 89.04% for better, medium and low wealth groups, respectively while the remaining proportion of lands were uncultivable and used for grazing. Cattle were the dominant (84.25%) livestock owned by the households. The productive performances of the livestock were poor and feed scarcity was the prominent constraint (ranked 1st). The major feeds overall mean DM contributions were 71.26%, 13.01% and 12.35% from straws, crop aftermath and mixed native pasture, respectively while significantly ($P < 0.001$) higher private grassland DM yield belongs to the better wealth group. The previous (1986) grazing lands converted to cultivation were estimated to be 99.22% from the land use land cover changes in 2014. This situation appeared to be the major

problem of feed resource of the existing livestock production in the area. Roughage feeds have lower ME, DCP and relative feed value (RVF). The mean IVDOMD of the dominant feeds ranges 49.92-54.68% (cereal straw), 40.36% (crop aftermath) and 58.59-62.61% (mixed native pasture) across the wealth group households. Average deficit of 24.2% ME observed for the better wealth group while DCP satisfied 33.3% of the requirement which advises to search a solution for the thrilling deficit that associated to grazing constraint. Weather information access showed differences between the wealth groups. Farmers perceived rainfall pattern variability, and increased temperature and drought frequency over the past years were the variations impede livestock productivity. The respondents witnessed that livestock and grazing land productivity decreased due to land use/land cover changes and accompanied climate variability. Farmers said that they were at a critical state of livestock production that accounted to diminished grazing land, nutrient deficit and climate variability not to sustain the existing livestock. The estimated enteric CH₄ emission rate from mature cattle, growing cattle, sheep >1 year, sheep ≤ 1 year, horse and donkey were significantly ($P < 0.001$) higher for the better wealth group while mature cattle (69.78%) shared the highest rate. Though, higher emission rates credited to the large number of animals in the area, cattle stay crucial to the livelihoods of the households, beside the major sources of CH₄. In conclusion, poor husbandry practices (veterinary infrastructures, housing, feed quantity and quality, and productive performances), climate variability and the subsequent CH₄ emissions should be focus areas of interventions. Therefore, proper husbandry and quality feed supply, improved weather forecast services and promotion of farm level livestock technologies should be practiced wisely to increase productivity and protect the environment from degradation and emissions of the livestock sector.

Key words: Climate variability; Feed resources; Husbandry practices; Livestock; Methane emission; Mixed farming

1. INTRODUCTION

Mixed farming system dominated the highlands of Ethiopia that approximated to cover less than 40% of the land mass of the country and maintains 85% human population (Mekasha *et al.*, 2014). The mixed farming area is defined as ‘livestock production system in which more than 10% of the dry matter fed to livestock comes from crop by-products and crop aftermath (FAO, 1996). However, reports from different part of the country estimated that crop residue contribution to the dry matter supply of livestock feed in the mixed farming system ranges 50-80% (Abera *et al.*, 2014; Gurmessa *et al.*, 2015). In Ethiopia, 95% of the cultivated land is from the highland areas to produce cereals, pulses, oilseeds and vegetables (Mengistu, 2006). The community greatly depends on rainfed subsistence crop-livestock farming where the livestock are integrally linked to cultivation and complement each other. Crop residues are used to feed the livestock while draught power and manure are crucial inputs of crop production (Gebremedhin *et al.*, 2009; Duguma *et al.*, 2012). In the system, since long time, livestock have been used for draught power, crop threshing, transportation, source of food, manure (fuel and fertilizer), replacement, savings, income generation and grant some degree of food security during crop failure (Gizaw *et al.*, 2010; Abate *et al.*, 2012).

Ethiopia is the home to the Africa’s largest livestock population standing eighth from the world and is the principal exporter of live animals and meat to the Middle East (Rich *et al.*, 2008; Gebremariam *et al.*, 2010) being endowed with the diversified species and breeds of animals. According to the recent report (CSA, 2016), the country is endowed with 57.8, 28.0, 28.6, 2.1, 7.9, 0.4, 1.2 and 60.5 million heads of cattle, sheep, goat, horse, donkey, mule, camel and chicken, respectively with the exclusion of the non-sedentary three Zones of Afar and six Zones of Somali regions. Gebremariam *et al.* (2010) reported that the livestock sector provides 15-17% to GDP, and 37-87% of the household incomes. From the total livestock population, more than 75% inhabited the mixed farming areas (Deressa *et al.*, 2010; FDRE-CRGE, 2011).

Despite the huge livestock number and diversified roles: low production outputs were a key challenge in the subsistence mixed farming areas of Ethiopia. The root causes were linked to resources limitation and poor utilization, husbandry practices, inherent genetic potential (Admassu, 2007), unclear production objectives, poor institutional linkage and climate change (Shapiro *et al.*, 2015) coupled with the low emphasis given to the sector. The key constraints hampering production performance were low quantity and quality feeds due to land use change under the dynamic system of crop intensification (Amsalu and Addisu, 2014) and continuing climate variability (Thornton, 2010; Jiri *et al.*, 2015). Since grazing land becomes scarce, feed shortage frequently mentioned as a major constraint of the sector in mixed farming (Geleti *et al.*, 2013). Nowadays, feed is the major input and most limited resource which is panic to obtain optimum product from livestock. To the contrary, the sector is gradually booming due to increasing global and domestic demand for their products linked to population and economic growth (IUCN, 2010; IGAD, 2011). Therefore, current and future livestock feeding strategies need a systematic and area specific approach to exploit the available resources to optimize productivity.

To the other end, climate variability is seen as a global phenomenon and is reported to have its biggest impact on mixed farming where people are reliant on rainfed farming (IPCC, 2007; Thornton, 2010). The situation affects livestock and other sectors seriously and becomes an international endeavor of the concerned parties. In Ethiopia, the phenomenon occurs throughout the country, affecting livestock production directly (heat stress) and indirectly (feed and disease) though the effect is different for the various agro-ecologies (IPCC, 2007; Salehu *et al.*, 2011). Smallholder farmers able to identify climate variation in their area and tried to establish their own coping or adaptation strategies at local level differently to sustain their livelihoods keeping livestock (Shemdoe, 2011; Kassie *et al.*, 2013). Hence, restraining the impact to boost adaptive capacity and resilience could be addressed through the farmers' participation as they perceived about the variability that occurred and the accompanied risks in their area.

Beside to the effect of climate variability on livestock, farm animals from mixed farming contribute to climate change mainly through natural resource degradation and greenhouse gas emissions (Herrero *et al.*, 2008). Because livestock and environment are closely related having a mutual impact on each other (livestock depends on land and water availability, and at the same time emits pollutant gases). These let the sector recently to be blamed for significant contributions to the global climate (IPCC, 2006; CDR, 2011). Worldwide, livestock systems are major contributors of anthropogenic global warming since emissions are related to livestock feeding systems and husbandry practices (Steinfeld *et al.*, 2006). Researchers also underpin that in mixed farming areas livestock diets were composed of grazing, crop residues, cut and carry, concentrates and opportunistic feeds. These dietary differences were important for the disparity in CH₄ emissions within the system. For example, an average figure of 32 kg CH₄ per TLU per year for African ruminants is high compared to the low production performance of the animals (Herrero *et al.* 2008).

In Ethiopia, CDR (2011) reported that the livestock sector offers a potential CH₄ emission abatement, though the type of production systems and feed resources used not mentioned. The estimation of emissions from livestock in smallholder mixed farming systems helps to generate baseline information that could be an input to the national emission inventory of the sector and subsequent mitigation strategy development. However, no attempt has been made to estimate CH₄ emissions from the livestock sector in the mixed farming system areas of Ethiopia in particular. Provided that, livestock husbandry practices and feed resources are dynamic; livestock CH₄ emission assessment of area specific data are pertinent for the further actions (Jo *et al.*, 2015). In addition, the situation constrained by the factors that limit estimation of emissions from the sector due to lack of to date temporal and spatial data on livestock husbandry, population trend, production type and feed resources (Silvia and Deborah, 2012).

Bale highland is one of the potential mixed farming areas of Ethiopia where crop-livestock farming is the predominant agricultural practice with the existing intricate problems. To understand level of the problems, the existing husbandry practices,

available feed resources and utilization, climate variability and the interrelationships for efficient livestock production, have to be assessed. Only few studies (Bogale *et al.*, 2008; Serekebrhan, 2009; Abate *et al.*, 2012) were not comprehensive of the existing livestock husbandry practices, farmers' perception of the present climate variability and the continued land competition between crop and livestock in the area (Duga, 2013; Hailemariam *et al.*, 2016). This condition stays a limit to develop strategies of future livestock fate to address livestock constraints and climate variability issues in the area at farm level in particular. The farm/household scale is the focal point where biophysical resources and their interactions can be clearly treated to attain the ultimate decisions on the available resource use (Abegaz, 2005). Therefore, it is imperative to look at existing livestock husbandry practices, available feed resources, climate variability and methane emission interrelationships across wealth groups to explore baseline information that could be used for the future design of improved livestock production by the policy makers and livestock development intervention actors. With this consent, this PhD study was initiated to address the following objectives:

General objective:

To explore the existing livestock husbandry practices, available feed resources and climate variability interconnections and their implication to methane gas emissions.

Specific objectives:

1. To characterize the existing livestock husbandry practices at smallholder level in the study area;
2. To characterize major feed resources and estimate the nutrient balance;
3. To assess farmers' perceptions of climate variability and livestock production interrelationships; and
4. To estimate methane emissions from the existing livestock under the prevailing production system.

2. LITERATURE REVIEW

2.1. Livestock Production Systems in Ethiopia

Worldwide, livestock are raised in many production systems of different agro-ecosystems (Steinfeld *et al.*, 2006). Different authors used different criteria to classify livestock production systems in tropics. Though, some five production systems have been identified in Ethiopia based on integration of livestock with other resources: level of input and intensity of production, agro-ecology and market orientation. The major production systems were pastoral, agro-pastoral, mixed crop-livestock farming, urban and peri-urban dairy farming, and specialized intensive dairy farming systems (MoA, 1998; Mohammed *et al.*, 2004; Ayenew *et al.*, 2007). Basically, production systems have emerged because of agro-ecological potentials, availability of resources and the demand for livestock products and services.

The lowland agro-ecological setup of pastoral and agro-pastoral production system were not extensively integrated with cropping, but prominent number of draft oxen supply to the mid and highland mixed farming are from these production systems (Mengistu, 2007). The agro-pastoral and pastoral systems are characterized by sparsely populated rangelands; where subsistence of the pastoralists is mainly based on livestock and their products. Here the livestock herding is dominated by cattle, goats, sheep and camels (Coppock, 1994). Pastoral and agro-pastoral livestock production depend predominately on natural pasture and some with crop residues with livestock performance markedly limited by deficits in forage quantity and quality during dry seasons. Poor nutrition is therefore considered as the major impediment to livestock production in Ethiopia's Rangelands particularly in times of grazing scarcity such as during prolonged drought (MoA, 1998). Particular to the pastoral system, livestock do not provide inputs for crop production; rather they are the very backbone of life for their owners, providing the consumable and saleable outputs in addition to representing a living bank account and form of insurance against adversity. Moreover, since the main source of food is milk,

pastoralists tend to keep large herds to ensure mainly sufficient milk supply and generate income (Coppock, 1994).

Agro-pastoral form of livestock production system characterized by both pastoral and mixed farming Zones where a tendency for crop production has shown besides livestock production (Sileshi *et al.*, 2001). Agro pastoralists are those capable to grow some crops and raise livestock as sedentary farming like mixed farming, while they are also mobile with part of their herds in search of feed and water as a pastoralist. In this type of production system, cattle and small ruminants play a critical role in the household economy and agro-pastoralists tend to retain female stock to produce milk and to maintain the reproductive potential of the herd (Coppock, 1994).

Urban and pre-urban small scale livestock production are practiced for a variety of reasons, from commercial to food self-sufficiency of the community among which small scale dairy production is more practiced in Ethiopia (Ayenew *et al.*, 2007). In line with this, in central highlands of Ethiopia and in Regional States (Oromiya, Amhara and Southern Nation, Nationalities and Peoples) of smallholder Dairy Development Project (SDDP) has been addressing commendably dairy development activities during early 1990s' (MoA, 1998). During this project to support the farmers, the government has delivered improved dairy animals, improved livestock management practice, introduce high-yielding fodder seeds, rendering of veterinary services, development of water supply. Hence, the considerable potential for smallholder income and employment generation from high-value dairy products, development of the dairy sector in Ethiopia can contribute significantly to poverty alleviation and nutrition in the country (Mohammed *et al.*, 2004).

In particular, the peri-urban small scale dairy production system is found in the outskirts of the cities and small to big regional district to zonal towns based on resource availability. Whereas, urban dairy production system comprises small scale to specialized commercial farms mostly private owned in and around regional cities, towns and Addis Ababa city in particular. These dairy farms have no access to grazing lands and basically

keep exotic dairy stocks. The main feed resources are agro-industrial by-products and purchased roughages with the primary objective of milk production is profit making (Ayenew *et al.*, 2007).

The highlands (>1500 m.a.s.l) in Ethiopia comprise nearly half of the land area of the country and hold more than 85% of the total human population, and about two thirds of the livestock population (Sileshi *et al.*, 2001; Deressa *et al.*, 2011, Tesfa and Mekuriaw, 2014). The farming system is based on cropping and livestock herding considering as two major livelihoods component on a continuum phenomenon. That is the reason why the highest livestock population of the ecological Zones is found in the highlands of Ethiopia. More than 75% of Ethiopia's livestock population inhabited in the mixed farming areas of the highland and middle altitude areas (Mengistu, 2006; Deressa *et al.*, 2011; FDRE-CRGE, 2011).

In Ethiopia, the work function of animals (oxen for draught and crop threshing, equines for transport) is predominant while the other categories contributed a diversified livelihood needs. However, nowadays, some global drivers: economic and income growth, demographic and land use changes, dietary preferences and technology interventions (FAO, 2008; Steinfeld *et al.*, 2006) challenging the sector. Hereby, production and productivity of livestock in the highlands differ greatly not only with respect to farming system, population pressure and development level. An integrated farming system consists of a range of resource saving practices that aim to achieve acceptable high and sustained production levels while minimizing the negative effects of intensive farming and preserving the environment (Delgado *et al.*, 1999; Tolemariam and Jaleta, 2015). Though the concept of system analysis is not new in the study of farming systems; the multiple roles of animals have been not given emphasis until recently due to their extreme complexities.

2.2. Importance of livestock and existing husbandry practices

For the smallholder mixed crop-livestock system, the major goal was crop production while animals are a means to achieve this goal together with complementary inputs of labor, capital and land (Udo *et al.*, 2011). Here, animals are part of a subsistence mixed farming complex and provide inputs (draught power, transport, manure) to crop production and generate consumable and/or saleable outputs (milk, manure, meat, hides and skins, wool, hair and eggs) to the livelihoods of the community. In Ethiopia, livestock and their products fulfill different and often complementary functions for herders since they serve a wide variety of functions in the society from social to subsistence purposes (Negassa *et al.*, 2011). The annual economic benefits of livestock goods and services may be more than 113 billion Ethiopian Birr, which is over three times greater than MoFED's standard estimate (IGAD, 2010). This estimate puts into perspective how vital livestock are to the Ethiopian economy, not only in terms of their product value, but their wide array of services.

Apart from the market outputs; inputs to crop production, subsistence home consumption, asset making and socio-cultural importance at the household level are major one. More importantly, livestock represent more than half average wealth of rural households of many families' net value measured in terms of livestock number owned with cattle at the top of valuation (Descheemaeker *et al.*, 2010; Duguma *et al.*, 2012). The functions of livestock as farm inputs (draught, threshing, manure and transport) are more important in highland mixed farming than in other areas. Older reports (FAO, 1979), traditional use of draught animals in Ethiopia estimated to contribute more than 26% of the total labor requirements of crop agriculture compared to the recent reports (Bekele, 2008; Serekebrhan, 2009) that indicated traction was the primary preference in mixed farming system of the country. Livestock husbandry can be routine management practices including labor, animal health services, stock of production and outputs which are the products in addition to unforeseen activities. Most of the rural stocks are kept under extremely traditional and simple management condition and receives little proper attention; supplement feed, poor housing and health care services (Serekebrhan, 2009;

Yasar *et al.*, 2016). The purpose of animal manure collection is widespread but its effect on agricultural productivity is low due it can be used as fuel wood. In general, livestock managed in a traditional way and closely linked to the socio-culture of the holders.

The species of livestock kept were almost uniform to the previous years in the intended farming system in number and age composition of herd varies; nowadays, adult or aged animals dominate herds in all districts because of severe grazing land decline and farmers tend to keep only animals which could be currently used. Fertility rate of animals declined because of feed scarcity while oxen per household have been increasing relative to the other herds for the need of cultivation. The total number of animals kept per household was by far less than the past few years (Daba *et al.*, 2009). Despite their socio-economic importance, low output, poor growth rate and reproductive performance are the major problems limiting animal performance in Ethiopia (Wondatir, 2010; Duguma *et al.*, 2012). Beside the inherent low production trait performance; major reasons for low animal productivities were: poor husbandry practice, high ambient temperature, prolonged drought, feed and water shortages, diseases prevalence, and poor infrastructure provision (Membere *et al.*, 2008; Guyo and Tamir, 2014; Defar *et al.*, 2016).

2.3. Livestock Feed Resource Dynamics and Feeding Management

Generally, the existing grassland productivity is declining at a higher rate because of technical and climate factors (temperature and rainfall stress). Moreover, the continual conversions of productive grasslands to cultivation in the study Zone (Figure 1) and poor grazing land management are some of the technical reasons for declined annual DM yield from grassland (Admassu, 2007; Abera *et al.*, 2014). Many studies have indicated that the grazing lands of the country are in a very poor condition and will deteriorate further unless immediate action taken (Alemayehu *et al.*, 2017; Mengistu *et al.*, 2017). Guyo and Tamir (2014) reported that heavy grazing is cause of grazing land deterioration in the highland area followed by reduction in forage species composition in Burji, Ethiopia. Hence, grazing is restricted to areas that have little or no value of farming potential: hillside, swampy area, roadside and marginal lands which is evident in the mixed farming

areas (Mengistu *et al.*, 2017). The old reports of the productivity study indicated that in seasonally water logged fertile areas 4-6 tons DM per hectare (Mengistu, 1985) which is impossible these days. However, most pasture grasses generally have less DM yield though there is variation between seasons and areas (Hassen *et al.*, 2010; Yisehak and Geert, 2014).

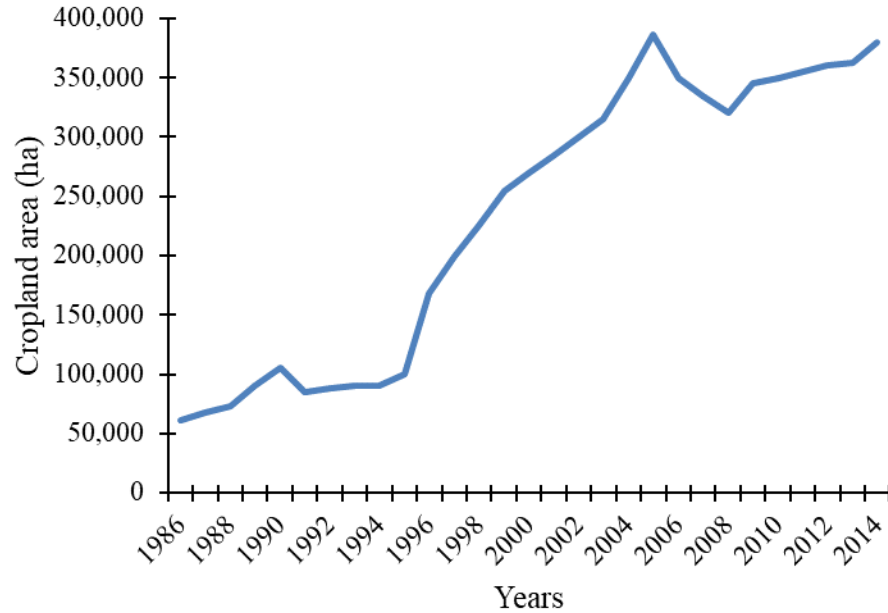


Figure 1. Cropland trends in the highland mixed farming areas of Bale Zone

Source: Hailemariam *et al.* (2016)

Ruminant and other livestock continue to rely mainly on available native grass as their source of feed to satisfy their requirement. The earlier report (ILCA, 1995) indicated that farmers in mixed farming rural area had averagely available feed per farm to meet only their animals' maintenance requirements and very little left for growth and production. But, the recent study reports argue this situation and confirmed the persistent occurrence of annual feed deficit at farm level (Tegene *et al.*, 2010; Hassen *et al.*, 2010; Abera *et al.*, 2014; Hailemariam *et al.*, 2016) in the highlands of Ethiopia. This is due to a significant shrinkage of grazing land and existing natural pastures are heavily grazed by livestock and in dry season animals not able to meet even maintenance requirements leading to substantial body weight loss. Thus, in Ethiopia grazing pressure is high and eventually

results in ground cover and productivity decrease. To achieve the targeted level of production, efficient feeding is necessary as feed is the major driver of livestock production accounting for more than 65% of recurring expenditure. In this context, crop residues: comprising mainly straw from fine grains and stover from coarse grains obtained after harvesting form available feed stock in the mixed farming areas. Despite the fact that cereal straws are of low feeding value (CP and digestibility) and low voluntary intakes (1.5 to 2 kg per 100 kg body weight); continue to be important feed resource in the developing world (Mahesh and Mohini, 2014).

Much has been said about the livestock feed sources in mixed farming areas (Bediye *et al.*, 2001; Mengistu, 2006; Daba *et al.*, 2009; Yadessa *et al.*, 2016) in Ethiopia. The major basal feeds are straws (cereal and pulse); native grass (communal and private grazing) and crop aftermath with the contribution to the total feed resources base vary from area to area based on the cropping intensity. Currently, with the expansion of arable land and the continuing decrease of grazing land (Figure 1), the use of crop residues and associated by-products are regularly increasing in integrated crop-livestock areas (Tolemariam and Jaleta, 2015; Yadessa *et al.*, 2016). In the high and mid altitude, some other refused vegetable parts are providing a considerable quantity of dry season feed supply in mixed farming areas of Ethiopia (Kossila, 1988; Blümmel *et al.*, 2009).

The principal crop residues available to feed livestock in Bale highlands include cereals and pulse straws (Bogale *et al.*, 2008). These feed sources were reported to have very low CP content to maintain the animal body condition as CP determines quality of feeds (Bediye *et al.* 2007; Yami *et al.*, 2013). Hence, local oilseed mill by-products are mixed with straw and other available supplements at household level such as residue of local brewing practices (*atela*) to enhance the palatability, feed intake and digestibility. In this situation, crop straws are primarily used for the feeding of draught animals in Bale highland mixed-farming system. Overall, straws were the main feed source for livestock during the dry period when pasture from grazing area cease to provide reasonable quantity of feed in the area (Bogale *et al.*, 2008).

2.4. Nutritional Quality of Common Roughage Feeds in Ethiopia

In Ethiopia, crop straws form a major portion of ruminant diets (Tegegne and Assefa, 2010, Tolera *et al.*, 2012). Most livestock production systems are faced one or more seasons with low feed availability and quality. Production during such seasons is absent or even negative because animals rely solely on crop residues. Quality of native grass in the central highlands also revealed remarkable seasonality (Sileshi and Bediye, 1991). The CP content varied from 3.2% to 12.1% while (IVOMD ranged from 42% during the dry season to 57% during the main rainy season. In the same study, the critical nutrient lacking was indicated to be protein, and the supply of this nutrient to fall below maintenance requirement. In Ethiopia, crop residues provide 50-81% of the total feed source for ruminant livestock (Bogale *et al.*, 2008; Hassen *et al.*, 2010), despite high in fiber content and low in CP (Bogale *et al.*, 2008; Tolera *et al.*, 2012). Though crop residues contain 60-80% potentially fermentable nutrients by ruminant animals, their availability for digestion by rumen micro-organisms is limited partly due to their association with lignin (Van Soest, 1991; Singh and Oosting, 1992). In agreement, Kellems and Church (1998) (as cited in Geleti, 2014) categorized roughages with more than 40% ADF as low quality feeds that not satisfy the requirement of animals (Table 1). Keftesa (1988) reported that the feeding value of crop residue depends on intake and digestibility, and to achieve maximum intake, CP content of 66-85 g/kg DM is required.

In support of the mentioned feed scenarios, ILRI (2011) reported that Ethiopian crop residue feeds: wheat, barley and teff straw have 53.61, 53.5 and 53.17% IVOMD, respectively. In addition, it was reported that feeds with ADL higher than the maximum level of 7% per kg DM limits intake and livestock productivity (Reed and Michael, 1989). Therefore, in order to improve the production and reproductive performance of animals in the country, the nutritional deficiencies of roughage based diets need to be boosted with more economical ways of supplementation. Wondatir (2010) also suggested that lower CP content for both residues and stubbles grazing compensated with strategic supplementation of proteinaceous feeds to improve livestock performance. Hence, the differences in chemical constitutes of the same feed reported by different authors (Table 1) is mainly due to temporal and spatial difference of the mentioned feeds.

Table 1. Summary of major roughage feeds chemical composition in the mixed farming system of Ethiopia

Feed type	DM	Chemical composition (g/kg DM)						Authors
		OM	CP	NDF	ADF	ADL	IVOMD	
Native grass	940	900	96	736	420	51	668	Bogale <i>et al.</i> , 2008
	916	840	109	562	393	88	503	Bediye <i>et al.</i> , 2007
	NA	910	66	663	388	47	620	Tolera, 2008
	915	899	72	757	422	83	542	Wondatir, 2010
	920	902	58	639	450	60	604	Geleti <i>et al.</i> , 2013
	NA	920	76	625	319	38	572	Lemma <i>et al.</i> , 2016
	913	759	79	798	512	89	NA	Hailemariam <i>et al.</i> , 2017
Crop aftermath	945	910	35	791	550	110	456	Bogale <i>et al.</i> , 2008
	928	939	26	785	649	91	475	Wondatir, 2010
Cereal crop residue	NA	NA	29	728	492	50	58	Reed & Michael, 1989
	970	920	52	729	518	125	558	Bogale <i>et al.</i> , 2008
	NA	833	48	669	NA	NA	457	Abegaz <i>et al.</i> , 2007
	927	915	53	714	492	96	499	Bediye <i>et al.</i> , 2007
	921	923	65	627	NA	84	562	Tolera, 2008
	925	920	51	765	537	115	477	Wondatir, 2010
	922	900	34	777	526	97	448	Geleti <i>et al.</i> , 2013
	932	917	37	845	525	109	415	Chalchissa <i>et al.</i> , 2014
NA	910	45	746	376	88	525	Lemma <i>et al.</i> , 2016	

NA=not available; DM=dry matter; OM=organic matter; CP=crude protein; NDF=neutral detergent fiber; ADF=acid detergent fiber; ADL=acid detergent lignin; IVDOMD=in vitro digestible organic matter in the dry matter

2.5. Existing Global Climate Change Scenarios versus Livestock Production

Evidence from the IPCC is now overwhelmingly convincing that climate change is real, it will become worse and the poor are vulnerable people and the worst affected. The changed climatic factors include warmer temperature, altered patterns of precipitation, increased frequency and severity of climatic events and rising sea levels (IPCC, 2007). The Change is attributed directly or indirectly to human activity that alters the composition of the atmosphere in addition to natural climate variability (ESAFF, 2010). It refers to changes in the total attributes that define climate (surface temperature, precipitation patterns, wind directions and intensity, ocean currents, and other measures of the earth's climate (Michael, 2009) which are anthropogenic in origin (mainly industrialization) and natural phenomena has played a role both in the past and current climate variability. Beside these scenarios, animal agriculture is responsible for 18% of global GHG emissions from all the human activities, which is a potential cause of climate change because of its global warming potential (Steinfeld *et al.*, 2006).

Climate change refers to statistical changes in weather over time including long-term changes in rainfall, wind, temperature or other patterns. The changes so far observed were: warmer surface temperature, shift in rainfall pattern, widespread drought, rising sea levels and others (Table 2). Evidences indicated that global mean temperature has risen by about 0.3-0.6 °C since the 20th century (IPCC, 1995; Nkomo, 2006). Solar radiation is the driving force of global climate change where a portion of the radiation reaching earth's surface is scattered or reflected by clouds, aerosols, dust and other particles. In line with the existing situation projections of future climate change suggest further global warming, sea level rise and increase in the frequency of some extreme weather events (IPCC, 2007). Rainfall in Ethiopia has varied greatly across seasons, years and regions and there is an evidence of a 20% decrease in rainfall in the South part of the country from 1960 to 2010 (Irish Aid, 2015; FDRE, 2016).

Different reports indicated that climate change profile for Ethiopia shows the mean annual temperature increased by 1.3°C between 1960 and 2006 (McSweeney *et al.*,

2010), average minimum temperature increased by 0.37 °C (NMA, 2007) while in highlands the temperature has been increasing 0.3 °C per decade. Furthermore, Herrero *et al.* (2010) suggested, in East Africa across Ethiopia, Kenya, Somalia and Tanzania while mean temperature varies with elevation; the more remarkable climate variation is of precipitation. These changes are likely to have profound impacts on ecosystems, water resources, agriculture, livestock production and others (Michael, 2009; Amsalu *et al.*, 2013). Likewise, Thornton *et al.* (2006) presented length of plant growth change will continue for Africa to 2050, even though there were areas where the combination of increased temperature and rainfall changes may lead to an extension of the growing season. According to Elsa *et al.* (2012), of all the factors influencing livestock production, ambient temperature and rainfall patterns variations are undoubtedly the most significant contributors to feed scarcity and the newly emerging diseases of livestock and plants in tropics.

Table 2. The past years observed climate change effects around the glob

Indicators		Observed Changes
Atmospheric concentration indicators	CO ₂	280 ppm during 1000-1750 to 380 ppm in 2000
	CH ₄	700 ppb during 1000-1750 to 1,750 ppb in 2000
	N ₂ O	270 ppb during 1000-1750 to 316 ppb in 2000
Weather indicators	Mean temperature	Increased by 0.6±0.2°c over the 20 th century
	Northern temperature	20 th century were warmest over 19 th century
	Cold or frost days	Decreased for nearly all land areas in 20 th century
	Heavy precipitation	Increased at mid and high northern latitudes
	Drought severity	Increased in frequency & intensity in recent years
Biological and physical indicators	Mean sea level	Increased at a rate of 1-2mm during 20 th century
	Arctic ice thickness	Thinned by 40% in recent decades
	Snow cover	Decreased by 10% since global observations become available from satellites in the 1960s.
	El Nino events	More frequent and persistent for the last 30 years
	Growing season	Increased 1-4 days per decade for the last 40 years
	Breeding, flowering migration	Earlier (flowering, bird arrival, date of breeding season and emerging insects)

CO₂=carbon dioxide; CH₄=methane; N₂O=nitrous oxide; ppm=parts per million; ppb=parts per billion

Source: IPCC (2001)

2.5.1. Farmers' perceptions of climate change and global consequences

The report from IPCC (2007) indicated that for a while, people did not believe the earth's temperature was rising, but now everyone accepts that climate change is real (Table 2). The preliminary evidence from a number of African countries reveals that agriculturalists already perceive that the climate has become hotter and the rains less predictable and shorter in duration (Maddison, 2007; Irish Aid, 2015). This implies experienced farmers would be better at distinguishing climate variability from merely inter-annual climate variation. A study by Maddison (2006) from eleven African countries compares the probability that the climate has changed revealed by analysis of the statistical record, with the proportion of individuals who believe that such a change has occurred. Hageback *et al.* (2005) assess small-scale farmers' perceptions of climate variability in the Danagou watershed in China by comparing the local precipitation and temperature data trend. They conclude that farmer's perception of climatic variability correspond with the climatic data records.

In Sidama area of Ethiopia, Hameso (2015) reported that farmers rely on their own counsel, fellow farmers and extension workers as prime sources of information to form opinion about their environment. Their direct experience based on years' of personal knowledge about climate conditions, which they share with fellow farmers, community elders, religious leaders, peers and neighbors that are more accessible than formal sources. The significance of farmer-to-farmer interaction appears that the government promoted what it calls 'model farmers' to help farmers share experiences and adopt new methods from fellow farmers. The farmers best placed to say on whether climate change has occurred are presumably those who have had the most experience of farming. Mengistu (2011) reported that climate change is observed by the farmers in Adiha village, Ethiopia such as changes in temperature, precipitation, timing of rainfall and related frequent drought. As experience increases, farmers are more likely to claim that there is less rainfall, changes in the timing of the rains and a change in the frequency of droughts (Maddison, 2007). Farmers may take time to realize that unusual weather

represents a permanent shift in the climate attributes and in this regard it is important whether farmers engage in forward or backward looking behavior (Belay, 2010).

To confirm farmers' perceptions of climate change and variability, first look at how climate data recorded at meteorological stations evolved (trends and variability) and how farmers perceived these changes. However, there is a limited knowledge whether farmers perceive climate change and how responding to the effects (Deressa and Hassan, 2009; Belay, 2010). But, a study conducted by Ishaya and Abaje (2008) in Nigeria, revealed that farmers perceived climate change to have occurred over the years due to diverse human activities. In addition, Mertz *et al.* (2009) in Sahel reported Senegal farmers were aware of the climate variability and identified wind and occasional excess rainfall as the most significant factors that need adaptation. Similarly, Nhemachena and Hassan (2007) in Southern Africa reported that there is a perception that most farmers perceive long-term temperature increase, changes in precipitation and pronounced changes in timing of rain and frequency of droughts in their area. Therefore, it is important to note that local perceptions cannot be underestimated and there is a need to document how the lives of the local community affected by the recent climate changes for further remedy.

2.5.2. Interrelationships between climate variability and livestock production

Livestock established their current geographic ranges through long-term adaptation to seasonal climate patterns to sustain and stay productive. The linkages between livestock production and climate change are a two-way interaction and dynamic (Emanuel, 2005). Because, climate change has significant impacts on several aspects of livestock production such as feed quantity and quality, rangeland diversity, distribution of diseases, production system changes and others. The other way, livestock has impacts on climate change through natural resource degradation and GHG emissions (Herrero *et al.*, 2009; Thorpe, 2009). Whatever the situation, the complex balancing act of resource use, GHG emissions and sustainable livelihoods require better understanding of future livestock herding. Therefore, weighting the environmental impacts versus social benefits is a subject that deserves a study to advocate the existing scenario. Hence, Ethiopia has

committed and show a progressive strengthening of political resolve to address the problems associated with climate change (FDRE-CRGE, 2011), although agriculture and ruminant livestock production globally are a significant contributor to GHG emissions (IPCC, 2006).

Since the majority of Ethiopia's population lives in rural areas and depends heavily on rain-fed agriculture, climate change presents a huge challenge (Kimball, 2011). Any change in climate, mostly manifested as an increase in frequency and severity of extreme weather events such as drought has a potential to reduce significantly crop-livestock productivity and affects household livelihoods. Such scenario of climate change will create new environmental conflict hotspots that could lead to a significant increase in national and international conflicts over shared environmental resources, such as water and land (ESAFF, 2010).

The impacts of climate change on livestock are reflected mainly through feeds, water, livestock diseases and management system change (Lemma, 2012; Amsalu *et al.*, 2013; Gashaw *et al.*, 2014). Heat is the major challenge in tropical and sub-tropical climatic conditions which negatively affects production and reproduction of livestock species directly; its stress causes a chain reaction of physiological, behavioral and anatomical changes leading to reduction in growth, productive and reproductive functions (Teka *et al.*, 2012; Pankaj *et al.*, 2013). It is also expected to be resulted in increasing demand for water. Another report from Zambia indicated that impact of climate change on livestock production pronounced due to lack of better quality grazing pasture and drinking water. Consequently, heat stress adversely impacted livestock by reducing appetite, production, fertility and increasing mortality rates (FAO, 2011).

On the other hand, the supply chain of livestock kept for food sources and services have been vastly under estimated as a source of environmental impact and GHG emissions (Kimball, 2011). The multiple environmental impacts include: erosion, soil degradation, deforestation, GHG emissions and water pollutions. Global livestock are known to contribute 18% (FAO, 2006; Steinfeld *et al.*, 2006) annual global GHG emissions that

attributed to cattle, buffalo, sheep, goats, camels, horses, pigs, and poultry (Figure 2). However, some researchers believe that the contribution of livestock, their production system and associated industries have been vastly underestimated as a source of GHGs (Nandolo, 2011; Vellinga *et al.*, 2013). Different reports (Herero *et al.*, 2008; ILRI, 2009; Gerber *et al.*, 2013) mentioned that animal number, production system, feed used and volume of product are the main factors those determine extent of GHG emission from livestock sector (Figure 2). As to Ethiopia, the FDRE-CRGE (2011) reported that large share of GHG emissions originates from livestock sector and is expected to expand even faster than population growth in the future. In addition, few studies (FDRE-CRGE, 2011; EPA, 2013) had undertaken to determine impact of agriculture on climate change in general though limitations with these studies where they are aggregate and lacks to indicate livestock system implications and farmers' perceptions towards the problem in mixed farming in particular.

The livestock production system contributes to global climate change directly through the production of GHGs emissions and indirectly through the destruction of biodiversity, degradation, desertification, and water and air pollution (Gill *et al.*, 2009). Enteric fermentation and manure decomposition are direct GHG emissions from livestock which are the largest CH₄ and N₂O sources from animal production and are the area of emphasis (Solomon *et al.*, 2007). Hence, the inter-relationships between climate change and the livestock sector is important to explore for a reasons, the sector recently blamed as contributing to global warming and ruminant numbers particularly cattle with the level of productivity affect feed intake and enteric emissions (O'Mara, 2011; Leinonen *et al.*, 2012).

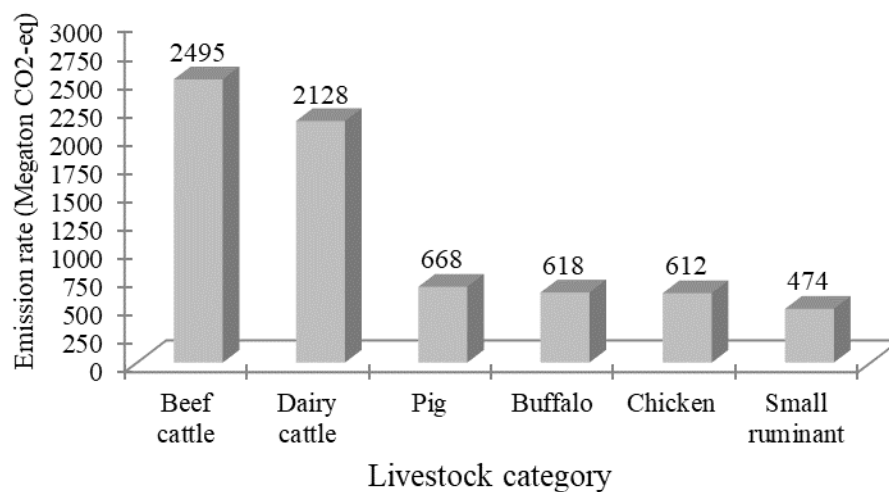


Figure 2. Methane emissions from global livestock sector by 2005 (Mega ton CO₂-eq)

Source: Gerber *et al.* (2013)

2.6. Livestock Feed Resources and Implication to Greenhouse Gas Emissions

Animal feeds in mixed farming system would have different diets consisting of grazing, cut and carry forages, crop residue, roadside grass, weeds and some sort of concentrates. Unless livestock producers determine the quantity and quality of forage available for their livestock, the investment might be uneconomic and environmentally unsustainable. Hence, different livestock species show variation in feed utilization and affect the environment differently through emissions as feed quality affects efficiency of utilization and GHG emissions per kg of product (Gerber *et al.*, 2010). Feed processing for ruminant and non-ruminant farm animals is aimed at increasing feed energy intake use and animal productivity. The same author suggested that in ruminant feeding; forage particle size reduction is important to enhance digestibility providing greater microbial access to the substrate, reducing energy expenditure and feed intake and animal productivity which helps to reduce CH₄ emission.

Type of diet is a major source of variations in CH₄ emitted in respect to fermentation and production of total gas. Relative concentration of CH₄ produced as a result of particular feed fermentation relies mainly on its quantity and nature of chemical entities. As to CH₄

emission from different feeds, the availability of nutrients, particularly energy, will be different for different diets related to feeding standard. Hence, measurement of CH₄ emission factor for a particular feeding system helps in ranking the feed type for a relative CH₄ production in a particular locality livestock category. Thus, it is important to reduce the share of CH₄ from ruminants to environment pollution and utilize the energy of feed for the benefit of the host animal (Singh *et al.*, 2012) while ruminants are an important source of CH₄ because of their large population and high CH₄ emission rate due to inherent digestive system (IPCC, 2006).

There are a variety of factors that affect CH₄ emission in animals, such as: physical and chemical characteristics of the feed, feeding level, use of feed additives to promote production efficiency and health of the animal. It has been also suggested that there is a genetic factor that influences emissions since enteric fermentation is a natural digestive process result for many ruminant animals. Hence, the anaerobic methanogen microbes decompose feed present in the digestive tract producing compounds that are absorbed by the host animal. Production of CH₄ in ruminants is directly correlated to a loss of ME and has been studied to improve feed efficiency (Johnson and Johnson, 1995; Jungbluth *et al.*, 2001). Since digestion process is not 100% efficient, some of the feed energy is lost in the form of CH₄, estimated to be 7-10% (Moss and Givens, 1993), 3.5-7.5% (Clark, 2009) and 2-12% (Patra, 2014) of a ruminant's GE intake to be lost to enteric fermentation. Cattle typically lose 2-12% of their ingested GE as eructated CH₄ (Johnson and Johnson, 1995). In general, poor quality feeds those accessed easily to livestock producers' leads to higher CH₄ production due to rumen fermentation, whereas, high quality feeds responsible for emissions through production, manufacturing process and transport (Marius, 2009; IUCN, 2010).

Better quality feeds such as concentrates produce a higher proportion of propionate in the rumen than poor quality feeds (crop residues), which produce higher acetate and butyrate (Van Soest, 1994). The reason for this aligned to the fact that rumen microbes can convert a unit of hexose (6 carbons) into 2 units of propionate (2_C₃) when feed is better quality while only two units of acetate (2_C₂) and/or one unit of butyrate (1_C₄) when

feed is poor quality. Then, the two carbons per unit of hexose are not captured in short chain fatty acids in the case of acetate and butyrate production and are available for gas production. Accordingly, gaseous losses per kg of feed digested in the rumen are calculated to be 17% higher for poor quality feeds compared to the better quality. The consequence is that livestock fed on crop residue based diets will have higher CH₄ emissions per kg meat or milk produced than livestock fed better quality feeds which has environmental implications (Blümmel *et al.*, 2009). There is a clear relationship between feed OM digestibility, concentrate feed or starch intake and livestock productivity. Johnson and Johnson (1995) stated that when quality feed intake increases, the Y_m factor decreases by about 1.6% per each level of intake above maintenance.

Noziere *et al.* (2010) estimated that VFAs molar proportions (acetate, propionate and butyrate) would average 66, 17 and 14 mol per 100 mol of NDF, and 41, 44 and 12 mol per 100 mol of starch, respectively. Indeed, a 72% versus 52% concentrate diet produced a 59% increase in propionate concentration and a 44% drop in acetate to propionate ratio in lactating dairy cows (Agle *et al.*, 2010). This implies that higher inclusion of forages with higher starch content such as cereal crop silages in ruminant diets lowers enteric CH₄ production. Comparably, Pelletier and Tyedmers, (2010) reported 30% higher total GHG emissions for pasture finished cattle compared with cattle in a grain based feedlot system. Generally, livestock production result in CH₄ emissions from fermentation and both CH₄ and N₂O from manure management systems. Methane from manure is generated during anaerobic decomposition of OM in faeces and bedding material when manure managed under anaerobic condition (Chadwick *et al.*, 2011; CDR, 2011).

3. MATERIALS AND METHODS

3.1. Study Area Description

The study was conducted in Bale Zone of Oromia National Regional State, Southeast Ethiopia. Recent demographic report revealed that the human population of the Zone is estimated at 1,616,061 of which, 87.3% live in the rural area (Bale Zone BoFED, 2012). The Zone holds three town administrations and 18 rural districts. From the 18 rural districts, 9 fall under the mixed farming system where the rest 9 are pastoral and agropastoral. The study area was situated at the highland altitude with mean annual rainfall of 860.00 mm. The average minimum and maximum daily temperatures were 9.4 °C and 25.2 °C with overall daily average temperature of 16.3 °C (NMA Bale branch unpublished data). The rainfall pattern of the study area is characterized as bimodal type. The area has two distinct seasons namely: *Belg* which extends from March to July and *Meher* which extends from August to January (Bale Zone BoFED, 2012).

Topography of the study area is characterized by major flat plain suitable for both small scale and mechanized crop cultivation (Chibsa and Ta'a, 2009). The vegetations in the area are natural pasture from meager wetlands, riverbanks and few sparsely distributed trees while eucalyptus is dominant around the settlement areas. Forest and shrub lands are mainly restricted to religious and cultural reserved areas, periphery of the study area districts such as along the Wabe river valley hills and gorges. The dominant soil types in the study area are Cambisols, Vertisols and Fluvisols which usually occur in flat plateau highland areas and are suitable for various crop production and natural vegetations of a wide range (Chibsa and Ta'a, 2009; Serekebrhan, 2009).

Major crops cultivated in the area are wheat, barley, emmer wheat, teff, faba bean, field pea, maize, and some oil crops. Moreover, the study area has large livestock resources, since the smallholder livelihood bases are livestock herding and cultivation. The major livestock species traditionally reared by the study area inhabitants include cattle, sheep, donkey, horse and chicken (CSA, 2016). The districts used for this study were among the

first few potential mixed farming districts of the Zone known for the extensive cultivation and raising high livestock population (Chibsa and Ta'a, 2009, Figure 4).

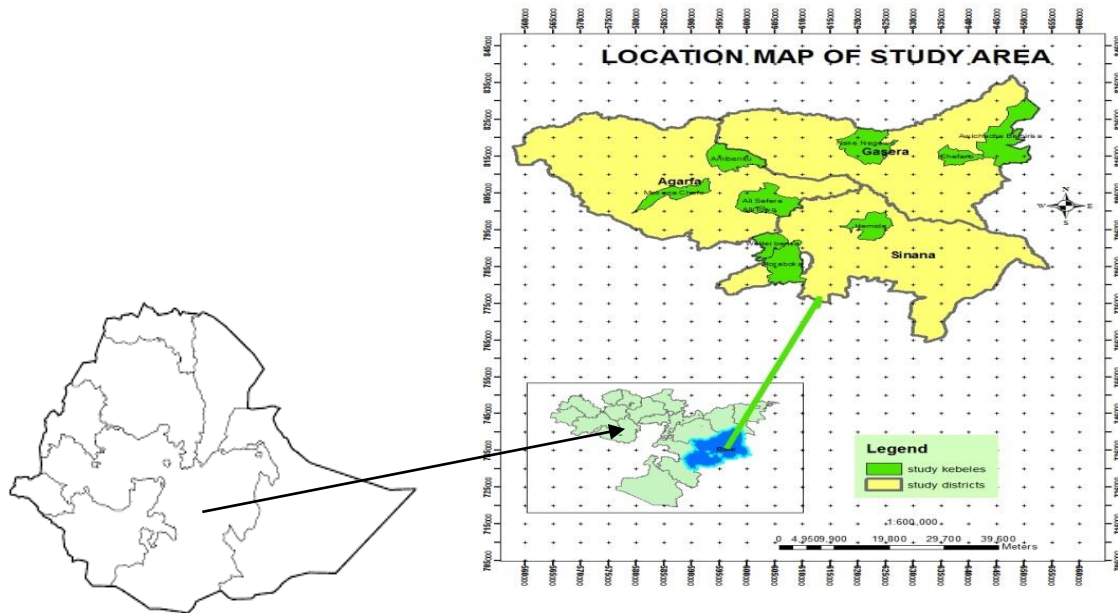


Figure 3. Location map of the study area

3.2. Procedures of Sampling and Data Collection

3.2.1. Sample size and sampling procedures

The potential mixed farming system (cereal-cattle dominant) districts were purposively selected from the nine highland farming districts based on cropland cover (Figure 4, Appendix Table 31) and livestock population potential (Appendix Table 1). The land use/land cover of the mixed farming districts were categorized into cultivation land, forest land, bush-shrub land grassland and others (alpine, exposed rock and soil surface areas, town districts and settlement areas). Further, the nine *kebeles* namely (*Hamida, Hora-Boka, Weltei-Berisa, Ali-Sefera, Mokonna-Chefe, Ambentu, Nake, Chifaro and Birbirs*) were randomly selected from the fifty-five highland crop-livestock farming *kebeles* of the districts. The households (HHs) were stratified into three different wealth

3.2.2. Data collection

A single visit multiple subject formal survey (ILCA, 1990) was done using pre-tested structured questionnaire. Before the commencement of the actual interview, the questionnaire was pre-tested with farmers and experts for further refinement. Following the pre-test, appropriate modifications were made to some questions to fit the purpose. The survey covered subjects like demographic characteristics, landholding, cropping pattern, livestock holding, herd composition, purpose of livestock keeping, herding labour, livestock housing, manure management and utilization, major feeds and water sources, common livestock disease, productive performance, livestock and feed production constraints, climate variability perceptions, livestock climate variability relationships and traditional climate variability adaptation strategies. Nine enumerators who were working as development agents in the sample *kebeles* were selected and trained on the primary data collection methods under close supervision of the researcher. A single focus group discussion (FGD) comprising 9-13 people, who were drawn from farmers of different wealth groups, sex, farming experience and development agents were conducted in all nine *kebeles* by the researcher (Figure 5). The employed data collection methods were: cross-sectional survey, focus group discussions, key informant interview field observations and feed samples collection.



Figure 5. Focus group discussions at sample *kebeles*

3.2.3. Feed sample collection and chemical composition analysis

Mixed natural pasture herbage from protected private grazing and fallow land of the wealth groups (9 kebeles * 3 wealth groups * 3 quadrants) at the midway mature age were harvested from 1m * 1m quadrant (Tessema *et al.*, 2011) and 27 samples from each private grazing and fallow lands of the wealth groups, bulked and dried under shade for further chemical analysis. The dominant herbage species from these lands were: *Cyperus rigidifolius*, *Andropogona abisinica*, *Hyperrhenia rufa*, *Digitaria* and *Trifolium*. Major crop straws: wheat (*Triticum sativum*), barley (*Hondrium vulgare*), emmer wheat (*Triticale species*), teff (*Eragrostis tef*) and highland pulses (*Vicia faba* and *Pisum sativum*) used as livestock feed in the area were collected from straw stacks owned by the respondent HHs (9 kebeles * 3 wealth groups * 3 straw stacks). The collected feed samples were manually chopped into small size and ground to pass through 1mm screen sieve. The chopped pasture herbage and crop straws from the nine *kebeles* were pooled to their respective categories of the wealth groups (7 feed samples for each wealth groups) and mixed thoroughly. The mixed representative sub-samples were taken per the feed type and packed in a paper bag (Figure 6) at room temperature pending chemical analysis at Holeta Agricultural Research Center's Animal Nutrition Laboratory.



Figure 6. Major livestock feed samples pending chemical analysis

The wealth group based pooled sub-samples (mixed natural pasture, fallow land herbage, wheat, barley, emmer wheat, teff and pulse straws, and homemade concentrates) were dried in air draft oven at 65 °C for 72 hours to determine herbage DM. The DM and ash contents were determined by oven drying at 105 °C overnight and igniting in a muffle furnace at 500 °C for 6 hours, respectively. Nitrogen (N) content was determined by the Kjeldahl method and crude protein (CP) was calculated as N * 6.25 (AOAC, 1995).

Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) were analyzed according to Van Soest and Robertson (1985). The *in vitro* digestibility organic matter in the dry matter (IVDOMD) was determined by Tilley and Terry method as modified by Van Soest and Robertson (1985).

Chemical constituents of crop aftermath grazing and forage crops were used from Bogale *et al.* (2008) and Bediye *et al.* (2007), respectively.

Metabolizable energy and digestible crude protein contents of a given feed were estimated from IVDOMD and CP contents, respectively, employing the following formulae:

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

DCP (g) = [0.929 * CP (g/kg DM) - 3.48] (Church and Pond, 1982 as cited in Bogale *et al.*, 2008). Where, IVDOMD = *In vitro* organic matter digestibility and DCP = digestible crude protein.

Relative Feed Value (RFV) was calculated according to Uttam *et al.* (2010) and Schroeder (2013):

RFV = [DDM (%DM) * DMI (%BW)/1.29]: Where, DDM and DMI calculated from ADF and NDF the feeds, respectively:

DDM (%DM) = 88.9 - 0.78 * ADF (%DM) and DMI (%BW) = 120/NDF (%DM)

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

3.2.4. Estimation of available feeds annual biomass yield

The quantity of feed DM obtained annually from the different land use types were calculated by multiplying hectare of the land under each land use type by its conversion factors (FAO, 1987). The conversion factors of 2.0 and 0.5 tons DM per hectare per year were used for communal and crop aftermath grazing, respectively. The herbage DM from fallow and private grazing lands was calculated from harvested samples DM. The quantities of crop residues produced by the respondent HHs were estimated by converting crop grain yield to straw yield. Accordingly, for a ton of wheat, barley, emmer wheat and teff straw, a multiplier of 1.5; for the highland pulse (faba bean and field pea) a multiplier of 1.2 and for oilseeds a multiplier of 4.0 were used (FAO, 1987; Appendix Table 2). The quantity of potentially available crop residues for animal consumption was estimated by considering 10% wastage due to collection, transport, storage, processing and other alternative uses (Tolera and Said, 1994).

3.2.5. Land use/land cover change assessment

The previous and existing grazing lands of the study area were assessed from two different period Landsat images using GIS and ERDAS IMAGINE software (ERDAS, 2010). The images were analyzed to figure out the major existing land covers. The type and characteristics of the past and present land use/land cover changes were generated from Landsat satellite imagery of 1986 and 2014 ETM (Enhanced Thematic Mapper) at 30 m spatial resolution for both satellite imageries. Field observations, interviews, and discussion with the land users were also employed to substantiate the information.

3.2.6. Estimation of livestock nutrient requirement

The study sample HHs livestock population was converted to tropical livestock unit (TLU). The animal specific TLU conversion factors used for ox/bull, cow, heifer, steer, calf, sheep, horse and donkey were 1.1, 0.8, 0.5, 0.6, 0.2, 0.1, 0.8 and 0.5, respectively as recommended by (Jahnke, 1982; Gryseels, 1988) (Appendix Table 3). The daily DM

demand for the standard TLU of 250 kg at 2.5% of the body weight, which is equivalent to 6.25 per day or 2280 kg per year suggested by (Jahnke, 1982) was used. The ME and DCP maintenance requirement for the livestock were estimated according to the daily average recommendations suggested by Kears (1982) (Appendix Table 4).

3.2.7. Estimation of enteric methane emission

Enteric CH₄ emission estimation requires definitions of the livestock categories such as species, herd structure and existing population in the study area. Hence, cattle divided into growing and mature type based on average live body weight of 200 kg and 280 kg, respectively, sheep into (\leq 1 year and $>$ 1 year) and equines into (horse and donkey). The separation was done in line with the CDR (2011) and IPCC (2006) recommendations which has stated as “it is good practice to classify existing livestock population into sub-categories according to weight, age, production type and sex”. With respect to animal productivity, the local cattle were used for more than one purpose (milk, meat and draught). The energy used for draught was estimated using 8 hours heavy work per day (IPCC, 2006) while emission factors were developed according to the dual purpose cattle of the developing countries and country specific previous research reports (CDR, 2011).

Emission from enteric fermentation of the ruminant animals (kg CH₄ per head/year) is a function of feed digestibility (i.e. the percent of GE intake that is metabolized) (Opio *et al.*, 2013). An enteric CH₄ conversion factor: Y_m (percent of GE converted to CH₄) was used to calculate CH₄ emission factors (EF) from enteric fermentation for ruminants. The enteric CH₄ EFs for horse and donkey 18 and 10 (kg CH₄ per head/year), respectively were adopted from Tier 1 of the developing countries suggested by IPCC (2006). The Tier 2 approach was applied to calculate the enteric CH₄ emissions due to sensitivity to the diet composition and relative importance of enteric CH₄ to the total GHG emissions from cattle and sheep. Hence, CH₄ EF was estimated based on IPCC (2006), and Appendix Table 19 and 20:

$$EF = \frac{GE * \left(\frac{Y_m}{100}\right) * 365}{55.65} \dots\dots\dots (1)$$

Where: EF = emission factor (kg CH₄ head⁻¹year⁻¹),

GE = gross energy requirement (MJ head⁻¹day⁻¹),

Y_m = methane conversion factor (% of GE in the feed converted to CH₄) and

The factor 55.65 (MJ/kg CH₄) = the energy content of CH₄.

In order to calculate the emissions, first need to the value the gross energy (GE) requirement using equation 2 below and (Appendix Table 19, 20):

$$GE = \left[\frac{\left(\frac{NE_m + NE_a + NE_l + NE_w + NE_p}{REM} \right) + \frac{NE_g}{REG}}{\frac{DE\%}{100}} \right] \dots\dots\dots (2)$$

GE = gross energy (MJ/day),

NE_m = net energy required by the animal for maintenance (MJ/day),

NE_a = net energy for animal activity (MJ/day),

NE_g = net energy needed for growth (MJ/day),

NE_l = net energy for lactation (MJ/day),

NE_{work} = net energy for work (MJ/day),

NE_p = net energy required for pregnancy (MJ/day),

REM = ratio of net energy available in a diet for maintenance to digestible energy consumed,

REG = ratio of net energy available for growth in a diet to digestible energy consumed,

DE% = digestible energy expressed as a percentage of gross energy.

After the values for GE requirement in the equation (2) calculated for each animal category, then values were substituted in the equation (1) above.

Table 3. The formulae used to estimate different forms of net energy used by the animal

S.N.	Type of energy required	Model used to estimate the required energy
2.1	Net energy for maintenance	$NE_m = C_{f_i} * (\text{weight})^{0.75}$
2.2	Net energy for activity	$NE_a = C_a * NE_m$
2.3	Net energy for growth	$NE_g = 22.02 * \left(\frac{BW}{C+MW}\right)^{0.75} * WG^{1.097}$
2.4	Net energy for work	$NE_w = 0.1 * NE_m * \text{working hours}$
2.5	Net energy for pregnancy	$NE_p = C_{\text{pregnancy}} * NE_m$
2.6	Sheep net energy of lactation	$NE_l = \text{milk} * EV$ (EV= 4.6MJ/kg)
2.7	REM	$REM = [1.123 - (4.092 * 10^{-3} * DE\%) + (1.126 * 10^{-5} * (DE\%))]$
2.8	REG	$REG = [1.164 - (5.160 * 10^{-3} * DE\%) + (1.308 * 10^{-5} * (DE\%))]$

REM=ratio of net energy available in a diet for maintenance to digestible energy consumed; DE%=digestible energy expressed as a percentage of gross energy; REG=ratio of net energy available for growth in a diet to digestible energy consumed; BW=the average live body weight of the animals in the population (kg); MW=the mature live body weight of an adult female in moderate body condition (kg); WG=the average daily weight gains of the animals in the population (kg day⁻¹)

Source: IPCC (2006)

3.2.8. Estimation of manure methane emission

In the developed world, substantial amount of CH₄ emissions from manure management associated with confined animal management operations where manure managed in liquid-based systems. However, in the study area there was no confined manure handling practices, since the livestock production system is more of extensive grazing. Therefore, the Tier 1 default values of the livestock grazed on the roughage feeds from Tropical Africa with annual temperature range of the environment (15-25 °C) and feed digestibility of 45-55% were used to estimate CH₄ emission factors of manure from the existing livestock. The default EF values for cattle, sheep, horse and donkey were 1, 0.15, 1.64 and 0.9, respectively (IPCC, 2006) and indicated in Appendix Table 16.

Therefore, based on the expressions above, the total annual CH₄ emissions from enteric fermentation and manure management of the existing livestock were estimated according to IPCC (2006):

$$\text{CH}_4 \text{ (kg/head/year)} = \text{EF} * \text{N}_t \dots\dots\dots (3)$$

Where: CH₄ = methane emission from defined livestock type,

EF = emission factor for the defined livestock population, kg CH₄ head⁻¹year⁻¹,

N_t = the number of head of the livestock species/category under consideration, and t is type of the livestock species or category.

3.2.9. Data analysis

The data were analyzed using Statistical Packages for Social Sciences (SPSS) software packages version 20.0 (Morgan *et al.*, 2004). The data which included livestock management: labour distribution, livestock housing, manure handling practice, livestock water sources and availability, livestock disease prevalence and veterinary service, productive performance, climate change perceptions, land use change and climate change effects were analyzed using descriptive statistics (means and frequencies), Chi-square test employed to compare the relationships (Pearson Chi-square when the expected counts in 80% of the cells greater than 5, and Fisher’s Exact Test for the expected counts in 20% of the cells less than 5). To compare the differences between the wealth group household characteristics, landholding, livestock holding, area under different land use types, annual feed DM yield, nutrient balance and the estimated livestock emissions: one-way analysis of variance (ANOVA) was used.

The One-way ANOVA model used was:

$$Y_{ij} = \mu_i + W_i + e_{ij}$$

Where:

Y_{ij} is the jth observation in the ith wealth group;

μ_i is the common effect for the whole wealth group,

W_i is the effect of the ith wealth group and

e_{ij} is the random error associated with the j^{th} observation in the i^{th} wealth groups assumed to be normally and independently distributed.

The tests were done at 95% level of confidence ($\alpha = 0.05$) and Turkey's' HSD mean comparison procedure was used to test mean differences.

The Indices (weighted averages) were used to obtain the aggregate rank of the considered variables or parameters. An index was calculated to provide overall rank of the variables by developing rank index formula based on the method used by Musa *et al.* (2006).

$$\text{Rank Index} = \frac{[R_n * C_1 + R_{n-1} * C_2 + \dots + R_1 * C_n]}{\sum R_n * C_1 + R_{n-1} * C_2 + \dots + R_1 * C_n}$$

Where,

R_n = value of the least ranks of value of variable under consideration (if the least rank is 5^{th} then $R_n = 5$, $R_{n-1} = 4$. . . $R_1 = 1$),

C_n = counted value of the least ranked level (the count of the 5^{th} rank = C_n , and the count of the 1^{st} rank = C_1),

$\sum R_n * C_1 + R_{n-1} * C_2 + \dots + R_1 * C_n$ = grand total of waited summations of each variable.

4. RESULT

4.1. Household Characteristics and Resource Holding

4.1.1. Demographic characteristics of the households

Table 4 presents the demographic characteristics of the study area sample units. The mean age of respondents, number of productive age and farm experience were significantly ($P < 0.05$) higher for the better and medium compared to the low wealth groups. Total family size per HH was also greater ($P < 0.01$) for the better wealth HHs than the other groups. Household family size levels showed a significant ($P < 0.05$) relationship with the wealth status of the households. But, there was no association between education levels attended by the wealth groups (Table 5). Here, education independently addressed to wealth groups and the majority of the respondents attended a primary education as compared to other levels.

Table 4. Wealth group respondent household characteristics of the study area

Description of variables	Wealth group			Overall mean(156)	P value
	Better (40)	Medium(85)	Low (31)		
	Mean (SE)	Mean (SE)	Mean (SE)	Mean (SE)	
Respondent age (years)	51.83(1.7) ^a	47.79(1.0) ^{ab}	46.13(2.1) ^b	48.49(0.8)	0.047
Household total family size	7.48(0.3) ^a	6.41(0.2) ^b	5.94(0.5) ^b	6.59(0.2)	0.004
Productive age (15-64) (years)	4.35(0.3) ^a	3.71(0.2) ^{ab}	3.23(0.3) ^b	3.78(0.1)	0.013
Unproductive (<15&>64) (years)	3.13(0.2)	2.71(0.2)	2.71(0.3)	2.81(0.1)	0.330
Farm experience (years)	28.03(1.5) ^a	23.51(0.9) ^{ab}	22.09(1.7) ^b	24.56(0.7)	0.026

abc= Means within the same row with different superscripts are significantly different

Table 5. Households' family size and education level in the mixed farming areas of Bale highlands

Description of variables	Wealth group			Overall mean (156)	X ² value	P value
	Better (40)	Medium (85)	Low (31)			
Level of family size					11.118	0.020
≤5 family member	6(15.0)	25(29.4)	15(48.4)	46(29.5)		
6-9 family member	29(72.5)	55(64.7)	13(41.9)	97(62.2)		
>9 family member	5(12.5)	5(5.9)	3(9.7)	13(8.3)		
Respondent education level					8.228	0.224
Illiterate	4(10.0)	5(5.9)	7(22.6)	16(10.3)		
Read and write	12(30.0)	23(27.1)	5(15.1)	40(25.6)		
Primary (1-6)	16(40.0)	36(42.4)	11(35.5)	63(40.4)		
Secondary and above	8(20.0)	21(24.7)	8(25.8)	37(23.7)		

Numbers outside and inside parenthesis are observed counts and percent, respectively

4.1.2. Household resource holding and utilization

Table 6 presents different types of land owned and utilization pattern by the different wealth group HHs in the study area. The average land allotted for crop cultivation and total land holding were significantly ($P < 0.001$) higher for the better wealth group while area of land for grazing and forage crops production significantly different ($P < 0.05$) between better and low groups. The study revealed that major portion of the land: 81.47%, 84.51% and 89.04% were allocated for crop cultivation by the better, medium and low wealth groups, respectively showing that how much the land was utilized for cultivation compared to grazing.

In terms of cropping pattern, the average land allotted to different crops and total cropland holding were significantly different ($P < 0.05$) and ($P < 0.001$), respectively, between the wealth groups while no significant difference ($P < 0.05$) between the groups for teff and oilseed crops. Average land allotted to wheat crop was the highest (60.06%)

followed by barley (25.88%). Though, few crops were dominant, cropping patterns depend on the prevailing weather conditions of the cropping season.

Table 6. Household land holding, land use types and cropping pattern (ha HH⁻¹) in the mixed farming areas of Bale highlands

Description of variables	Wealth group			Overall mean(156) Mean(SE)	P value
	Better (40) Mean(SE)	Medium(85) Mean(SE)	Low (31) Mean(SE)		
	Land use type				
Grazing land	0.59(0.08) ^a	0.32(0.04) ^{ab}	0.10(0.02) ^b	0.34(0.03)	0.020
Cropland	4.17(0.12) ^a	3.09(0.08) ^b	1.89(0.09) ^c	3.13(0.08)	0.000
Fallow land	0.27(0.05)	0.23(0.03)	0.13(0.03)	0.22(0.02)	0.186
Forage crops land	0.12(0.03) ^a	0.04(0.01) ^b	0.01(0.0) ^b	0.06(0.01)	0.047
Rented in/out cropland	0.14(0.08)	0.13(0.05)	0.06(0.04)	0.12(0.03)	0.703
Total land holding	5.29(0.19) ^a	3.81(0.29) ^b	2.19(0.11) ^c	3.87(0.19)	0.000
Total cropland (%)	81.47	84.51	89.04	83.98	
Cropping pattern					
Wheat	2.33(0.16) ^a	1.85(0.09) ^b	1.36(0.11) ^c	1.88(0.07)	0.015
Barley	1.07(0.07) ^a	0.80(0.05) ^{ab}	0.51(0.06) ^b	0.81(0.04)	0.013
Emmer wheat	0.32(0.05) ^a	0.26(0.03) ^{ab}	0.17(0.04) ^b	0.26(0.02)	0.039
Teff	0.13(0.03)	0.15(0.03)	0.0(0.0)	0.14(0.02)	0.679
Pulses	0.48(0.05) ^a	0.36(0.03) ^{ab}	0.18(0.04) ^b	0.36(0.02)	0.004
Oilseed crops	0.18(0.04)	0.11(0.03)	0.02(0.01)	0.11(0.02)	0.401

abc= means within the same row with different superscripts are significantly different

Table 7 depicts mean livestock categories and herd structures in TLU of the HHs. The mean total cattle, cow, ox and heifer were significantly ($P < 0.001$) different between the wealth groups. The mean steer and sheep TLU holding was significantly ($P < 0.01$) different between better and the other groups, while equine was significantly ($P < 0.001$) higher for the better wealth HHs. From the total livestock owned by the wealth groups, cattle accounted for 80 to 90% at HH level. Within the cattle herd structure, the oxen (48.75%) were the largest number followed by cows (31.03%) across the wealth groups.

Table 7. Household level livestock category and herd structure (TLU) in the mixed farming areas of Bale highlands

Livestock category	Herd structure	Wealth group			Overall mean (156) Mean(SE)	P value
		Better (40) Mean(SE)	Medium(85) Mean(SE)	Low (31) Mean(SE)		
Cattle	Total	13.99(0.44) ^a	7.59(0.27) ^b	3.48(0.19) ^c	8.41(0.35)	0.000
	Cow	4.78(0.1) ^a	2.22(0.11) ^b	0.88(0.10) ^c	2.61(0.13)	0.000
	Ox	6.23(0.23) ^a	3.88(0.13) ^b	1.95(0.09) ^c	4.10(0.15)	0.000
	Heifer	1.34(0.12) ^a	0.69(0.05) ^b	0.21(0.06) ^c	0.76(0.05)	0.000
	Steer	1.38(0.16) ^a	0.43(0.06) ^b	0.15(0.06) ^b	0.62(0.06)	0.007
	Calf	0.59(0.04) ^a	0.32(0.02) ^{ab}	0.14(0.02) ^b	0.36(0.02)	0.021
Sheep	Total	0.53(0.08) ^a	0.28(0.04) ^{ab}	0.14(0.04) ^b	0.31(0.03)	0.010
	Mature	0.26(0.04) ^a	0.15(0.03) ^{ab}	0.07(0.02) ^b	0.16(0.02)	0.031
	Yearling	0.25(0.04) ^a	0.15(0.03) ^{ab}	0.06(0.02) ^b	0.16(0.02)	0.022
Equine	Total	2.12(0.10) ^a	0.98(0.06) ^b	0.51(0.08) ^c	1.18(0.06)	0.001
	Horse	0.98(0.06) ^a	0.32(0.04) ^b	0.15(0.06) ^b	0.46(0.04)	0.046
	Donkey	1.22(0.05) ^a	0.65(0.04) ^b	0.30(0.06) ^b	0.73(0.04)	0.016
Cattle (%)		81.86	85.96	89.92	84.25	

abc= means within the same row with different superscripts are significantly different

4.2. Livestock Husbandry Practices

4.2.1. Labour distribution between livestock management practices

Proportions of the family members who participated in the livestock husbandry activities of the respondent HHs in the study area are shown in Figure 7. The result showed that livestock herding activities relied on the family members of different age, gender and hired personnel labour at different extent. Herding, watering and tethering activities were more managed by male, boys and hired personnel. The contribution of hired labour was more pronounced in herding, watering, backyard feeding and tethering activities.

Milking and barn cleaning were exclusively the activities of females and girls for all the respondents while breeding was the responsibility of males. The numbers from the figure indicated that males and females were participated in majority of the activities compared to the other family members.

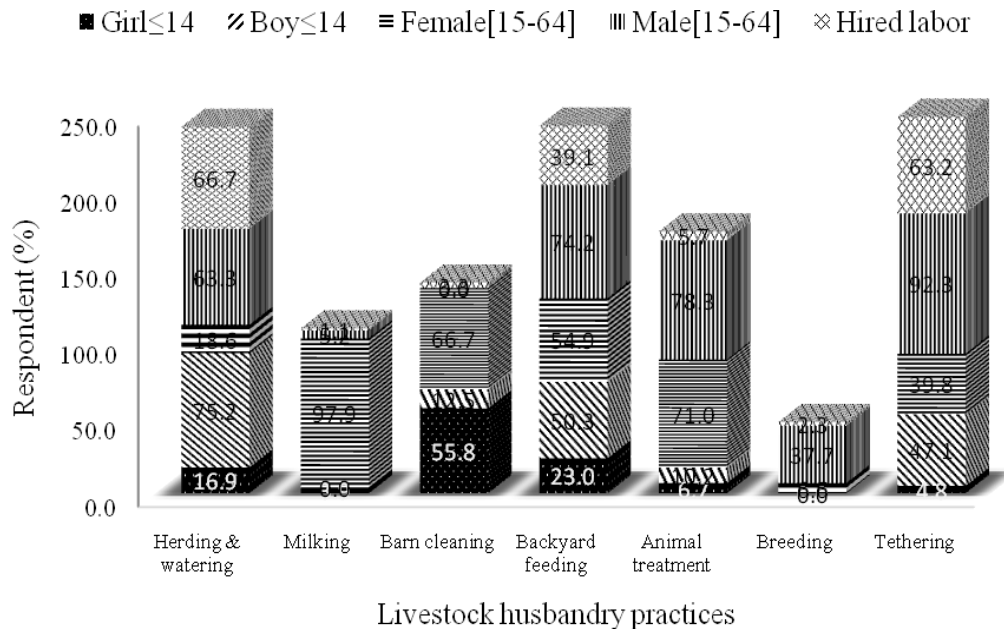


Figure 7. Household families’ livestock management labour distribution in the mixed farming areas of Bale highlands

4.2.2. Livestock housing system and manure management practices

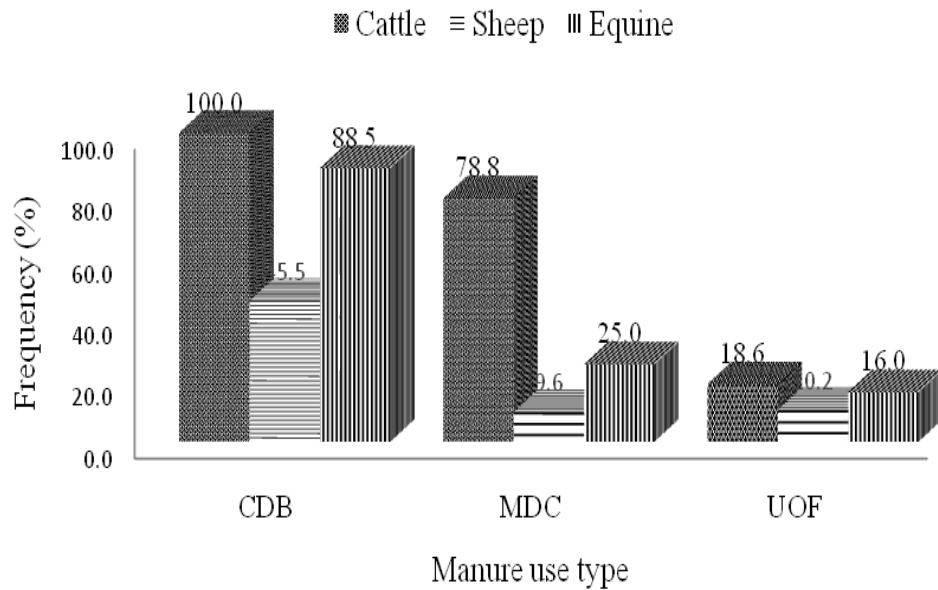
Type of houses used for different herd structures of livestock in the study area are shown in Table 8. Most commonly, livestock housing was practiced based on species type, sex and age of the animal. Calves housed either in the family house attachments or in the separate houses were significantly ($P < 0.001$) related to the wealth status of the HHs. Similarly, equines were not reported sheltered in separate houses. However, cattle (weaned and above) were reported exclusively housed in Kraals across the wealth group respondents.

Table 8. Livestock housing type reported in the mixed farming area of Bale highland (%)

Variables	Wealth group			Overall mean	X ² value	P value
	Better (40)	Medium (85)	Low (31)			
Cattle (weaned and above)						
Kraal	40(100)	85(100)	31(100)	156(100)		
Calf					20.316	0.000
House attachment/partitions	15(37.5)	48(56.5)	28(90.3)	91(58.3)		
Separate house/shed	25(62.5)	37(43.5)	3(9.7)	65(41.7)		
Sheep					1.859	0.426
House attachment/partitions	10(25.0)	17(20.0)	6(19.4)	33(21.2)		
Separate house/shed	15(37.5)	20(23.5)	3(9.7)	38(24.4)		
Equines					2.731	0.261
Kraal	18(45.0)	47(55.3)	20(64.5)	85(54.5)		
House attachment/partitions	22(55.5)	38(44.7)	11(35.5)	71(45.5)		

Numbers outside and inside parenthesis are observed counts and percent, respectively

Homestead manure management: collection from the place where the animal drops it (more often Kraal), family house and garden during night can be used either for dung cake (fuel) and/or organic fertilizer (Figure 8; Appendix Figure 3), and other minor uses which are not mentioned here. Numbers depicted that cattle manure collected 100% while that of equine was 88.5%. However, there were differences in that of manure made into dung cake from cattle (78.8%) and equine (25.0%). Whereas, manure used as farm yard fertilizer from all stocks looks similar, where more attention given to the use of manure as fuel (Appendix Table 9).



CDB = collected on daily basis; MDC= made into dung cake; UOF = use as organic fertilizer

Figure 8. Manure collection and utilization type at household level in the mixed farming areas of Bale highlands

4.2.3. Disease prevalence and health management

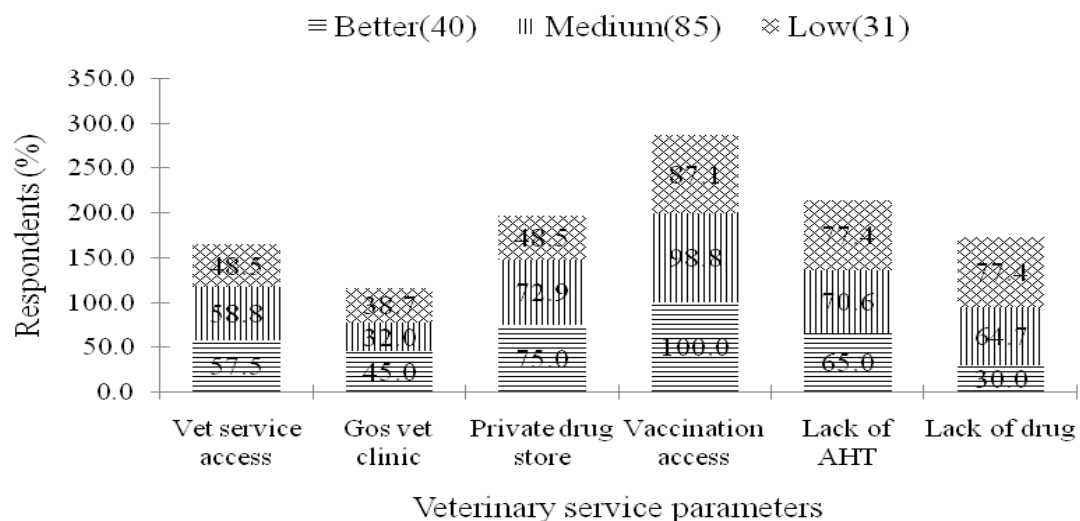
Table 9 shows the common livestock diseases in the study area. The diseases were categorized into viral (Foot and Mouth Disease, Rabies and African Horse Sickness), bacterial (Anthrax, Blackleg, Brucellosis, Pastuerelosis, Mastitis, CBPP and CCPP) and protozoan or fungal (Lymphangitis) and parasites (endo and exo) based on local name given by the farmers, symptoms seen and veterinary professional suggestions. All respondents of the wealth groups reported viral, bacterial and parasitic diseases affect cattle despite the differences in wealth across the groups while sheep were affected at different level across the HHs. Protozoan and/or fungal diseases were not reported by the farmers affecting both cattle and sheep. But there was a variation due to the effect of these diseases on equines.

Table 9. Households' observation of the common diseases affecting livestock as per disease categories of veterinarians in the mixed farming areas of Bale highlands (%)

Livestock category	Common prevalent diseases	Wealth group			Overall mean (156)
		Better (40)	Medium (85)	Low (31)	
Sheep	Viral	26 (65.0)	37 (43.53)	9 (29.03)	72(46.15)
	Bacterial	26 (65.0)	37 (43.53)	9 (29.03)	72(46.15)
	Parasite	26 (65.0)	37 (43.53)	9 (29.03)	72(46.15)
Equines	Viral	39 (97.5)	81 (95.29)	22 (70.97)	142(91.03)
	Bacterial	39 (97.5)	81 (95.29)	22 (70.97)	142(91.03)
	Protozoan/Fungal	31 (77.5)	36 (43.35)	8 (25.81)	75(48.07)
	Parasite	39 (97.5)	81 (95.29)	22 (70.97)	142(91.03)

Numbers outside and inside parenthesis are observed counts and percent, respectively

The study HHs' access to veterinary services and supplies are indicated in Figure 9. All the three wealth groups had access to vaccination services when there was disease outbreak in the area. When their animals become sick, more accessible treatments they used were private veterinary drug stores than government clinics due to scarcity of government veterinary clinics in number or poor service delivery.



GOs= government organizations; AHT= animal health technician

Figure 9. Respondents' access and use of livestock health supplies in the mixed farming areas of Bale highlands (%)

4.2.4. Livestock drinking water sources and utilization

Table 10 illustrates the major sources of the livestock drinking water in the dry and wet seasons in the study area. River and spring were the major sources used by the livestock both in dry and wet seasons while hand dug well was prominent in dry season. The watering frequencies of the livestock in the study area are presented in Table 11. In the current study, watering frequencies were different between seasons that accounted to the permanent water sources location (proximity) and availability of the hand dug wells. During the dry season livestock accessed drinking water once per day or at two-day interval. Whereas, during wet season, once a day and free access watering were used frequently by the farmers.

Table 10. Households' responses about the livestock drinking water sources during dry and wet season in the mixed farming areas of Bale highlands (%)

	Dry season				Wet season			
	Wealth group			Overall (156)	Wealth group			Overall (156)
	Better (40)	Medium (85)	Low (31)		Better (40)	Medium (85)	Low (31)	
River	32 (80.0)	69 (81.2)	22 (71.0)	123 (78.8)	38 (95.0)	84 (98.8)	30 (96.8)	152 (97.4)
Pond	11 (27.7)	12 (14.1)	6 (19.4)	29 (18.6)	15 (37.5)	30 (35.3)	8 (25.8)	53 (34.0)
Hand dug well	18 (45.0)	50 (58.6)	14 (45.2)	82 (52.6)	3 (7.5)	9 (10.6)	1 (3.2)	13 (8.3)
Spring	19 (47.5)	36 (42.4)	16 (51.6)	71 (45.5)	22 (55.0)	37 (43.5)	10 (32.3)	69 (44.2)
Tap water	14 (35.0)	31 (36.5)	5 (16.1)	50 (32.1)	11 (27.5)	14 (16.5)	4 (12.9)	29 (18.6)

Numbers outside and inside parenthesis are observed counts and percent, respectively

Table 11. Respondents' responses about the livestock watering frequency across the seasons in the mixed farming areas of Bale highlands

Wealth group	Watering frequency	Dry season			Wet season		
		Cattle	Sheep	Equine	Cattle	Sheep	Equine
Better (40)	Freely available	4 (10.0)	2 (7.7)	6 (15.4)	11 (27.5)	7 (26.9)	11 (28.2)
	Once a day	30 (75.0)	19 (73.1)	31 (79.5)	31 (77.5)	20 (76.9)	30 (76.9)
	One day interval	11(27.5)	8 (30.8)	6 (15.4)	1 (2.5)	0 (0.0)	0 (0.0)
Medium (85)	Freely available	6 (7.1)	2 (5.4)	6 (7.4)	13 (15.3)	10 (26.3)	14 (17.3)
	Once a day	67 (78.8)	29 (79.4)	72 (88.9)	77 (90.6)	33 (86.8)	73 (90.1)
	One day interval	15 (17.6)	7 (18.9)	7 (8.6)	0 (0.0)	0 (0.0)	0 (0.0)
Low (31)	Freely available	2 (6.5)	0 (0.0)	1 (4.8)	6 (19.4)	2 (22.2)	3 (14.3)
	Once a day	28 (90.3)	8 (88.9)	19 (90.5)	26 (83.9)	7 (77.8)	18 (85.7)
	One day interval	2 (6.5)	1(11.1)	2 (9.5)	0 (0.0)	1 (11.1)	0 (0.0)

Numbers outside and inside parenthesis are observed counts and percent, respectively

4.2.5. Productive Performance of Livestock

Table 12 presents productive performance of cows at HH level under the existing management practices. The overall, average daily milk yield (ADMY) was reported ≤ 0.5 liter by 77.0% of the HHs while the small percent (69.2%) responded from better group. More numbers of the respondents from the three wealth groups were reported that lactation length (≤ 6 months) and days open (12-24 months) and suggested that their cows performed poor. The calving interval of cows was also an extension of days open with additional 9 months after conception and most of the farmers (67.3%) reported it takes 24 to 36 months.

Table 12. Household level observed productive performance of cow in the mixed farming areas of Bale highlands (%)

Variables	Description	Wealth group			Overall mean (156)
		Better (40)	Medium (85)	Low (31)	
ADMY	≤ 0.5 liters	27(69.2)	66(78.6)	21(84.0)	114(77.0)
	0.5 to 1.0 liters	12(30.8)	18(21.4)	4(16.0)	34(23.0)
Lactation length	≤ 6 months	25(64.1)	54(64.3)	19(76.6)	98(66.2)
	6 to 12 months	14(35.9)	30(35.7)	6 (24.0)	50(33.8)
Days open	≤ 12 months	8(20.5)	8(9.4)	1(3.2)	17(11.5)
	12 to 24 months	31(79.5)	76 (90.6)	24(96.8)	131(88.5)
Calving interval	≤ 24 months	18(46.2)	17(20.2)	8(32.0)	43(27.6)
	24 to 36 months	21(53.8)	67(79.8)	17(68.0)	105(67.3)

Numbers outside and inside parenthesis are observed counts and percent, respectively; ADMY= average daily milk yield;

4.3. Major Livestock Production Constraints

The major constraints those predominantly influenced the livestock production of the study area were ranked and indicated in Table 13. Among the potential constraints, feed and grazing land shortage was prominent (ranked 1st). Low output of animals, disease prevalence, water scarcity and unreliable weather pattern were taking the 3rd to 6th ranks

differently by different wealth groups (Table 13; Appendix Table 17). The 2nd rank goes to labour scarcity for better and medium groups, while both disease prevalence and labour scarcity were ranked 2nd by the low wealth groups.

Table 13. Households' ranking major livestock production constraints in the mixed farming areas of Bale highlands

Major production constraints	Wealth group						Overall mean	
	Better (40)		Medium (85)		Low (31)		N	RI
	N	RI*	N	RI	N	RI		
Feed scarcity	56	0.407	126	0.431	52	0.496	78	0.445
Low output	34	0.126	76	0.129	26	0.123	136	0.126
Disease prevalence	37	0.139	72	0.129	26	0.139	135	0.136
Labour scarcity	33	0.143	73	0.149	28	0.117	134	0.136
Water scarcity	13	0.064	22	0.048	8	0.044	43	0.052
Unreliable weather	31	0.122	69	0.114	25	0.081	125	0.106

N=respondent number; RI=rank indices; * =first rank starts with the highest value indices

4.4. Livestock Feed Resources, Nutrient Contents and Feed Balance

4.4.1. Major feed types and their biomass yield

Feed resources potential biomass yield from the land use types are summarized and indicated in Table 14. Private grazing land and cereal straw DM yield were highly significant ($P < 0.001$) for the better wealth HHs while crop aftermath ($P < 0.001$) and HMCs DM yield ($P < 0.05$) significantly different between better and other wealth HH groups. Fallow land and pulse straw DM yield were higher ($P < 0.01$) and ($P < 0.05$) for better compared to low groups. Cereal straw takes the major share of annual DM yield, while the DM contributions of forage crops and HMC to the HH feed supply were very low compared to the poor quality roughage feeds.

Table 14. Households' major feed resources and annual dry matter yield (tons) in the mixed farming areas of Bale highlands

Feed resource type	Wealth group			Overall mean (156) Mean (SE)	P value	Total DM	% DM
	Better (40)	Medium (85)	Low (31)				
	Mean (SE)	Mean (SE)	Mean (SE)				
Private grazing*	2.29(0.31) ^a	1.13(0.12) ^b	0.29(0.07) ^c	1.26(0.12)	0.000		
Communal grazing*	0.14(0.01)	0.14(0.01)	0.15(0.01)	0.14(0.00)	0.868	5.61	12.35
Fallow land*	0.72(0.14) ^a	0.49(0.06) ^{ab}	0.26(0.7) ^b	0.50(0.05)	0.008		
Crop aftermath	2.71(0.33) ^a	1.90(0.06) ^b	1.30(0.12) ^b	1.99(0.10)	0.001	5.91	13.01
Cereals straws	13.43(0.88) ^a	10.37(0.45) ^b	6.51(0.38) ^c	10.39(0.39)	0.001	30.31	66.70
Pulse straws	0.89(0.10) ^a	0.74(0.07) ^{ab}	0.44(0.10) ^b	0.72(0.05)	0.012	2.07	4.56
Forage crops	0.96(0.22) ^a	0.34(0.08) ^b	0.02(0.00) ^b	0.44(0.08)	0.016	1.32	2.90
HMC	0.16(0.02) ^a	0.05(0.00) ^b	0.01(0.00) ^b	0.07(0.01)	0.042	0.22	0.48
Total DM	21.30	15.16	8.98	15.15		45.44	100.0

abc= Means within the same row with different superscripts are significantly different; HMC= homemade concentrates, DM= dry matter; *= fragile small area of lands

Overall, the contribution of crop straw of the wealth groups was influenced primarily by the crops grown and the prevailed cropping intensity. Collectively, straw (cereals and pulses), crop aftermath and mixed native pasture DM yields contributed 96.89% to the total household annual feed supply.

4.4.2. Feeding calendar and strategies

The months of feed resource availability and utilization pattern with respect to rain fall trend is indicated in Figure 10. For each study wealth groups, majority of the HHs used natural grazing and crop straws in more months of the year while crop aftermath and accessed supplements used for few months upon their availability (Figure 10). In the course of feeding calendar, farmers with the problem of herding labour practiced tethering which is recently emerged type of feeding strategy in the area. The distance (bar height) between stacked column trend lines across the months indicated level of feed availability and differences between the wealth group HHs. This was clearly observed from June to November (Figure 10).

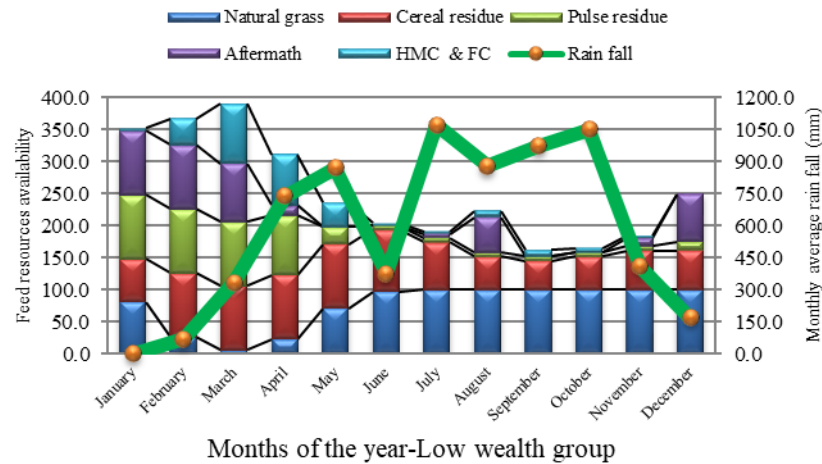
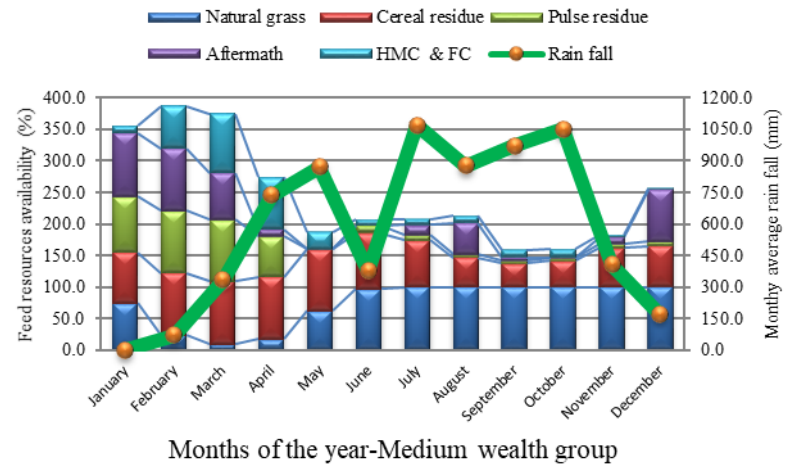
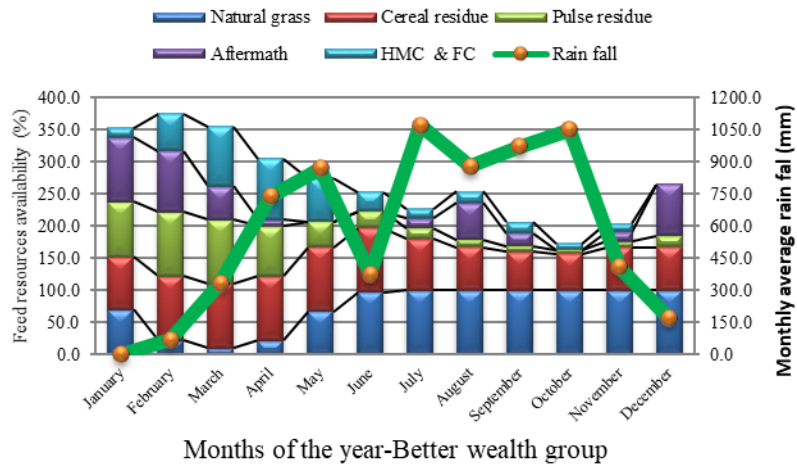


Figure 10. Households' year round livestock feeding calendar along the rainfall pattern in the mixed farming areas of Bale highlands

4.4.3. Grazing land availability and utilization

The land use/land cover change trend maps indicated cultivation were dominant (Figure 11) and resulted in grazing land shrinkage in the area. Grazing and forest lands were the major land use areas converted to cultivation during the indicated years. This observed land use change depicted cropland increased by (40.52%) while forest and grazing lands diminished by (56.95%) and (99.22%), respectively (Appendix Table 7). The change showed insignificant grazing lands were left currently even if the change detection tool not considered fragmented small private grazing areas (less than 30 m spatial resolution).

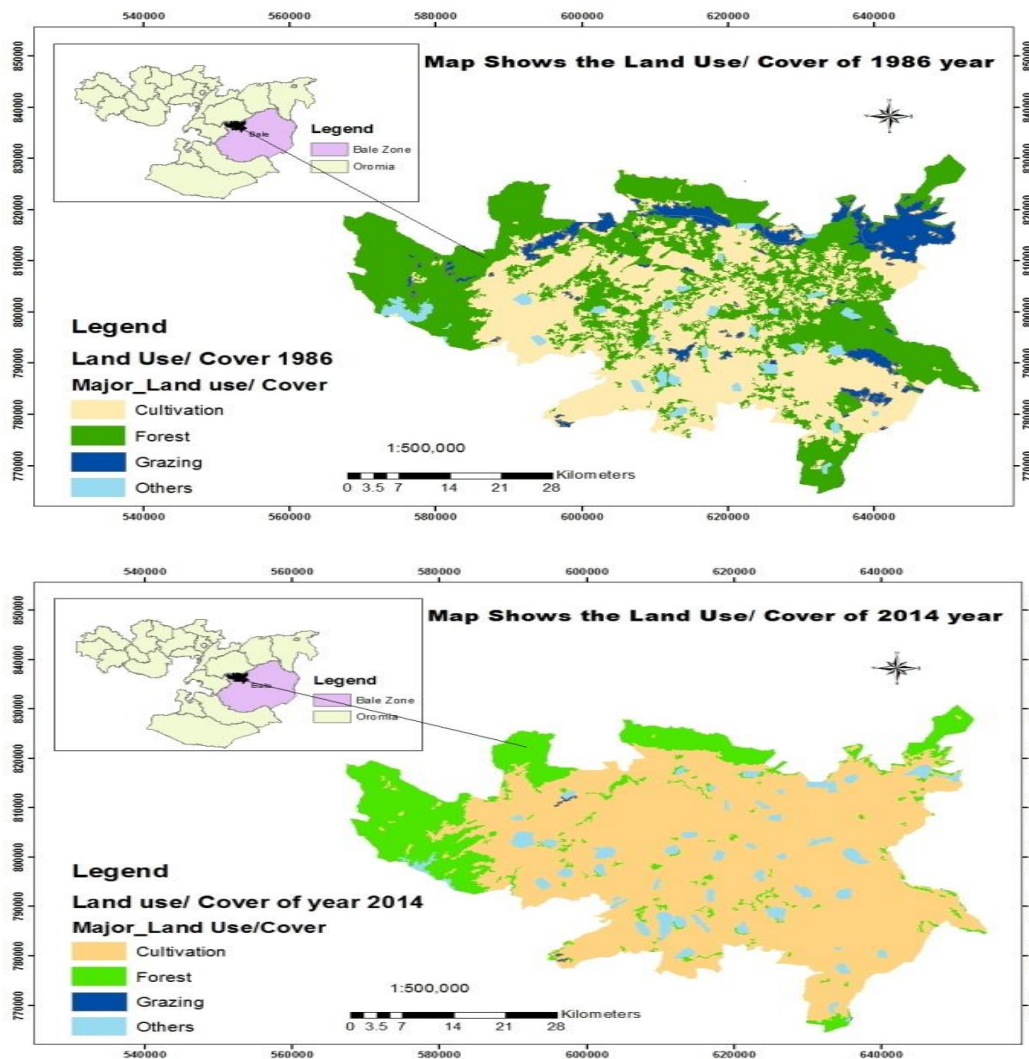


Figure 11. Land use/land cover change in the mixed farming area districts of Bale highlands between 1986 and 2014

Table 15 presents natural pasture grazing land utilization ranked by the wealth group HHs. The wealth group HHs ranked private grazing; marginal, communal, roadside and fallow land grazing differently based on used values they obtained from the lands. The grazing lands which have been relatively better source of green forages currently exist as a fragmented small sized private and fallow land. The available communal grazing lands were degraded due to overstocking and their inherent poor soil fertility. From the average total land of the HH, small portion of the land was allocated for grazing purpose and the feeds sourced were poor both in quality and DM yield. The differences in the rank of the lands for the wealth groups were attributed to the extent of the lands used by the HHs.

Table 15. Households' fragile grazing lands utilization ranks in the mixed farming areas of Bale highlands

Mixed natural pasture grazing type	Wealth group						Overall mean	
	Better (40)		Medium (85)		Low (31)		(156)	
	N	RI*	N	RI	N	RI	N	RI
Communal grassland	40	0.216	79	0.221	28	0.220	147	0.219
Private grassland	31	0.246	54	0.218	14	0.159	99	0.208
Roadside grazing	35	0.180	51	0.122	29	0.230	115	0.177
Fallow land	21	0.125	44	0.172	14	0.137	79	0.145
Marginal land	40	0.234	85	0.267	31	0.254	156	0.252

N=respondent number; RI=rank indices; *=first rank starts with the highest value indices

4.4.4. Nutritional quality of major feed resources

Chemical composition and nutritive value of the major livestock feeds in the study area are shown in Table 16. The DM content of all feeds across the wealth groups were exceeds 90%. The CP content of the mixed natural pasture, straws (barley and pulse) and emmer wheat straw showed some variations between the wealth groups. From straws: wheat and emmer wheat have the lowest CP compared to barley, teff and pulse (Table 16).

The relative low NDF content of mixed natural pasture from low wealth HHs might be linked to type of plants grown (species and maturity) and other prevailing factors. The NDF content of cereal straws and crop aftermath were high compared to pulse straw that categorized as medium quality roughages. Mean ADF values of the mixed natural pasture and wheat straw of the better wealth groups were lower compared to the other cereal straws and crop aftermath of the groups. The ADL content of roughage feeds ranges from 4.19% DM (teff straw) to 11.24% DM (crop aftermath) across the entire wealth HHs (Table 16). The IVDOMD from the mixed natural pasture was better than other roughage feeds (straws and crop aftermath) followed by the pulse straw across the wealth groups. The lower IVDOMD% was recorded for emmer wheat from medium wealth group, while the highest IVDOMD% was for barley straw from better wealth group that might be directly/indirectly associated with farm inputs and land preparation.

Table 16. Household level major feeds chemical composition in the mixed farming areas of Bale highlands

Wealth group	Feed type	DM%	%DM						
			OM	Ash	CP	NDF	ADF	ADL	IVDOMD
Better (40)	MNP	93.23	91.39	9.31	6.33	67.07	33.75	6.08	62.61
	Wheat S	92.43	91.55	8.45	2.91	76.88	39.36	5.81	50.17
	Barley S	92.45	91.81	8.18	3.45	74.55	46.02	6.13	54.68
	EWS	92.36	91.05	8.95	2.63	77.32	52.78	6.87	50.02
	Teff S	90.06	91.73	8.27	3.60	77.93	46.73	4.19	54.24
	Pulse S	90.69	90.21	9.46	5.75	53.93	42.55	8.58	57.01
	CA	94.62	90.88	9.12	3.77	79.85	56.34	11.24	40.36
	HMC	93.75	91.12	8.88	19.41	48.92	18.98	6.33	65.17
Medium (85)	MNP	92.82	90.48	9.52	5.33	65.92	39.30	5.33	58.29
	Wheat S	93.21	91.40	8.61	2.98	76.96	46.11	6.33	50.10
	Barley S	92.60	91.92	8.08	3.45	74.04	45.69	6.30	54.43
	EWS	92.32	91.75	8.25	2.69	76.95	52.49	6.82	49.92
	Teff S	90.05	91.95	8.05	3.31	76.48	49.14	4.74	53.26
	Pulse S	90.98	90.40	9.33	5.77	54.41	42.52	8.57	54.24
	CA	94.62	90.88	9.12	3.77	79.85	56.34	11.24	40.36
	HMC	94.74	91.44	7.02	19.11	49.54	19.83	6.51	64.93
Low (31)	MNP	93.17	92.47	8.87	6.63	58.88	37.33	6.51	59.82
	Wheat S	92.40	91.24	8.76	2.87	77.04	52.87	6.85	50.04
	Barley S	92.39	91.73	8.27	3.43	71.00	43.32	5.88	54.02
	EWS	92.37	90.86	9.14	2.67	77.02	52.68	6.81	49.98
	Pulse S	90.83	90.30	9.39	5.76	53.60	42.53	8.57	55.63
	CA	94.62	90.88	9.12	3.77	79.85	56.34	11.24	40.36
		HMC	94.77	90.92	8.22	18.83	49.92	19.97	6.66

MNP=mixed native pasture; EWS=emmer wheat straw; S=straw; CA=crop aftermath; HMC= homemade concentrate; DM=dry matter; OM=organic matter; CP=crude protein; NDF=neutral detergent fiber; ADF=acid detergent fiber; ADL=acid detergent lignin; IVDOMD=in vitro digestible organic matter in the dry matter

4.4.5. Nutrient availability and deficits

The estimated annual maintenance DM, ME and DCP requirement of the study HHs livestock are presented in Table 17. The total DM requirements for the livestock herded by the wealth groups were different based on the total number of animals owned and differences in the animal's requirement. The overall mean DM requirement at farm level was comparable to the medium HH animals' total requirement. The estimated ME requirements of the wealth groups varied due to their differences in herd categories owned and the type of products or services obtained from the animals which demanded different amount of energy. The highest ME (MJ) deficit (24.18%) belongs to the better wealth group while the medium and low wealth groups ME was the only excess nutrient. These difference accounted to the herd size belongs to the wealth groups and the energy concentration of the feed sources. To the other end, the low wealth HHs excess annual ME nutrient supply of the feeds (especially straws) was in question since wheat straws in the area claimed for poor palatability and intake.

The total DCP deficit of the better group was approximated to be doubled the requirement by the medium group HHs. This might be attributed to the relative larger TLU owned by the better groups. During feed scarcity, farmers move part of their herds to the other place in search of feed at some cost. Destocking and use of alternative feeds could also have mentioned as a means to cope up the feed scarcity and nutrient deficit. The deficit seen to the low wealth HHs appears to be compromised to fill the gap with some opportunistic and unconventional feeds when available as it needs only small amount of feeds.

Table 17. Estimated variability for household level maintenance dry matter, energy and digestible crude protein requirements for the livestock in the mixed farming areas of Bale highlands

Livestock category	Wealth group households									Overall mean (156)		
	Better (40)			Medium (85)			Low (31)			DM(ton)	ME(MJ)	DCP(g)
	DM(ton)	ME(MJ)	DCP(g)	DM(ton)	ME(MJ)	DCP(g)	DM(ton)	ME(MJ)	DCP(g)			
Cow	10.9	65043.0	498882.0	5.1	29703.0	227822.8	2.0	11490.9	88135.8	5.9	35123.2	269396.3
Ox/bull	14.2	68415.6	749047.2	8.9	42518.9	465517.0	4.5	21319.7	233417.9	9.4	44927.9	491891.9
Heifer	3.1	21623.0	231176.4	1.6	10771.9	115164.8	0.5	3564.2	38106.0	1.7	12118.4	129560.4
Steer	3.2	20284.9	217631.3	1.0	6491.2	69642.0	0.3	2344.0	25148.5	1.4	9195.8	98659.5
Calf	1.2	13997.7	155052.0	0.7	7686.9	85147.2	0.3	3368.9	37317.6	0.8	8446.1	93556.8
Sheep	1.2	8004.5	98659.5	0.6	4724.2	58228.5	0.3	2071.7	25535.4	0.7	5038.1	62097.5
Horse	2.2	12391.0	179759.6	0.7	29703.0	61381.3	0.3	1914.1	27767.7	1.1	5842.9	84764.7
Donkey	2.8	12671.7	163711.6	1.5	42518.9	90638.6	0.7	3317.5	42860.1	1.7	7722.7	99772.7
Requirement	38.8	222431.4	2293920.0	20.1	174118.0	1173542.0	8.9	49391.0	518289.0	22.7	128415.1	1329700.0
Available	21.3	168651.1	763408.6	15.2	181804.9	482522.3	8.9	66576.7	220398.3	15.2	117259.4	488776.4
Deficit	17.5	53780.3	1530511.4	4.9 (-)	7686.9	691019.7	0.0	17185.7	297890.7	7.5	11155.7	840923.6
	(-)	(-)	(-)		(+)	(-)		(+)	(-)	(-)	(-)	(-)
% deficit	45.1	24.2	66.7	24.4		58.9			57.5	33.0	8.7	63.2

DM=dry matter; ME=metabolizable energy; DCP=digestible crude protein - =deficit; + =excess

Table 18 presents mean comparison of aggregated feeds ME and DCP (content, available and deficit) and RFV index quantified at farm level for the wealth groups. The feeds ME and DCP content and RFV% were significantly ($P<0.001$) lower for the low wealth groups compared to the other groups HH. The nutrients (ME and DCP) availability and deficit were significantly ($P<0.001$) different between the wealth groups while ME from low wealth group was excess. Whereas, the DM availability and deficit was significantly ($P<0.001$) lower for the low group HHs compared to the others. The composite mean RFV was calculated from mixed natural pasture, cereals straw, pulse straw, crop aftermath, forage crops and HMC of the wealth groups.

Table 18. Wealth groups' major feeds mean DM, ME and DCP content, availability and deficit differences in the mixed farming areas of Bale highlands

Variables	Wealth group			Overall mean (156) Mean(SE)	P value
	Better (40) Mean(SE)	Medium (85) Mean(SE)	Low (31) Mean(SE)		
ME content (MJ)	8.24(0.00) ^a	8.07(0.00) ^a	7.12(0.03) ^b	7.92(0.03)	0.000
DCP content (g)	51.73(0.00) ^a	50.06(0.00) ^a	47.69(0.08) ^b	50.02(0.11)	0.000
RFV (%)	79.19(0.00) ^a	77.39(0.00) ^a	71.24(0.20) ^b	76.63(0.23)	0.000
DM available (ton)	21.30(0.00) ^a	15.20(0.00) ^b	8.90(0.18) ^c	15.20(0.29)	0.000
DM deficit (ton)	-17.50(0.00) ^a	-4.90(0.00) ^b	0.00(0.16) ^c	-7.50(0.50)	0.000
ME available (MJ)	168651.10(0.0) ^a	181804.90(0.0) ^b	66576.70(135.2) ^c	117259.40(217.4)	0.000
ME deficit (MJ)	-53780.30(0.0) ^a	+7686.90(0.0) ^c	+17185.70(84.2) ^b	-11155.70(237.7)	0.000
DCP available (g)	763408.60(0.00) ^a	482522.30(0.00) ^b	220398.30(4.9) ^c	488776.40(8.7)	0.000
DCP deficit (g)	-1530511.0(0.0) ^a	-691019.7(0.00) ^b	-297890.7(16.1) ^c	-840923.60(40.8)	0.000

abc= Means within the same row with different superscripts are significantly different;

DM=dry matter; ME=metabolizable energy; DCP=digestible crude protein; RFV=relative feed value; - =deficit; + =excess

4.4.6. Major constraints of feed production and utilization

The major constraints of livestock feed production and utilization ranked by the wealth groups are elaborated in the Table 19. Lack of grazing land, land degradation and low feed quality were given the first three ranks by the three wealth groups, respectively. This indicated that the constraints were strong enough to affect feed production at farm level. The ranks through 4th to 9th assigned to other constraints differently by the wealth groups based on the level of the effects the HHs faced from the constraints (Table 19). The HH level livestock number ranked the last by the entire HHs, since the herd size (TLU) at HH level was few in number as to the farmers knowledge.

Table 19. Households' feed production and utilization constraints rank in the mixed farming areas of Bale highlands

Feed production and utilization constraints	Wealth group						Overall mean	
	Better (40)		Medium (85)		Low (31)		(156)	
	N	RI*	N	RI	N	RI	N	RI
Household livestock size	113	0.063	222	0.057	69	0.049	404	0.056
Rainfall shortage	169	0.094	370	0.095	125	0.089	664	0.093
Lack of grazing land	349	0.195	741	0.189	273	0.195	1363	0.193
Land degradation	287	0.160	579	0.148	219	0.156	1095	0.155
Low feed quantity	196	0.110	450	0.115	161	0.115	807	0.113
Low feed quality	253	0.142	550	0.140	227	0.162	1030	0.148
poor extension service	190	0.106	492	0.126	154	0.110	836	0.114
Poor feed market access	118	0.066	242	0.062	85	0.061	445	0.063
Poor storage facilities	114	0.064	269	0.069	87	0.062	470	0.065

N=respondent number; RI=rank indices; * =first rank starts with the highest value indices

4.5. Farmers' Perceptions of Climate Variability Impacts on Livestock Production

4.5.1. Availability of information on weather and associated farm conditions

Weather variability information accessed and information source tools used by the targeted groups in the study area are indicated in Table 20. All respondents from the wealth groups were reported inconsistent weather pattern in course of their 20 years farm experience. Farmers access to weather information had highly significant ($P < 0.001$) relationship with the wealth status since wealth dictates information acquiring tools (electronic media tools) ownership. The respondent also reflected that accessing information from electronic media had significant ($P < 0.05$) relationship with the wealth of farmers. The large proportion of respondents reported they accessed the information through government offices.

Table 20. Household level weather information source tools access in the mixed farming areas of Bale highlands (%)

Variables	Wealth groups			Overall mean (156)	X ² value	P value
	Better (40)	Medium (85)	Low (31)			
Information access					14.212	0.000
-Yes	40(100)	76(89.4)	22(70.9)	138(88.5)		
-No	0(0.0)	9(10.6)	9(19.1)	18(11.5)		
Radio and/or Television					7.111	0.029
-Yes	24(60.0)	35(41.2)	7(22.6)	66(42.3)		
-No	16(40.0)	45(52.9)	19(61.1)	80(51.3)		
Newspaper/templates					2.549	0.452
-Yes	1(2.5)	0(0.0)	0(0.0)	1(0.6)		
-No	39(97.5)	80(94.1)	26(83.9)	145(92.3)		
Government offices					6.265	0.028
-Yes	40(100)	76(89.4)	22(70.9)	138(88.5)		
-No	0(0.0)	4(4.7)	4(12.9)	8(5.1)		

Numbers outside and inside parenthesis are observed counts and percent, respectively

The status of HH level farm productivity and the associated determinants are presented in Table 21. Fertility status of farmers' owned land and cropland productivity status were highly ($P < 0.001$) related to the wealth group respondents. The raining time variability

and low productivity of the livestock reported by the majority of the farmers indicated the effects of farm determinants.

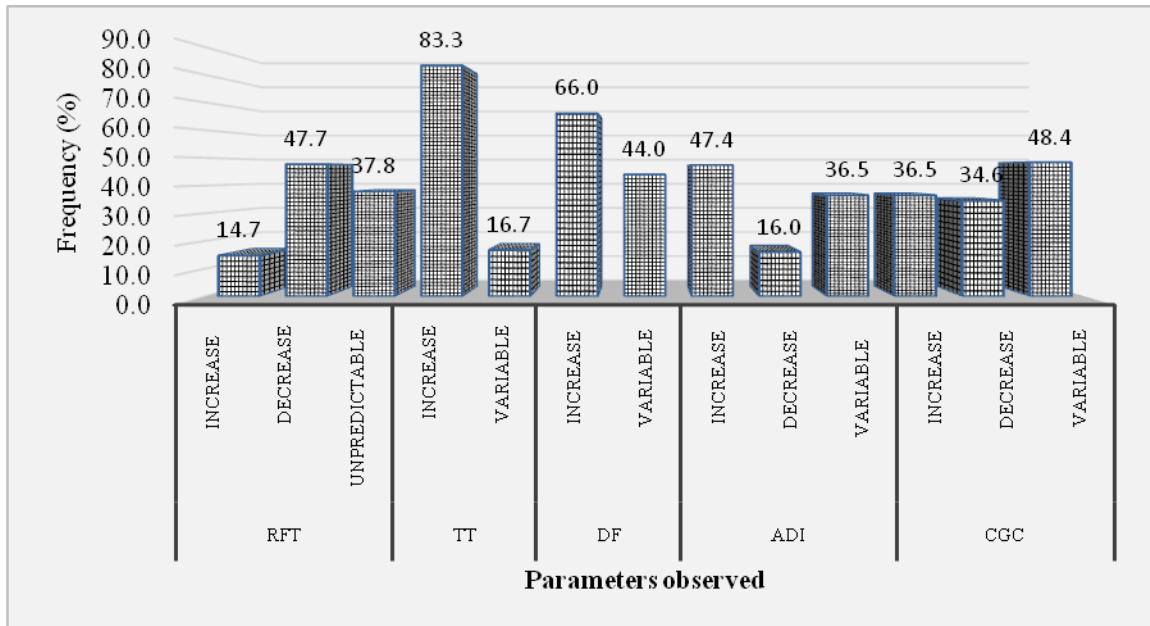
Table 21. Household level observed farm productivity and the associated determinants status in the mixed farming areas of Bale highlands

Variables	Wealth group			Overall mean	X ² value	P value
	Better (40)	Medium (85)	Low (31)			
Raining time					7.833	0.051
Unpredictable	32(80.0)	56(65.9)	15(48.4)	103(66.0)		
Predictable	8(20.0)	28(32.9)	16(51.6)	52(33.3)		
Land fertility status					21.059	0.000
Infertile	12(30.0)	36(42.3)	14(45.2)	62(39.7)		
Less fertile	39(97.5)	82(96.5)	31(100)	142(91.0)		
Fertile	23(57.5)	26(30.6)	2(6.4)	51(32.7)		
Crop land productivity					15.994	0.000
Low	27(67.5)	75(88.2)	31(100)	133(85.3)		
Medium	13(32.5)	10(11.8)	0(0.0)	23(14.7)		
Livestock productivity					1.288	0.629
Low	38(95.0)	81(95.3)	31(100)	150(96.1)		
Medium	2(5.0)	4(4.7)	0(0.0)	6(3.9)		

Numbers outside and inside parenthesis are observed counts and percent, respectively

4.5.2. Farmers' observation of climate variability and trends in rainfall and temperature

Figure 12 demonstrates farming HH's perceptions of weather elements trend and their aligned effects on the farm resource in the study area. Moderate numbers of overall mean HHs were perceived decreased (47.7%) and unpredictable (37.8%) rainfall trends. On the other hand, the large number of the HHs perceived the increased temperature (83.3%) and drought frequency (66.0%). Animal disease incidence was observed either increased or variably occurred while crop growth cycle was reported more variable from year.



RFT = rainfall trend; TT = temperature trend; ADI = animal disease incidence; CGC = crop growth cycle; DF = drought frequency

Figure 12. Households' perception of weather variability and associated effects on farm productivity in the mixed farming areas of Bale highlands

The twenty years (1995-2014) monthly average rainfall, minimum and maximum temperature trends from recorded data are presented in Figure 13. The linear solid lines indicated the minimum and maximum average temperature change had steadily increased and reached as high as 8.32 °C and 22.46 °C, respectively between the mention years. There were also variations in rainfall (precipitation) amount and patterns in the area (Figure 13). The indicated rainfall and temperature variation trend lines were in agreement with the respondents' perceptions of increased temperature and rainfall variability in their area (Figure 12; 13).

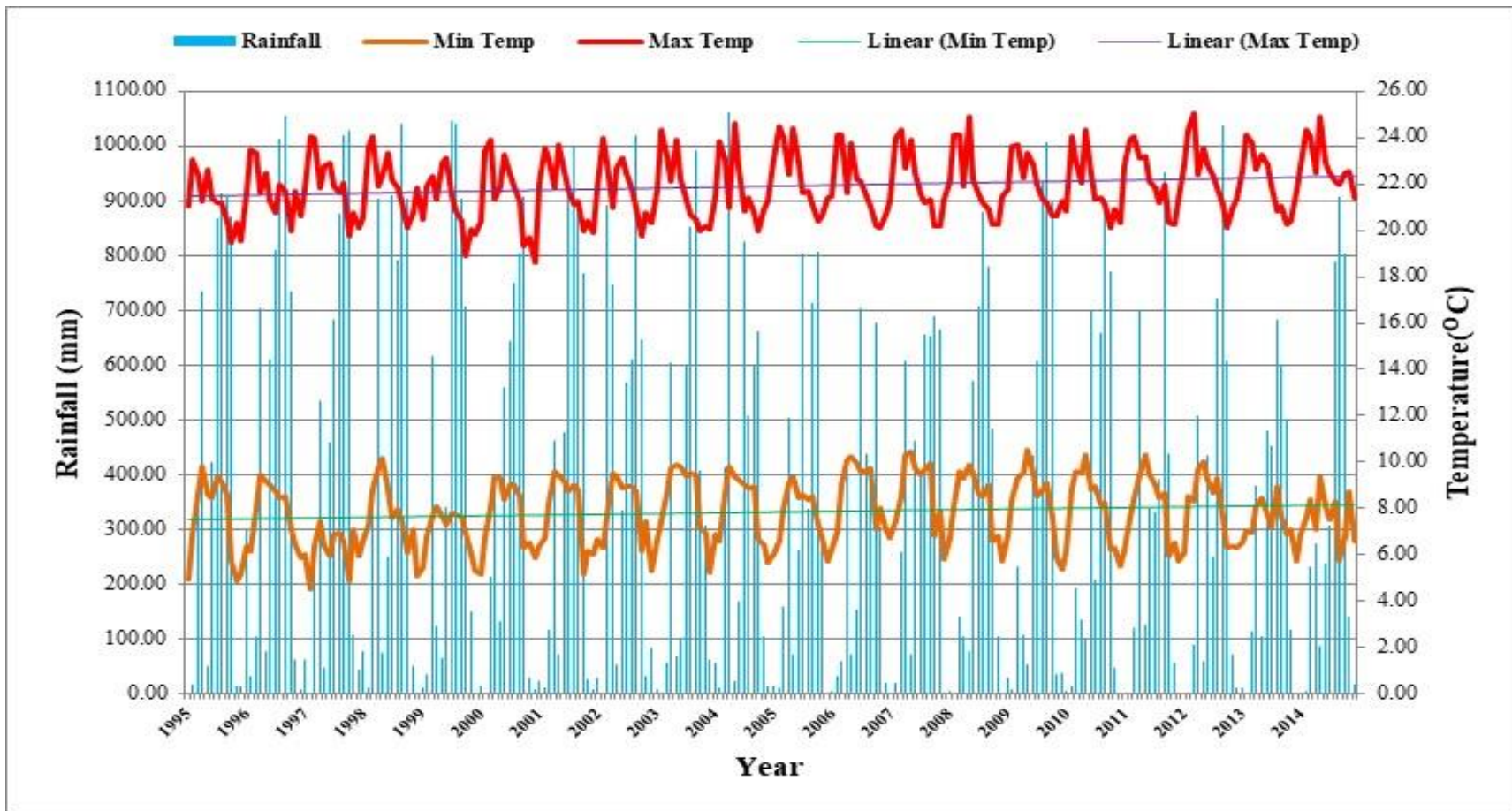


Figure 13. Monthly rainfall, minimum and maximum temperature trends over the past 20 years in the mixed farming areas of Bale highlands

4.5.3. Effect of climate attributes variability on livestock production and resources

Wealth group HHs' observation of climate variability effects on the livestock production and feed resources productivity are indicated in (Figure 14). The better wealth HHs reported relative study area livestock population increase. The productivity of the livestock and feed resources were reported decreased by over the 90% of the wealth group HHs. The situation suggested that the effect of climate variation was highly reflected by poor production performance of the HHs resources. In addition, the direct and/or indirect impacts of climate variability associated factors on livestock resource uses (feed, health and animal product) observed among the wealth groups in different level of effects (Appendix Figure 2).

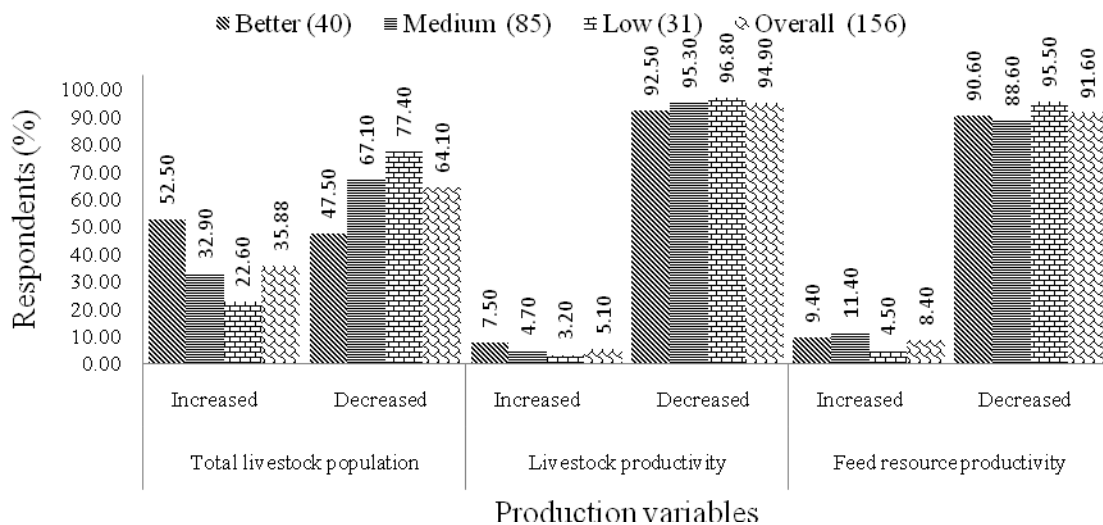


Figure 14. Households' perceptions of livestock and their productivity condition as affected by climate variability in the mixed farming areas of Bale highlands

4.5.4. Farmers' traditional coping mechanisms to climate variability

The rank of climate change adaptation measures practiced by the wealth groups in the study area are shown in Table 22. The potential measures were minimized farm level livestock herd size (ranked 1st) from the better and medium wealth groups. The change in

the crop varieties, conservation practices and change in animal species/breed ranked 2nd to 4th according to respondents practice. The low wealth HHs ranked crop varieties (1st) and minimum herd size (ranked 2nd). The differences in rank might be attributed to the small herd size owned by the low wealth groups.

Table 22. Rank of wealth groups climate variability coping measures in the mixed farming areas of Bale highlands

Adaptation measures by respondents	Wealth group						Overall	
	Better (40)		Medium(85)		Low (31)		mean (156)	
	N	RI*	N	RI	N	RI	N	RI
Animal species/breed diversity	20	0.058	17	0.027	1	0.004	38	0.030
Minimizing livestock number	40	0.389	85	0.389	12	0.342	137	0.373
Change in crop varieties	40	0.332	85	0.363	31	0.381	156	0.359
Soil and water conservation	38	0.221	79	0.221	26	0.273	143	0.238

N=respondent number; RI=rank indices; *=first rank starts with the highest value indices

The livestock production limited resources coping mechanisms practiced by the wealth group HHs are given in Table 23. Farmers practiced coping measures to water scarcity were significantly ($P<0.01$) related to the wealth differences among the HHs. The use of alternative feeds, destocking and moving part of the herds to other areas were showed a significant ($P<0.01$) relationship with the wealth differences.

Table 23. Household's coping mechanisms to livestock water and feed scarcity in the mixed farming areas of Bale highlands

Variables	Wealth groups			Overall mean (156)	X ² value	P value
	Better (40)	Medium (85)	Low (31)			
Water scarcity					10.081	0.004
Hand dug well	12(30.0)	29(34.1)	14(45.2)	55(35.2)		
Migrate to water points	9(22.5)	5(5.9)	0(0.0)	14(8.9)		
Feed shortage					18.050	0.002
Use of alternative feeds	19(47.5)	54(63.5)	29(93.5)	102(63.4)		
Migrate to other places	8(20.0)	11(12.9)	0(0.0)	19(12.2)		
Destocking	13(32.5)	20(23.5)	2(6.4)	35(22.4)		

Numbers outside and inside parenthesis are observed counts and percent, respectively

4.5.5. Farmers' perceptions of impact of livestock husbandry on climate variability

The farmers' perceptions of the impacts of the livestock production activities contributed to climate change are presented in Table 24. The observed livestock emissions and manure management effects on the climate change had a significance level of ($P < 0.05$) and ($P < 0.01$) relationship, respectively with the wealth status of the respondents. The overall livestock population increase and overgrazing were irrespective of the wealth stratum. The effects perceived due to emission and manure might be credited to herd size kept with HHs and the way manure produced from the animals had used.

Table 24. Farmers' perceptions of the livestock production activities effects on climate change in the mixed farming areas of Bale highlands

Variables	Wealth group			Overall mean (156)	X ² value	P value
	Better (40)	Medium (85)	Low (31)			
Overall livestock increase					1.150	0.580
Yes	17(42.5)	28(32.9)	12(38.7)	57(36.5)		
No	23(57.5)	57(67.1)	19(61.3)	99(63.5)		
Overgrazing (grass land)					4.387	0.133
Yes	39(97.5)	78(91.8)	26(83.9)	143(91.7)		
No	1(2.5)	7(8.2)	5(16.1)	13(8.3)		
Livestock emissions effect					5.818	0.330
Yes	4(10.0)	0(0.0)	0(0.0)	4(2.6)		
No	36(90.0)	85(100.0)	31(100)	152(97.4)		
Manure management					8.307	0.005
Yes	6(15.0)	0(0.0)	0(0.0)	4(3.8)		
No	34(85.0)	85(100)	31(100)	152(96.2)		

Numbers outside and inside parenthesis are observed counts and percent, respectively

4.5.6. Estimated livestock methane emissions

Table 25 presents enteric CH₄ (kg) emission factors and emission rates of different livestock categories of the wealth groups in the study area. The estimated enteric CH₄ EF from mature cattle was significantly ($P<0.001$) lower for the better wealth HHs compared to other groups while EF of growing cattle was significant ($P<0.05$) between better and other wealth groups. Whereas, EFs for sheep greater than one year, sheep up to one year, horse and donkey not significantly ($P<0.05$) different between the wealth groups. The enteric CH₄ emission rates from the livestock categories were significantly different ($P<0.001$) between the wealth group HHs. The overall mean estimated enteric CH₄ emission from mature cattle higher followed by growing cattle. The total enteric CH₄ emission at HH level of the wealth groups were more pronounced from the better group HHs compared to medium and the low group HHs.

The estimated CH₄ emission from manure handling practices in the study area wealth group HHs' livestock is presented in Table 26. There were a significant ($P<0.001$) difference between the three wealth group HHs manure CH₄ emissions from cattle. But, emission from donkey was significantly ($P<0.05$) higher for better groups. Similarly, CH₄ emission from sheep was different ($P<0.01$) between better and low groups.

Farm level livestock emitted CH₄ (kg/head/year) and its equivalent global warming potential in the study districts is indicated in Table 27. The large enteric CH₄ emission from cattle in the study *kebeles* wealth group HHs and total livestock emission of the districts had a higher GWP compared to the other animals raised by the farmers. Similarly, farm level CH₄ emission in the study area was very small amount compared to the total emission from the total study districts livestock of the mixed farming system.

Table 25. Household level estimated enteric CH₄ emissions in the mixed farming areas of Bale highlands

Livestock category	Wealth groups			Overall mean (156) Mean (SE)	P value	Total CH ₄	%
	Better (40)	Medium (85)	Low (31)				
	Mean (SE)	Mean (SE)	Mean (SE)				
Emission Factors (kg/head/year)							
Mature cattle**	39.40(0.0) ^b	40.34(0.0) ^a	40.20(0.02) ^a	40.08(0.03)	0.000		
Growing cattle*	20.02(0.0) ^b	20.56(0.0) ^a	20.51(0.0) ^a	20.42(0.02)	0.025		
Sheep > 1 year	3.48(0.0)	3.55(0.0)	3.54(0.0)	3.53(0.0)	0.070		
Sheep up to 1 year	1.74(0.0)	1.79(0.0)	1.78(0.0)	1.77(1.52)	0.202		
Horse	18.00(0.0)	18.00(0.0)	18.00(0.0)	18.00(0.0)	0.972		
Donkey	10.00(0.0)	10.00(0.0)	10.00(0.0)	10.00(0.0)	0.994		
Emission rates (kg/year)							
Mature cattle	459.99(13.19) ^a	252.96(8.66) ^b	114.27(5.31) ^c	278.48(11.22)	0.000	827.22	69.78
Growing cattle	153.61(9.63) ^a	75.64(4.35) ^b	28.45(3.88) ^c	86.25(4.93)	0.000	257.70	21.74
Sheep > 1 year	8.96(1.43) ^a	5.39(1.06) ^b	2.63(0.85) ^c	5.76(0.73)	0.000	16.98	1.43
Sheep up to 1 year	4.39(0.74) ^a	2.67(0.52) ^b	1.03(0.35) ^c	2.79(0.36)	0.000	8.09	0.68
Horse	22.05(1.36) ^a	7.62(0.97) ^b	3.48(1.29) ^b	10.50(0.88)	0.000	33.15	2.79
Donkey	23.25(0.97) ^a	12.94(0.73) ^b	6.13(1.19) ^c	14.23(0.70)	0.000	42.32	3.57
Total CH ₄	672.25	357.22	155.99	398.01		1185.46	
HH %	56.71	30.13	13.16				

abc= Means within the same row with different superscripts are significantly different

HH=household; **=280 kg average live weight; *=200 kg average live weight

Table 26. Household level estimated manure CH₄ emission in the mixed farming areas of Bale highlands

Livestock category	Wealth groups			Overall mean (156) Mean (SE) CH ₄ (kg/year)	P value	Total CH ₄ (kg/year)	Total emission (%)
	Better (40)	Medium (85)	Low (31)				
	Mean (SE)	Mean (SE)	Mean (SE)				
	CH ₄ (kg/year)	CH ₄ (kg/year)	CH ₄ (kg/year)				
Cattle	19.33(0.65) ^a	9.95(0.38) ^b	4.23(0.28) ^c	11.22(0.49)	0.000	33.51	80.28
Sheep	0.77(0.12) ^a	0.45(0.09) ^{ab}	0.19(0.06) ^b	0.48(0.06)	0.033	1.41	3.38
Horse	2.01(0.12) ^a	0.69(0.09) ^b	0.32(0.12) ^b	0.96(0.08)	0.016	3.02	7.24
Donkey	2.09(0.09) ^a	1.16(0.06) ^b	0.55(0.11) ^c	1.28(0.06)	0.012	3.80	9.10
HH total (kg)	24.20	12.25	5.29	13.94		41.74	
HH share (%)	57.98	29.35	12.67				

abc= Means within the same row with different superscripts are significantly different; HH=household

Table 27. Livestock emitted CH₄ global warming potential in the mixed farming areas of Bale highlands

Livestock species	Farm level total emission		Study districts total emission		
	CH ₄	*CO ₂ -e	Livestock	CH ₄ (kg/year)	CO ₂ -e GWP
	(kg/year)	GWP (MT)	(head)	('000)	(MT)
1 Cattle	375.95	1.28x10 ⁻⁶	388334.0	145994.2	4.96
2 Sheep	9.03	3.07x10 ⁻⁷	49815.0	449.8	0.015
3 Horse	11.46	3.91x10 ⁻⁷	23080.0	264.5	0.089
4 Donkey	15.51	1.55x10 ⁻⁷	23368.0	362.4	0.012
Total	411.95	1.40x10 ⁻⁵		147070.9	5.01

* = IPCC (2014); CO₂-e=carbon dioxide equivalent; GWP=global warming potential; MT=mega ton

5. DISCUSSION

5.1. Household Demographic Characteristics and Resource Holding

The study area farming HHs average age found in the standard productive age (15-64 years) of the country that considered as the potential workforce (Table 4). The present study overall mean household family size is higher than the 5.5 and 5.2 persons per HH reported by CSA (2013) for Oromia region and national average, respectively. The comparable family size per HHs was reported in the other mixed farming areas of Ethiopia (Worku *et al.*, 2012; Melesse *et al.*, 2013). The higher productive age and more family size of the better wealth groups might be credited to more assets owned, better living standards and work burden shared to hired labour. The comparable number of respondents attended primary education despite of the HHs' wealth difference might has impact on farm decision making (Table 5). Similarly, Anley *et al.* (2007) and Duguma *et al.* (2012) reported that the level of education correlates to knowledge and making positive farm decisions. Because better education level and farm experience improve productivity and farmer's perceptions of climate situation. In general, farm workforce age, family size and education have future implications of resource use to achieve optimum productivity.

In the study area, mixed farming is the livelihood pillar of the community and it has grounded on the land size and livestock number possessed. Here, livestock production has been a subsistence and important component of the system. However, major area of the land owned by the wealth groups used for cultivation and this extensive cultivation affects animal feed sources due to grazing land shrinkage (Table 6). The land cover dominated by wheat crop was due to suitable agro-ecology and the availability of better input packages compared to other crops. Hence, related to the grain yields of wheat, there was a concomitantly increased DM yield of the straw from this crop. Similarly, more area of the land was allocated for cultivation in the Dandi and Adami Tullu districts of Ethiopia (Duguma *et al.*, 2012; Assefa *et al.*, 2013). The overall land holding per HH observed was higher than reported by (Eshete, 2001; Duguma *et al.*, 2012) in the other

part of Ethiopia. The difference could be attributed to the population size and land topography suitability for cultivation.

The more number of TLU possessed by the better wealth HHs accounted to difference in grazing land owned that justified the importance of cattle in crop-livestock farming. Cattle were the dominant stock, while the number of oxen still pronounced within the herd across the wealth groups (Table 7). This was credited to the established facts, that cattle were primarily used for draught power in the area like in the other mixed farming areas of Ethiopia (Daba *et al.*, 2009). Livestock has been reared by the entire wealth groups for similar purposes and cattle are the most important component of draught power, food, income and savings. In addition, sheep raised for immediate cash need and meat, while equines for transportation of farm inputs and products, pulling cart and riding (Appendix Table 7). Comparable reports (Assefa *et al.*, 2014; Birhan and Adugna, 2014) were confirmed why livestock raised in the mixed farming system of the country.

The livestock herd proportions indicated that the better HHs had raised more number of diversified herd categories compared to the other wealth groups (Table 7). The observed difference between the wealth groups help to validate the diversity when planning a sustainable livestock development programs (McDermott *et al.*, 2010). The FGDs revealed that when constraints such as free grazing area and herding labour; more attention given for the cattle than sheep despite the advantage of small ruminants such as early maturing, high prolificacy, thriving on roughage feeds and others. This indicated, farmers deny the key advantages of sheep due to the mentioned constraints and low attention given to these animals in the study area. The small number of steers reported compared to other herd categories was because of early age sale to manage feed shortage and other problems.

5.2. Livestock Husbandry Practices and Production Constraints

5.2.1. Labour distribution and livestock management practices

In the study area, livestock rearing relied on the HH labour either in the homestead livestock related activities or in the herding areas using available labour (Figure 7, Appendix Table 11). Hired labour contributed more on the herding activities during cropping season and when children attending school basically for the better groups. Nowadays, due to shrinkage of free grazing areas and scarce herding labour in the area, tethering becomes a common practice except from January to April. This could be attributed to the school attending of the children and lack of the hired labour (Tarawali *et al.*, 2011). The present labour distribution among HH members for the livestock management activities agreed to the practices in the east Hararghe Zone of Ethiopia (Assefa *et al.*, 2014).

In principle, livestock housing is used to protect animals from predator, theft and bad weather conditions, and other factors that affect herd performance and temperaments. In the study area, in respective of the wealth groups, only calf and sheep were housed in relatively better shelters than the other herds (cattle and equine) (Table 8). Poor housing that fails to protect animals from environmental factors could contribute to poor production performance. Contingent to this study, weaned and mature cattle were housed throughout the year in a Kraal and calves kept in separate sheds or living rooms with family (Tola *et al.*, 2004; Ftiwi, 2015) in western and north western part of Ethiopia. The FGD reported that separate house was used for cattle under special conditions (health case and at early parturition during bad weather).

The livestock manure collected from the place where the animal drops it (in Kraal or around backyard) and made in to dung cake to be used as fuel at home or marketed in the study area. But in some cases when manure remains in the Kraal and not collected regularly for some time (weeks), dried and swept from the spot and used as organic fertilizer on croplands (Figure 8). On the other hand, manure dropped in the grazing areas

during dry period collected and used as fuel (Appendix Figure 3) while the remained dung used to maintain ecosystem via supplying organic fertilizer to the soil (IPCC, 2006). Similarly, Onduru *et al.* (2008) reported that in Kenya, animals graze in fields during the day adds a potential *in situ* manure utilization of soil fertility. In general, the present result implies that farmers are not much valued manure as organic fertilizer and biogas generation compared to the current practice (fuel) which has environmental effect.

5.2.2. Prevalent diseases and livestock health management

The most important livestock diseases for the entire wealth group HHs of the study area were viral, bacterial, protozoan or fungal and parasites (Table 9). The diseases reported and the observed inaccessibility of veterinary service were a pronounced problem of the HHs though government plans to establish a single veterinary health post for every three *kebeles* that not implemented properly in the area. However, there was a difference in the control mechanism and level of medicaments used by the HHs owing to their wealth status. The viral and bacterial diseases affected cattle herd despite wealth difference in the area though the potential impacts of the diseases depend on suitable environment and animal conditions (emaciation) due to inadequate feed supply during the dry periods. Such diseases are also reported important by the previous works (Bogale, 2008; Yami *et al.*, 2013) in Sinana district and highlands of Arsi area, respectively.

In the area, there was a scarcity of veterinary services delivery where only one veterinary clinic or health post per three or more *kebeles* with the meager services, lack of medicaments and qualified veterinary personnel (Figure 9). The situation aligned to the recent report of the country's less than 50% animal health delivery coverage (MoA and ILRI, 2013). Similarly, (Gebremariam *et al.*, 2010; Shapiro *et al.*, 2015; Susan, 2016) reported that access to veterinary services in Ethiopia cannot address rural areas to the required level and leads to high demand for black market drugs of an unconfirmed quality. The only accessible animal treatment by all the wealth groups was vaccination during disease outbreak (Appendix Table 5). Hence, lack of well-trained veterinary technicians and drug scarcity in the area were an indicative of limited veterinary service

that has significant effect on productivity and become a bottleneck of production (Serkebrhan, 2009).

5.2.3. Livestock drinking water sources and utilization

The lack of livestock drinking water was pronounced during the dry season since the available temporary surface water sources dry out. During this period, though animals need frequent watering due to the higher ambient temperature and dry feed consumption, it was difficult to water the animals to the required frequency. Rather once in two days was common when some sources dry out while the other alternative sources located at far distance of grazing or camping area (personal communication (Table 11). The situation was related with the existing climate factor and influences watering frequency of the livestock. Comparably, (Gebremariam *et al.*, 2010; Sennye and Peter, 2009) reported that the problem is pronounced where water sources are not co-located with feed commonly during the dry season and prolonged droughts in Ethiopia and Botswana, respectively. This indicated that seasonal water availability and watering frequency have an implication on livestock productivity. Abebe (2012) reported that similar livestock drinking water availability in Blue Nile Basin highlands, Ethiopia. To the contrary, Yadessa *et al.* (2016) reported that 52% of the respondent watering their animals twice a day in central highlands of Ethiopia. The variation might be credited to surface or ground water availability of the area that enables the farmers' more watering frequency. Between the seasons, there were differences in the use of the available sources and watering frequency of the herds of the wealth groups. Therefore, the seasonal water availability and watering frequency disparity affects the water intake of different livestock classes that decreased feed intake and dictates animal productive performance.

5.2.4. Productive performances of livestock

In the study area, long calving interval due to several months open, short lactation length were observed by respondents beside the low milk yield of cows (Table 12). Though average herd size per HH was in declining trend there was no tangible improved

productivity. Whereas, the study area livestock population were large subjected to increasing human population whose livelihood depends on livestock and it is in accordance with CSA (2014) report. The livestock population decrease at HH level was presumably affected by the grazing land scarcity due to cultivation from high population pressure where the scenario is a paradox for livestock framing (Yami *et al.*, 2013). Hence, in the future, better to transform the old and traditional animal husbandry system into semi-intensive and feedlot system (Shapiro *et al.*, 2015). The poor productive performance of the stock observed from this particular study indicated the worse condition of farm level animal production.

The low ADMY, short lactation period, longer dry periods leads to long calving interval that indicates a wide-range of problems remained in the area (Table 12). This could be attributed to the difference in management practice, feed quality and quantity supplied by the wealth groups. Majority of the respondents reported that short lactation period was expressed basically when second phase of lactation aligned with dry season and cows milked only once per day (morning or evening). In support of the situation, (FAO, 2013; Ftiwi, 2015) reported that livestock productivity in Ethiopia were the lowest compared to the other world currently. In general, low milk yield, poor conception rate, long calving interval and short lactation period mainly attributed to poor feeding, low genetic makeup of the breeds, climate factors (temperature and rainfall) and existing husbandry practices.

5.2.5. Major livestock production constraints

Though, there are many factors constraining livestock production, feed quality and grazing land scarcity were the prominent in the area (Table 13). Key informant consultation corroborate that farmers were fallow less fertile lands for grazing purpose as a solution under sever circumstances both for feed resource and restoration of soil fertility. Though, the better group owned more land (Table 6); feed and grazing land shortage were ranked as a major constraint. Some communal grazing lands used by all farmers during off-season and restricted to farmers whose cropland adjoining the area during wet season. Livestock diseases were the potential constraint mainly in favor of the

environmental condition and feed shortage coupled with the poor access and affordability of animal health services. The constraints to the smallholder mainly caused by interrelated man-made factors those linked to population growth, cropland expansion, land degradation and overgrazing and the same is reported in similar farming system elsewhere in Ethiopia (Desalew, 2008; Tolera *et al.*, 2012; Agza *et al.*, 2013). During cropping season, when grazing area become scanty, farmers with large herd size (perhaps better wealth HHs) move part of their stock (often cattle) to the other areas (Weyib and Wabe-Shebele River valley) negotiating with the resource owner in terms of (cash, lactating cow, oxen, grain and others). Other similar studies (Duguma *et al.*, 2012; Takele *et al.*, 2014) were reported feed shortage, disease prevalence and low productivity of livestock as the major constraints limiting livestock production in different part of Ethiopia.

5.3. Livestock Feed Resources, Feeding strategies and Feed Balance

5.3.1. Feed availability and feeding strategies

The type and quantity of feeds used throughout the year showed variation across the wealth groups related to feed resource basis owned (Table 14). Major area of the land owned by the HHs covered by the crop and only small proportion that not suitable for cultivation used as grazing (Figure 11). Similar scenarios reported that livestock producers in different part of Ethiopia suffer the problem (Tadesse *et al.*, 2014; Gilo and Berta, 2016). Hence, the contribution of crop residue to livestock feed presumably takes the major DM supply (Table 14) since the land use has been dominated by cultivation (Gizaw *et al.*, 2017). Because, the residue and grazing biomass yields were related to the area of land allocated to crop and pasture production. Conversely, the meager land left for grazing has been overgrazed and degraded through time unless restoration actions implemented urgently to sustain land productivity.

The major feed resources identified in the study area were mixed native pasture (grass, legume and herbs), straw (cereals and pulses), crop aftermath composed of weeds, herbs

and remained grains during harvest), while forage crops (maize and oat) and HMCs were occasionally used feeds (Table 14). The bulk DM of wheat straw found in abundant during harvest was not conserved by the majority of the HHs due to its poor palatability and low nutrient content. However, the annual DM contributions of green forages (grazing) were very low to the total feed budget of the area (Table 15) due to limited communal grazing and overstocking. The communal grazing includes wetlands, riverbanks, ragged areas and abandoned pieces of lands from state farms (*Sheneka and Dinkitti*) mainly due to degradation and poor soil fertility (Yadessa *et al.*, 2016). Straws from cereals were fed to animals throughout the year with an argument that the DM from available residues were not efficiently utilized as farmers strongly claim the palatability of wheat straw compared to others.

The controversy between mixed native pasture and crop aftermath estimated DM (Table 14), and the feeding calendar (Figure 10) was found a vague to the feed value of the resources. Because, annual DM yields from natural pasture is less than crop aftermath, whereas grazing used year round while crop aftermath used for some months. The reason might be seasonal mobility of some herds to different grazing areas, use of fragile lands (e.g. roadsides not used for current DM estimation). The overall, seasonal feed availability was associated to rainfall pattern (Figure 10) than the differences between wealth groups and in some parts of the study area crop aftermath possibly used twice a year. During critical feed problem (March to July) because of cropping, livestock rely mainly on straws that are low in feeding value. Similar situation was reported in Sinana district and other areas (Abate *et al.*, 2012; Tolera *et al.*, 2012).

Forage crops (oat and maize) and HMCs fed to oxen, lactating cows, calves, sick animal and equines (pulling cart) in small amount by setting priority to the importance of the animals. Hence, supplement feeds used during critical feed problem (quantity and quality) for special group of stocks. Because, the respondents barely grow improved forage crops and use industrial by-products due to unaffordable price of these feeds. Forage crops (maize and oat) cultivation as a buffer crops were restricted to Sinana area *Kebeles*. Concomitantly, free grazing was changed to restrict (confine and tethering) for

cattle (cows and oxen) too on private, rented and alley pasture and straws at farm or homestead (Appendix Figure 5, 6). But, donkey, sheep and other cattle were used communal grazing, crop aftermath and provided with straws at home seldom (Appendix Figure 4). Actually, livestock owners follow different feeding strategies for efficient utilization of available sources at hand throughout the year. However, wheat straw was by far the largest feed component with low utilization as farmers complained its palatability and intake.

5.3.2. Major roughage feeds utilization

The production system of the study area is exclusively mixed farming, where livestock managed in an extensive system with the scanty grazing land. The DM produced from the grazing areas of wealth groups were small compared to other feed types (Table 6, 14) mainly attributed to the size of land, use type and productivity of the lands due to overstocking and degradation. In support of this work, the observed overgrazing and extensive cropping has degraded much of the grasslands and resulted in feed quantity and quality deterioration (Appendix Table 7). Thus, grazing was restricted to areas not suitable for cultivation in the study area. In accordance, Feyissa *et al.* (2013) and Mengistu *et al.* (2017) reported that grasslands significantly dwindled, highly fragmented and limited to areas where conditions are adverse for cropping. Therefore, grazing areas reduced to small area of fallow lands, waterlogged, steep slopes, roadside and other marginal lands in the study site due to the expansion of mechanized cultivation.

As to utilization, there was no restriction to communal and roadside grazing by the animals of farmers living in the same administrative *kebeles*. But access to private, fallow and alley land utilization, the other HHs than the owners were restricted until the commencement of the dry season. Similarly, Hassen *et al.* (2010) states permission to use by other HHs is possible after much herbage grazed by the owner's stock. Here, restricted herding and tethering were highly common during wet season as major lands of the area covered by crop. Generally, communal and roadside grasslands were used by animals such as sheep, equines and younger cattle that able to thrive on poor quality feeds.

Farmers in the study area cultivate different crops during short and main rainy seasons and crop residues and crop aftermath were available. But, there was a great variation of the land allocated for different crops (Table 6) and the total straw DM yield per annum by the wealth groups found different. However, the palatability of these straws also different for livestock categories and farmers confirmed that selective feeding was obligatory. Amede *et al.* (2005) reported that straw from pulses looks quality and it is fed mainly to oxen and milking cows mixed with cereal straws for few months as it easily develops moulds under storage (conservation) when moisture is available.

The bulk proportion of straw available as animal feed was very large and comparable to 76.72% and 78.72% reported by (Yadessa *et al.*, 2016; Admassu *et al.*, 2007), respectively. Contrary to the bulkiness of the study area straw, its nutrient content where low due to inherent high fiber content and loss of nutritious part during harvest, threshing and drying. The coarse structure of wheat straw after the combine harvest that removes the leaf parts needs to thresh the straw by oxen. Crop residue conservation (Appendix Figure 7) has been practiced by the farmers while wastage, competing uses (fuel and mulching) were another concern. The contribution of crop aftermath to the livestock feeding in the study site found to be significant particularly during dry season. Crop aftermath use after short rainy season crop harvest for few weeks during July/August depends on time of harvesting (Figure 10). Crop aftermath DM yield of the wealth groups of a particular year shows variation due to cultivated land area and productivity. The aftermaths grazed depending on crops grown while DM yield difference was mainly due to land size owned and area allocated for cultivation. Therefore, the problem of feed scarcity should be addressed through improved forages (fodder trees and legumes) plantation around homesteads, hedge and degraded areas as suggested by Oluyede *et al.* (2007).

5.3.3. Chemical composition and nutritive value of the major feeds

Based on the laboratory chemical composition analysis of the feeds, CP of mixed native pasture estimated between 5.33-6.33% for the wealth groups was lower than 6.4% of native grass hay in Ethiopia Tolera (2008). The difference might be attributed to agro-ecology and forage species of the locations. The differences in CP content of the mixed native pasture might be attributed to management practices (tillage frequency, fertilizer application and weeding), degree of soil fertility and differences in the proportion of grass-legume of the grazing areas. The earlier report (Keftesa, 1988) suggested that the feeding value of straw depends on intake and digestibility. Thus, to achieve the maximum intake of straw, CP content of 66-85 g per kg DM is necessary and lower CP feeds should be compensated by supplementation of protein feeds to meet the requirement. But, when CP of feed declines, DCP supply become increasingly depend on microbial protein synthesized in the rumen (Bakrie *et al.*, 1996). All the study feeds, except HMCs had less than the minimum level 7% CP requirement of optimum rumen microbial function.

Though, Van Soest (1967) reported that NDF above 55% can limit DM intake, the present study feeds NDF content confirmed the low intake. The NDF content of cereal straws and crop aftermath was higher than 65% (Table 16) and enough to influence voluntary intake. But, the pulse straw with the moderate NDF grouped under medium quality feed (Singh and Oosting, 1992). However, pulse crops were cultivated on small area of land for a single season per year mainly to increase fertility of the soil for the subsequent cropping season of cereal crops. Therefore, cereal straws and crop aftermath from all the wealth groups and mixed native pasture had NDF higher than 65% were low quality feeds. The result is in accordance with (Bogale *et al.*, 2008; Wondatir, 2010) of studies from different area of Ethiopia. The straw ADF content values variation (42.52% to 52.87%) of the wealth groups could be attributed to crop varieties, agronomic practices and soil fertility that determine quality. Similarly, ADF of both cereals and pulses were lower than wheat and haricot bean reported by Wondatir (2010) in central Rift Valley. Generally, (Kellems and Church, 1998) categorized roughages with higher than 40% ADF as low quality feeds. Except for crop aftermath and pulse straw, the ADL values

were lower than the maximum level of 7% that limits DM intake and livestock productivity (Reed and Michael, 1989). Therefore, the current result suggests supplementation with less fiber feeds to meet animal requirement especially during dry period.

The study area feeds IVDOMD value ranges between 49.92-54.68% for cereal straw and 54.24-57.01% pulse straw across the wealth groups. Whereas, the IVDOMD from mixed native pasture of the wealth groups looks good and the value where comparable to 57.2% native grass hay of Ethiopian feeds (Tolera, 2008). But, emmer wheat straw and crop aftermath had less than 50% IVDOMD to limit the voluntary feed intake of animals. Accordingly, Mosi and Butterworth (1985) stated that feeds with less than 50% IVDOMD reduce the intake to $50 \text{ g/kg LW}^{0.75}$ or less. The report by ILRI (2011) of the Ethiopian feeds such as wheat, barley and teff straw have about 53% IVDOMD that closes to present results and this suggests the need for supplementation. The native pasture IVDOMD value was within the range of roughage feeds IVDOMD values to maintain the voluntary intake of the animals though the annual DM yield from native pasture was very low in the area.

The ME (MJ per kg DM) of wheat and emmer wheat straw, and crop aftermath were comparable, while that of mixed native pasture, barley, teff and pulse straw (Table 18) higher than the value 7.3 MJ per kg DM reported previously for the roughage feeds in Ethiopia (Bediye *et al.*, 2007). The HMC was observed to contain slightly lower ME than noug cake (10.1 MJ per kg DM) reported by the same authors. Besides, except for HMC, the overall mean DCP of the study feeds range between 21.33-50.74 g per kg DM across the wealth groups which is within the range 14.00-87.00 g per kg DM for straw and native grass of the earlier report (Keftesa, 1988). The overall mean RFV of cereal straws were closer to teff straw (Appendix Table 23) and higher than that reported for wheat straw (53.5) by Geleti (2014). The mixed native pasture and pulse straw had comparable indices of RFV that was in agreement with native hay1 value reported by the same author. Except for HMCs, the other feeds had a quality index of lower than 100, ensuring their lower nutritive value when compared to full blooming alfalfa hay. However, these

lower quality feeds contributed 96.89% (Table 14) to the total annual feed supply. In general straws, crop aftermath and native pasture which dominantly fed to the existing livestock were low in quality (ME, CP and RFV) compared to homemade concentrates.

5.3.4. Nutrient availability and deficits

In the study area livestock herders expect products such as milk, meat, growth, reproduction, draught power and other services from their animals under the existing husbandry practices and feeding regime. Actually, the major input cost of the livestock production is the supply of balanced diet with emphasis to the major nutrients that determine productivity. The differences in farm land, land use type and cropping pattern of the wealth groups brought disparity in quantity and quality of the feeds. With this regard, Van Soest *et al.* (1985) and Bediye *et al.* (2001) suggested the importance of DCP and ME since these nutrients limit the extent of livestock productivity. Hence, feed requirement of the animals principally adjusted for these nutrients from the available feeds to minimize nutrient lose and meet animal requirement. However, there was a huge nutrient deficit among the wealth groups in the study site to maintain the requirement.

The annual maintenance DM requirement of the animals herded by the wealth group HHs was range from 8.9 to 38.8 tons (Table 17). The estimated values show the deficit for the better group was approximated to 45.1% that could be attributed to the more number of animals owned. Contrary to the present study, Mulu (2009) reported a positive DM balance of the study conducted at Bure district, Ethiopia. Other studies (Yisehak and Geert, 2014; Yadessa *et al.*, 2016) reported annual DM deficit variation exists linked to temporal and spatial feed resource availability. The available DM supplies were not support the maintenance requirement throughout the year in the study area.

The existence of feed deficit was also observed from the body condition of the herds and other studies in Ethiopia reveled that livestock production constrained due to feed deficit (Assefa *et al.*, 2013; Yadessa *et al.*, 2016; Gizaw *et al.*, 2017). The deficit might be compensated from seldom grown forage crops, opportunistic and unconventional feeds

(peals of cactus and vegetables, crop thinning, household wastes) those not considered for this particular study while herds seasonal mobility to other places was also a remedy. Such feeds might be more nutritious to compensate the deficit to a significant level.

The higher ME deficit belongs to the better wealth while there was a significant excess with the low groups and the total mean ME coverage was 91.3% (Table 17). However, the argument is that “whether all the available energy is utilized or/not due to lingo-cellulose complex of the feeds”. Similarly, Abate *et al.* (2012) reported that the ME content of feed indicated adequate, though the intake of the roughage feeds is low due to the high fiber content with the decreased grazing lands, livestock subjected to trek long distance daily to acquire feeds using a significant portion of body energy for maintenance instead to use for production and which is associated with the more GHG emissions per a given amount of product (Herrero *et al.*, 2013). This implies, the situation hampers the productivity of the animal and enhances emission from the animal (particularly ruminant) beyond the loss of energy and maintenance body condition.

The annual DCP deficit estimated for wealth groups was high and looks the animals maintained with the emaciated body conditions. In support of these scenarios, Bediye *et al.* (2007) and Yami *et al.* (2013) reported that feed resources with very low DCP content not maintain the animal body condition. The result implies there was a thrilling scarcity of annual DCP demand for maintenance which contributes to slow growth rate of the animal. The deficient might be compensate through microbial protein, seasonal mobility of the herd to use opportunistic feeds, seldom grown forage crops and disproportionate DM intake percent to body weight (Blümmel *et al.*, 2009). Furthermore; household wastes, occasional purchased green forages from other areas and shared part of the herds to their relatives for some period of time were compulsory. The CP deficit in the present study was comparable with previous reports (Admasu, 2007; Wondatir, 2010; Abera *et al.*, 2014) in different part of Ethiopia.

As far as the roughage feeds low nutrient content found in excess backyard *ad lib* straw feeding has been emerged and let the animals to feed more time than usual (Appendix

Figure 5). In addition, as herd size become small per HH, such feeding system possibly practiced and animals able to attain maintenance condition in course of time. However, the paradox due to increased DM intake of roughage feeds by the ruminant animals accompanied with an increased enteric CH₄ emission. This calls for the intervention of concerned parties to search appropriate solutions. Hence, supplementation with quality feeds (concentrate and improved forages), physiochemical treatment of roughage feeds and decreased herd size were the likely solutions beside the strong extension service. The small amount of green feed from grazing, bulk poor quality straws, less adoption of forage crops and inaccessibility of industrial by-products were the major contributors to the animal diet imbalances in the area.

5.3.5. Livestock feed production constraints

In the mixed farming system highland of Bale Zone, due to population increase, the conversion of the productive pasture lands to state or private intensified and smallholder crop farms were pronounced in the area in particular. Hence, less fertile marginal lands unsuitable for crop production were the only grazing areas. The respondents argue that the emerged large scale crop farms as the main reason of prevailing feed shortage. The wealth groups ranked grazing land scarcity as a prominent constraint, followed by land degradation and low quality feeds (Table 16; Appendix Table 18) which corresponds the report by Tesfa and Mekuriaw (2014). The situation was clearly elaborated by the nutrient deficit (DM, ME and DCP) across the wealth groups in the area.

Moreover, the available meager grazing areas were deteriorating due to lack of attention and high stocking rate and consequently decline productivity. The likely causes (investment and crop expansion) were contingent to the report by Assefa *et al.* (2013) in central rift valley of Ethiopia. Thus, grazing could not achieve the nutrient requirement of animals especially during the dry season due to the low quantity and quality yields. Similar conditions were reviewed and reported by Birhan and Adugna (2014) in feed resources assessment of Ethiopia. Moreover, Mekasha *et al.* (2014) confirmed that the highland plateaus of Ethiopia were under extensive mixed farming. Hence, when grazing

feed resource lands progressively changed to cultivation; feeds from crop straws become the major sources as witnessed in the study area (Table 14; Appendix Figure 7).

5.4. Farmers' Perception of Climate Variability Scenario and Livestock Production

5.4.1. Climate variability information and farm conditions

Climate variability information access is vital for the farming communities particularly for those who depend on rainfed agriculture. In the study area, farmers observed inconsistent climate pattern in course of their farming experience and perceived climate attributes variability (temperature, timing and intensity of rainfall, and frequent drought) which has implication on the livestock productivity. Similarly, Mengistu (2011) and Hameso (2015) reported that climate change is well perceived by the farmers in Adiha village and Sidama area, respectively in Ethiopia. The study revealed access to climate information from electronic media was limited to the better and merely medium wealth groups. Though farmers access additional weather information from government office, the problem was to bring the likely solution in to practice due to knowledge gap and resource limitation of the farmers'. In support of the current finding, Gross *et al.* (2012) reported that practical implementation of climate information into farm activities help to increase adoption and risk management which was the like of Agricultural Transformation Agency in Ethiopia. In the area, farming activities were solely weather dependent and climate attributes were important constraints of productivity (CSA, 2013) with the recognition of farmers' perception of climate elements change by their own traditional methods in the area (Table 20).

The wealth groups have cultivated less fertile lands resulted from long term physical damage, climate factors and consecutive years of cropping the land with low/no organic matter gain to the land. These conditions negatively affected livestock feed sources because of degradation, reduced moisture, and increased temperature and hot conditions that affected the livestock performance. The poor land fertility resulted in low crop productivity and preceded by poor straw production that eventual decreased livestock

farm output. In agreement, different authors confirmed that unreliable rainfall and poor soil fertility pose challenges to farm productivity and the need to restore fertility of long cultivated land using proper land use policy to sustain productivity (Chibsa and Ta'a, 2009; Alemayehu *et al.*, 2017).

5.4.2. Farmers' observations of rainfall and temperature trends

Climate elements such as rainfall and temperature were the major contributors to the changes and important factors of agricultural production. In the study area, farmers reported seasonal rainfall variability, temperature increase, frequent drought, emerged livestock diseases and inconsistency crop growth cycle those occurred due to climate change resulted in decreased herd size and poor productive performance. In agreement, Elsa *et al.* (2012) reported that ambient temperature and rainfall patterns were significant contributors to the newly emerging livestock diseases and parasites in tropics. Farmers were informed about the forthcoming weather situation of their area by elders those have experience of climate scenarios as reported by Mengistu (2011) and Mekasha *et al.* (2016).

The gradual increase (minimum and maximum) temperature, and rainfall amount and pattern variability in the study area of the indicated period (Figure 13) was in accordance with farmers' perception. The seasonal irregularity of rainfall pattern has been a concern similar to amount of precipitation required. The rainy seasons gradually become shorter; starts late and stops earlier than the usual rainy season. The result was consistent with (Herrero *et al.*, 2010; McSweeney *et al.*, 2010; ONRS, 2011) reported that in East African across Ethiopia mean temperature varies with the elevation and remarkable rainfall variation. This study presents farmers' believe that the climate was changing for the bad and resulted in changes in livestock productivity. Notably, key informants were witnessed that there was agro-climatic zone shift of their area that looks the lowland features (birds unique to lowland) seen in the area and studies those assessed farmers' perception in Africa reported comparable findings (Nyanga *et al.*, 2011; Rao *et al.*, 2011). In general, farmers' responses imply that they have comparable observation of the climate variability despite their wealth status difference. The changes in the level of

temperature, rainfall patterns and frequent drought occurrence are among the major elements of climate change observed in the area.

5.4.3. Climate variability and livestock production interactions

Under the prevailing conditions of the study area, livestock productivity, grazing land size and grassland productivity showed a reduction. This commands the farming community and stakeholders to pay attention to implement rehabilitation measures. Because the combination of increased temperature and shifted rainfall patterns have been affected the livestock while feed was and will remain a critical constraint of livestock production in the area. Accordingly, matching feed resources and livestock requirement could be a current and future task as suggested (IPCC, 2007) using crop production as a valuable proxy to feed availability in the mixed farming areas. Furthermore, (Thornton, 2010; Salehu *et al.*, 2011) stated that effect of climate change on livestock production is measured through the effects on natural pastures, water sources, livestock diseases and biodiversity under smallholder farming.

In the study area, climate change affects livestock production through indirect effect (feed availability and quality, newly emerged diseases) and the direct effect (extreme weather variability causes heat stress and low feed intake) which alter growth and production performance. Although, the direct effects of heat stress on livestock have not been studied in the area, the collective effect has a negative impact on livestock productivity. Similarly, MoA and ILRI (2013) suggested that climate change and altered weather patterns will affect the range, intensity and seasonality of livestock diseases. Thus, the combined effects of the factors have significant negative impacts on livestock production as different studies had also concluded that livestock production affected by climate factors (Deressa *et al.*, 2011; Salehu *et al.*, 2011).

The interaction of livestock with environment is complex and depends on production system and management practices. The study area traditional livestock production was the available resource dependent such as feed from scarce grazing areas and observed

that livestock affects environment and climate change due to overgrazing and trampling causing erosion and degradation of resources which contributes to climate change. In agreement of the stated scenario, Mengistu (2006) and Kimball (2011) confirmed that Ethiopia's ever growing livestock population has led to heavy grazing due to resource misuse beyond the carrying capacity. The problem further aggravates unless formal grazing use policy and community bylaws implemented to curb the effect on scarce grazing lands.

Regarding the effect of GHG emissions from livestock enteric fermentation and manure management, farmers' understanding was insignificant linked to knowledge gap on the contribution of livestock emissions to global warming. However, IPCC (2006 and Rust and Rust (2013) reported that livestock sector contributed to and being affected by climate change where CH₄ gas from livestock is the most significant pollutant. But, study area farmers' perception was linked to overgrazing and degradation. Moreover, livestock under extensive system has low productivity since more nutrients used for maintenance than product or services from the animals (FAO, 2009; ILRI, 2009). Indeed, existing livestock system have resulted in ecological disturbance along with climate change and increased carrying capacity in the area that decline animal productivity.

5.4.4. Farmers' climate variability coping/adaptation strategies

The study area livestock resource is one of the available options to sustain the wealth of farmers and their livelihoods beside cultivation. The wealth group HHs practiced adaptation tools available and affordable to the potential of their economic status. Herding less number of animals and cultivation of adaptive crop varieties that provided with available packages for the agro-ecology were used. The 1st or 2nd rank given to crop variety by the wealth groups were due to the better farm input technology availability. The soil and water conservation works were recently emerged adaptation measures in the area planned by the government as part of the country's Climate Resilient Green Economy (CRGE) program. Though, the unceasing climate change influence in the area, livestock has vital roles as adaptation tools by the rural community. In parallel, efficient

use of resources, such as water is required with the expectation of notable water demand increase of the livestock onward. Likewise, Nardone *et al.* (2010) confirmed, the possibility to cope with climate change effects vary according to the area where the livestock raised, species type, technologies and extension services used.

The effects and coping measures also mediated through changes in feed type (alternative feed uses), destocking and part of herd relocation as practiced by the wealth groups. The alternative feeds (milled grains, HH waste and others) mostly fed to lactating cows and draught oxen. The forage crops (oat and maize) and juvenile crops supposed not to be fruitful at the harvest period were used as supplement feeds. The uses of alternative feeds available to the HHs were common during seasonal feed quantity and quality discrepancy existed (Table 23). The major resources potentially used (water and feed) were under big limitations in the area in the course of livestock production particularly to HHs with large number of the herd size. Aligned to the observed state of climate change, key informants said that the local animal breeds and few crop varieties have been adapted and survive over the past years.

5.5. Effects of Livestock on Climate Change and Implications to Greenhouse Gas Emissions

Climate change is a complex global, continental and regional problem that intertwined with many observable facts such as livestock population, production system diversification, land use and land cover changes which are the fundamental pillars of agriculture. The husbandry practices, production objectives and input resource access were some of the fueling elements of livestock productivity and contribution to climate change (global warming) directly/indirectly under the existing scenario. Likewise, the discussion with farmers and personal observations confirmed that the overall production system where traditional: poor (housing, health management, watering system, manure management, grazing management) and prolonged dry season have contributed to climate change and GHG emissions in course of livestock production activities in the study area. The mentioned factors have effect on productivity that ultimately resulted in environmental degradation and increased GHG emission per unit product of the stock

under consideration. The report by Nandolo (2011) and Hristov *et al.* (2013) confirmed that less product per animal, poor nutrition and veterinary services facilitated the footpath to more GHG emission from poor quality available feeds. The reported potential livestock effects on climate were associated with the open access use of communal grazing and trampling that ultimately resulted in degradation. Thus, farmers' perceptions of the livestock contribution to climate change were linked to the husbandry practice than the physiological effect of emissions.

5.5.1. Methane gas emissions

The quantification of emissions from the livestock production on the basis of area and production system specific support the national inventory to design possible emission lessening strategies. The study revealed enteric CH₄ emission from mature and growing cattle were very high (91.52%) compared to sheep and equines which has credited to the more number of cattle herds at HH level was comparable to the 84% livestock emission from cattle reported by FDRE-CRGE (2011). The present enteric CH₄ EFs for cattle and sheep categories were in close agreement with the IPCC values from developing countries (African, Middle East and other tropical regions) livestock EFs under similar production system and animal functions (IPCC, 2006, Herrero *et al.*, 2008). However, EF from mature cattle was higher than an average figure of 32 kg CH₄ per TLU per year for African ruminants (Herrero *et al.* 2008). The emission rates from enteric CH₄ production aligned with higher EFs, large number of animals and complex herd structure possessed by the better group HHs. Likewise, Herrero *et al.* (2013), Hristov *et al.* (2013) and Teenstra *et al.* (2015) reported that from the total CH₄ emission, 90% is from enteric fermentation while mixed system produce the bulk of emissions from ruminants. On the other hand, the estimated low enteric CH₄ emission from herds of the low wealth group HHs might be due to less number of animals possessed and similar condition where reported by Singh *et al.* (2012).

The other concern is that when roughage feeds intake increased beyond maintenance requirement for working animals; CH₄ escalates from the additional feed to generate

more energy for ploughing. The scenario recalls for efficient use of draught power or mechanized cultivation to curb CH₄ emission from extra GEI which is also accompanied by lose of energy whenever feed energy converted to CH₄. Singh *et al.* (2012) justified that enteric CH₄ from working males (53.6%) is more than female (46.4%) in India, while Dlamini and Dube (2014) reported animals with a higher feed intake have higher CH₄ emission. Hence, herding animals of better productivity performance with the low enteric emission rate per product or services rendered is a likely solution to lessen livestock sector contribution to GHG emissions. In addition, ruminants (cattle and sheep) were the important emitter of enteric CH₄, the husbandry practices and feeding system needs special attention.

Different reports indicate CH₄ conversion rate as loss of energy from cattle ranged 2 to 12% of GE intake from tropical cattle because of feed's higher fiber content (Chuntrakort *et al.*, 2014; Natthamon *et al.*, 2015) which is in agreement with the present result. Thus, increasing roughage feeds digestibility was an expedient way to reduce enteric CH₄ emissions with accompanied minimized animal number and increased product. In general, CH₄ emission from livestock is influenced by husbandry practices, feed intake, diet composition, feed digestibility and differences between animals (Scholtz *et al.*, 2012). Therefore, the present report of feed digestibility and enteric CH₄ production of the existing livestock herd categories of the prevailing feeding regime presents ample scopes to abate CH₄ emission through appropriate feeding interventions.

In the mixed farming areas of Ethiopia; manure has been used for fuel and sometimes as organic fertilizer on farm lands. The manure was obtained either from Kraals or the place where the animals spent during feeding. Similarly, in the study area, manure was collected mainly from Kraal and made into dungcake in open environment (Figure 8; Appendix Figure 3). When manure handled in such a way, the potential CH₄ emission was less significant due to aerobic condition of the open environment. Likewise, when manure utilized in a dry form such as in stacks or dry lots for fertilizer on fields, it tends to decompose under aerobic conditions and insignificant amounts of CH₄ produced (Steinfeld *et al.*, 2006; Hristov *et al.*, 2013). The manure from kraal was collected and

made into dung cake on the dry ground/soil under the sun and used as fuel. Therefore, though small amount of CH₄ produced from manure under the existing traditional husbandry practice, it is not a sound problem of the CH₄ effect compared to the enteric emissions observed from the existing livestock. However, the increase in the herd size might lead to the increased manure CH₄ emission particularly when manure stored for long period of time under anaerobic condition at farm level.

5.5.2. Livestock production, climate variability and methane emission complications

While livestock contributions to the socio-cultural and sustainable livelihoods are substantial, their influence on climate change cannot be overlooked. In the study area, decreased and variable seasonal rainfall pattern, extended dry season and extreme weather events intricate livestock productivity in general. This situation intern reflected as a constraint of livestock husbandry practices which have contributed to livestock emissions in the area. Similarly, the relevant studies reported that the likely increase of CH₄ emissions in the coming decades because of the ever increasing demand for livestock products (IPCC, 2006; FAO, 2013). Therefore, livestock sector become an attractive target of GHG reduction campaigns. From this sector, a small change per animal emissions could result in large changes in total GHG emissions due to large livestock population broadly in Ethiopia and in the study area in particular which greatly affected climate change. The overall, estimated CH₄ emission has prominent effect on climate change due to its high global warming potential (34 times that of CO₂) when the concentration increased in the atmosphere (IPCC, 2014). In general, the cumulative effect of CH₄ emission was a sound problem of the highland mixed farming areas compared to the farm level relative small amount of emission in the study area due to its higher GWP (Table 27). Therefore, a key starting point to assess coping/mitigation potential of the livestock sector emissions were to understand baseline level of CH₄ emissions associated with different livestock categories, major GHGs emitted, the main sources and the farming community wealth differences under the prevailing livestock production system.

6. CONCLUSION AND RECCOMENDATIONS

6.1. Conclusion

From this study, it can be concluded that livestock production is a hub sector that plays crucial role to the smallholder's livelihood in the study area. Since, the area is under high crop-livestock interaction, interventions made in either of the sectors affect the other. Here, livestock sector faced persistent feed shortage, diminished grazing land, and increased and continued risks of climate variability that entangled with different challenges such as extensive cultivation, population growth, poor livestock husbandry and land use changes. These all add trouble to livestock productivity in the area. Indeed, this scenario calls for timely intervention among the concerned parties to bring a solution.

Cattle, the largest herd size across all households, play a significant role in their livelihoods while equine and sheep herding is limited to availability of labour and grazing areas. But, improper husbandry practices (housing, disease, watering and feeding) were the major reasons for low productivity of mainly cattle following feed shortage. It was observed that feeding strategies changed from free grazing to a restrict (confine and tether) system for cattle too (cows and oxen) on the private grass land, rented pasture, cropland and homestead while others let to graze on poor communal areas.

Low productivity of the fragile and depleted grazing lands, poor quality of the crop residues and wastage during surplus and the way conserved were gaps observed of feed use. Though, the straws looks a potential source of feed energy particularly for ruminants, the nutrient is not easily available for the animals and loses of the energy as emitted gases from ruminant become high. The bulky feeds (cereal straws) which accounted 66.70% of total supply IVDOMD ranges 49.92-54.68% in the study site. Hence, the lower range of straw IVDOMD (49.92%) tends to reduce feed intake to $50 \text{ g/kg LW}^{0.75}$ (Mosi and Butterworth, 1985) and become determinant of the animal productivity. The DCP supply was at the chronic level of deficit for those households possessed more herds and ME found at different level of deficit among the wealth groups while RFV for all roughage feeds was low. These were the major actors to decrease productivity per the animal.

Farmers differently accessed climate information, though facing the risk and practice the coping measures to their own potential. They noticed that their area gets warmer than before due to increased temperature and unpredictable rainfall that let them to anticipate agro-climate zone shift of their area by their own judgment. The disparity in seasonal rainfall pattern, increased temperature, drought frequency, livestock disease incidence and decreased livestock productivity were among the observed climate variability and associated factors effect perceived by the farmers. This implies that getting reliable weather information was a means to minimize the effect of unpredictable climate attributes variability to maintain productivity. Hence, farmers practiced herding less number of livestock (destocking), use of alternative feeds and shifting crop varieties as adaptation tools.

Livestock farming contribute to climate attributes variation in different ways in course of production due to perceived traditional husbandry practices, species raised (large number of ruminants) and poor resource allocation that increase livestock contribution to climate change through hampering animal productivity and enhancing CH₄ emissions. In the area, mature and growing cattle emitted 69.78% and 21.74 % enteric CH₄, respectively at farm level. Though sheep and equine emitted low enteric CH₄, compared to cattle, they lack some products and services provided by cattle to the households. Hence, emission from study area livestock could be linked to species type, population size, and low productivity which cause extra emission without obtaining valuable product. This tends to increase CH₄ emissions from the sector that has a global warming potential of 34 times that of CO₂ in the atmosphere and the total CH₄ emission from the study area total livestock population has implication global warming at lower extent compared to tropical African's livestock CH₄ emission rates.

To this end, poor livestock management, high feed scarcity due to diminished grazing land, poor disease management, less climate information access was observed multi-faceted constraints and a basis for the low productivity of the livestock and a significant CH₄ emission to the environment that is a setback embedding the sector.

6.2. Recommendations

- Identifying and searching for better adaptive and productive animal breeds (dairy and/or meat) and promotion of farm level available technology packages should be implemented with the concern of environment and climate variability.
- Helping the farmers to exploit the bulky roughage feeds (crop residues), forage crop plantation and concentrate feed use offers opportunities through land use based production to improve feed utilization efficiency and increase output.
- Future planning of smallholder livestock projects should be inclusive of climate change and greenhouse gas emission mitigation strategies while responding to the growing demand of livestock products.
- Technical supports (training, cooperative resource uses and generated technology provision) to the farmers are essential to address the impact of livestock production on climate change and the vice-versa. Therefore, livestock and crop sectors should have think innovatively of the sectors' mutualism and implement relevant strategies to optimize productivity.
- Increasing roughage feeds digestibility (through chemical treatment and concentrate supplementation) for ruminants should be used as an expedient way to reduce enteric CH₄ emission along with improved perennial forage cultivation that used as supplement and other multiple functions.
- In general, determined stocking rate, species and breed diversification, disease control, improved feeding practices and improved weather forecast services are potential areas of research and development intervention to enhance productivity and to minimize CH₄ emissions.
- The huge gap between nutrient quality (ME, DCP) and quantity of the roughage feeds is an unreciprocated question that contributed to enteric CH₄ emission of different group of animals. Therefore, further study should be undertaken along the livestock supply chains of specified production objective (product or service) and feeding levels to estimate methane emission and the subsequent effect on the global warming.

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8. APPENDICES

8.1. Tables in the Appendices

Appendix Table 1. Bale Zone mixed farming districts livestock population (TLU)

Livestock type	Mixed farming districts								
	Sinana	Agarfa	Gasera	Goba	Dinsho	Ginnir	Goro	Gololcha	Berbera
Cattle	172214	131560	84560	66710	41741	133016	108406	104885	187246.5
Sheep	2670.7	6824.2	40320	8746.3	6315.6	2277	1462.2	1102.1	1493.1
Goat	1765	1567.4	302.0	795.6	761.6	6583.4	3590	4967	15526.2
Camel	0	0	0	0	0	4985	1692	2976	8133
Donkey	11505	2663	9200	7324	3474.5	2182.5	5477.5	10763.5	9022.5
Mule	3996.3	13703	868	1890	245	1983.8	2882.6	2295.3	11989.6
Horse	7330.4	10118	5632	26120	14768.8	22.27.2	1572	1298.4	670.4
Chicken	696.6	10.5	465.6	176.4	240.7	759.8	270.4	405.1	327.6
Total TLU	200178	166447	144066	111762	67547.2	151788	125353	128693	234408.9

Source: Bale Zone office of agriculture, planning section (2012)

Appendix Table 2. Feed sources DM (ton per hectare) yield conversion factors

Sources of crop types	Conversion factor *	Source
Barley straw	1.5	FAO, 1987
Wheat straw	1.5	FAO, 1987
Maize Stover	2.0	FAO, 1987
Teff straw	1.5	FAO, 1987
Faba bean straw	1.2	FAO, 1987
Field pea straw	1.2	FAO, 1987
Linseed	4.0	FAO, 1987
Communal grazing land	2.0	FAO, 1987
Fallow land	1.8	FAO, 1987
Crop aftermath	0.5	FAO, 1987
Forage crops	6.0-8.0	Mengistu, 2006

Appendix Table 3. Conversion factors of the livestock to tropical livestock unit (TLU)

Livestock type	Tropical livestock unit (TLU)
Oxen/bulls	1.1
Cows	0.8
Heifers	0.5
Steers	0.6
Calves	0.2
Sheep	0.1
Horses	0.8
Donkey	0.5

Source: Jahnke (1982); Gryseels (1988)

Appendix Table 4. Daily maintenance nutrient requirement per the animal types

Livestock type	DM (kg)	DCP (g)	ME (MJ)
Oxen/bulls	4.8	361.3	33.0
Cows	4.4	227.8	29.7
Heifers	3.3	232.0	21.7
Steers	3.5	265	24.7
Calves	1.9	144.0	13.0
Sheep	0.65	53.0	4.3
Horses	5.3	400.4	27.6
Donkey	2.5	192.5	14.9

Source: Kearn (1982)

Appendix Table 5. Respondents' opinion of livestock health supply access in the mixed farming areas of Bale highlands (%)

Variables	Wealth group		
	Better (40)	Medium (85)	Low (31)
Veterinary service access	23 (57.5)	50 (58.0)	15 (48.4)
GOs veterinary clinic	18 (45.0)	28 (32.9)	12 (38.7)
Private drug store	30 (75.0)	62 (72.9)	15 (48.4)
Vaccination access	40 (100)	84 (98.8)	27 (87.1)
Lack of AHT	26 (65.0)	60 (70.6)	24 (77.4)
Lack of drugs	12 (30.0)	55 (64.7)	24 (77.4)

Numbers outside and inside bracket represents observed count and percent, respectively

Appendix Table 6. Purpose of livestock keeping among the wealth groups (%) in the mixed farming areas of Bale highlands

Herd structure	Purpose of keeping	Household category		
		Better (40)	Medium (85)	Low (31)
Cow	Milk	39 (97.5)	84 (98.8)	25 (80.6)
	Manure	39 (97.5)	84 (98.8)	25 (80.6)
	Sell	15 (38.5)	19 (22.6)	0.0
	Others	33 (84.6)	47 (56.0)	10 (40.0)
Ox/bull	Traction	40 (100.0)	85 (100.0)	30 (96.8)
	Manure	40 (100.0)	85 (100.0)	30 (96.8)
	Sell	39 (97.5)	69 (81.2)	13 (43.3)
	Others	0.0	0.0	0.0
Heifer	Replacement	35 (87.5)	72 (84.7)	13 (41.9)
	Manure	35 (87.5)	72 (84.7)	13 (41.9)
	Sell	7 (21.2)	16 (22.5)	2 (15.4)
	Others	22 (62.9)	21 (29.2)	3 (23.1)
Steer	Replacement	22 (75.9)	32 (84.2)	5 (83.3)
	Manure	29 (100.0)	38 (100.0)	6 (100.0)
	Sell	26 (89.7)	26 (68.4)	4 (66.7)
	Others	0.0	0.0	0.0
Sheep	Meat	26 (100.0)	29 (78.4)	2 (22.2)
	Manure	26 (100.0)	35 (94.6)	8 (88.9)
	Sell	25 (96.2)	37 (100.0)	9 (100.0)
	Others	0.0	0.0	0.0
Equine	Transport	39 (100.0)	81 (100.0)	21 (100.0)
	Manure	39 (100.0)	71 (87.7)	20 (90.9)
	Sell	25 (64.1)	33 (40.7)	4 (18.2)
	Others	0.0	0.0	0.0

Numbers outside and inside bracket represents observed count and percent, respectively

Appendix Table 7. Land use and land covers changes in the mixed farming areas of Bale highlands

Land use type	Data record years						Total change (%)
	1986		2001		2014		
	Hectare	%	Hectare	%	Hectare	%	
Cultivation	127303.40	45.25	207123.80	73.62	214019.20	76.07	+40.52
Forest	124178.20	44.14	59368.90	21.10	53462.06	19.00	-56.95
Grazing	21679.92	7.71	4757.41	1.69	176.44	0.06	-99.22
Others	8190.33	2.91	10105.77	3.59	13698.16	4.87	+40.25
Total area	281355.8	100.0	281355.8	100.0	281355.8	100.0	

Source: Compiled using ERDAS (2010)

Appendix Table 8. Wealth group households' perception of farming activity related climate change indicators in the mixed farming areas of Bale highlands (%)

Variable	Variable description	Wealth group			Total HHs %
		Better (40)	Medium (85)	Low (31)	
Rainfall trend	Increase	12.5	18.8	6.4	14.7
	Decrease	57.5	38.1	58.1	47.7
	Unpredictable	30.0	42.3	35.5	37.8
Temperature trend	Increase	92.5	80.0	80.6	83.3
	Variable	7.5	20.0	19.3	16.7
Drought frequency	Increase	77.5	62.4	61.3	66.0
	Variable	22.5	37.6	38.7	44.0
Animal disease incidence	Increase	62.5	48.2	25.8	47.4
	Decrease	10.0	16.4	22.6	16.0
	Variable	26.5	35.3	51.6	36.5
Crop growth cycle	Increase	5.0	21.2	19.3	36.5
	Decrease	47.5	29.4	32.2	34.6
	Variable	47.5	49.4	48.4	48.4

Appendix Table 9. Manure collection and utilization type at household level (%) in the mixed farming areas of Bale highlands

Livestock species	Variable description	Wealth group			Total (156)
		Better (40)	Medium (85)	Low (31)	
Cattle	Collected daily	100.0	100.0	100.0	100.0
	Made to dung cake	85.0	76.5	77.4	78.8
	Used as organic fertilizer	17.5	17.6	22.6	18.6
Sheep	Collected daily	62.5	43.5	29.0	45.5
	Made to dung cake	10.0	9.4	9.7	9.6
	Used as organic fertilizer	15.0	10.6	3.2	10.2
Equine	Collected daily	97.5	92.9	64.5	88.5
	Made to dung cake	25.0	24.7	12.9	25.0
	Used as organic fertilizer	17.5	16.5	12.9	16.0

Appendix Table 10. Households' perceptions of some farm production situation (%) in the mixed farming areas of Bale highlands

Variables	Farm condition	Wealth group			Overall (156)
		Better (40)	Medium (85)	Low (31)	
Livestock population	Increased	52.5	32.9	22.6	65.9
	Decreased	47.5	67.1	77.4	64.1
Livestock productivity	Increased	7.5	4.7	3.2	5.1
	Decreased	92.5	95.3	96.8	94.9
Feed resource productivity	Increased	9.4	11.4	4.5	8.4
	Decreased	90.6	88.6	95.5	91.6
Grazing land size	Increased	0	0	0	0
	Decreased	100	100	100	100

Appendix Table 11. Wealth group households' livestock herding labour share (%) in the mixed farming areas of Bale highlands

Wealth group	Variable description	Family members' category				
		Girl≤14 year	Boy≤14 year	Female [15-64]	Male [15-64]	Hired labor
Better (40)	Herding and watering	3 (12)	25 (75.8)	2 (5)	11 (27.5)	19 (100)
	Milking	0 (0.0)	0 (0.0)	39 (100)	1 (2.6)	0 (0.0)
	Barn cleaning	14 (53.8)	4 (12.1)	40 (100)	0 (0.0)	0 (0.0)
	Stall feeding	6 (24)	19 (57.6)	19 (48.7)	29 (72.5)	11 (55)
	Sick animal handling	0 (0.0)	6 (18.2)	27 (67.5)	34 (85)	3 (15)
	Breeding (AI)	0 (0.0)	0 (0.0)	3 (7.7)	29 (74.4)	2 (10.0)
	Tethering	1 (3.8)	16 (48.5)	8 (20.5)	36 (90)	20 (100)
Medium (85)	Herding and watering	12 (21.4)	50 (73.5)	13 (15.3)	61 (72.6)	24 (100)
	Milking	0 (0.0)	0 (0.0)	82 (97.5)	7 (8.8)	1 (4.3)
	Barn cleaning	32 (57.1)	11 (15.9)	85 (100)	0 (0.0)	0 (0.0)
	Stall feeding	13 (23.2)	31 (45.6)	52 (61.2)	65 (80.2)	16(66.7)
	Sick animal handling	4 (7.1)	5 (7.5)	68 (81)	64 (80)	1 (4.3)
	Breeding (AI)	0 (0.0)	0 (0.0)	7 (8.3)	28 (35)	0 (0.0)
	Tethering	1 (1.8)	34 (50)	32 (37.6)	73 (90.1)	24 (100)
Low (31)	Herding and watering	4 (17.4)	16 (76.2)	11 (35.5)	26 (89.7)	1 (100)
	Milking	0 (0.0)	0 (0.0)	24 (96)	1 (4.3)	0 (0.0)
	Barn cleaning	13 (56.5)	2 (9.5)	31 (100)	0 (0.0)	0 (0.0)
	Stall feeding	5 (21.7)	10 (47.6)	17 (54.8)	21 (70)	0 (0.0)
	Sick animal handling	3 (13)	1 (4.8)	20 (64.5)	21 (70)	0 (0.0)
	Breeding (AI)	0 (0.0)	0 (0.0)	1 (3.8)	1 (3.8)	0 (0.0)
	Tethering	2 (8.7)	9 (42.9)	19 (61.3)	29 (96.7)	0 (0.0)

Numbers outside and inside bracket represents observed count and percent, respectively

Appendix Table 12. Family members' livestock keeping labour force sources (%) in the mixed farming areas of Bale highlands

Household wealth group	Age and sex group	Livestock keeping routine activities						
		Herding & watering	Milking	Barn cleaning	Stall feeding	Animal treatment	Breeding	Tethering
Better (40)	Girl≤14	3 (12.0)	0 (0.0)	14 (53.8)	6 (24.0)	0 (0.0)	0 (0.0)	1 (3.8)
	Boy≤14	25 (75.8)	0 (0.0)	4 (12.1)	19 (57.6)	6 (18.2)	0 (0.0)	16 (48.5)
	Female[15-64]	2 (5.0)	39 (100)	40 (100)	19 (48.7)	27 (67.5)	3 (7.7)	8 (20.5)
	Male[15-64]	11 9 (27.5)	1 (2.6)	0 (0.0)	29 (72.5)	34 (85.0)	29 (74.4)	36 (90.0)
	Hired labour	29 (100)	0 (0.0)	1 (10.0)	16 (55.2)	4 (13.8)	2 (6.89)	28 (96.6)
Medium (85)	Girl≤14	12 (21.4)	0 (0.0)	32 (57.1)	13 (23.2)	4 (7.1)	0 (0.0)	1 (1.8)
	Boy≤14	50 (73.5)	0 (0.0)	11 (15.9)	31 (45.6)	5 (7.5)	0 (0.0)	34 (50.0)
	Female[15-64]	13 (15.3)	82 (97.6)	85 (100)	52 (61.2)	68 (81.0)	7 (8.3)	32 (37.6)
	Male[15-64]	61 (72.6)	7 (8.8)	0 (0.0)	65 (80.2)	64 (80.0)	27 (35.0)	73 (90.1)
	Hired labour	29 (100)	1(3.4)	0 (0.0)	18 (62.1)	1 (3.4)	0 (0.0)	27 (93.1)
Low (31)	Girl≤14	4 (17.4)	2 (11.8)	13 (56.5)	5 (21.7)	3 (13.0)	0 (0.0)	2 (8.7)
	Boy≤14	16 (76.2)	0 (0.0)	2 (9.5)	10 (47.6)	1 (4.8)	0 (0.0)	9 (42.9)
	Female[15-64]	11 (35.5)	24 (96.0)	31 (100)	17 (54.8)	20 (64.5)	1 (3.8)	19 (61.3)
	Male[15-64]	26 (89.7)	1 (4.3)	0 (0.0)	21 (70.0)	21 (70.0)	1 (3.8)	29 (96.7)
	Hired labour	0(0.0)	0 (0.0)	(0.00)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Numbers outside and inside bracket represents observed count and percent, respectively

Appendix Table 13. Farmers' observation of climate factors effect on livestock production (%) in the mixed farming areas of Bale highlands

Variables	Indicators	Wealth group		
		Better (40)	Medium (85)	Low (31)
Rainfall Variability	Lack of feed	85.0	75.3	61.3
	Low output	85.0	77.6	80.6
	Poor health	42.5	38.8	29.0
Increased Temperature	Lack of feed	92.5	87.1	67.7
	Low output	80.0	82.4	87.1
	Poor health	65.0	52.9	32.3
Extended Drought	Lack of feed	95.0	98.8	90.3
	Low output	90.0	89.4	83.9
	Poor health	55.0	50.6	51.6
Disease incidence	Lack of feed	67.5	56.5	48.4
	Low output	67.5	72.9	74.2
	Poor health	97.5	94.1	90.3

Appendix Table 14. Wealth group HHs' climate change traditional coping measures in the mixed farming areas of Bale highlands

Wealth group	Adaptation measures	Rank given by respondents				Index	Rank
		1 st	2 nd	3 rd	4 th		
Better (40)	Animal species/breed change	0	0	2	18	0.058	4
	Minimizing livestock number	30	8	2	0	0.389	1
	Change in crop varieties	8	30	2	0	0.332	2
	Soil and water conservation	2	2	34	2	0.221	3
Medium (85)	Animal species/breed change	0	0	4	13	0.027	4
	Minimizing livestock number	53	27	5	0	0.389	1
	Change in crop varieties	30	53	2	0	0.363	2
	Soil and water conservation	2	4	74	4	0.221	3
Low (31)	Animal species/breed change	0	0	0	1	0.004	4
	Minimizing livestock number	12	9	10	0	0.342	2
	Change in crop varieties	15	14	2	0	0.381	1
	Soil and water conservation	4	8	18	0	0.273	3

Appendix Table 15. Households' major available feeds and feeding calendar in the mixed farming areas of Bale highlands (%)

Wealth group	Feed type	Months of the year											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Better (40)	MNG	70	22.5	10	22.5	67.5	97.5	100	100	100	100	100	100
	Cereal S	82.5	100	100	100	100	100	80.0	67.5	60.0	57.5	67.5	67.5
	Pulses S	85.7	100	100	77.1	40.0	25.7	17.1	11.4	8.6	5.7	8.6	17.1
	CA	100	95.0	52.5	10.0	0.0	0.0	15.0	57.5	20.0	0.0	15.0	80.0
	HMC-FC	15.0	57.5	92.5	95.0	67.5	30.0	15.0	17.5	17.5	10.0	12.5	0.0
Medium (85)	MNG	74.1	23.5	9.4	17.6	62.4	96.5	100	100	100	100	100	100
	Cereal S	81.2	98.8	100	98.8	97.6	89.4	74.1	47.2	37.6	41.2	62.4	64.7
	Pulses S	88.4	98.6	97.1	63.8	29.0	11.6	8.8	4.3	4.3	4.3	5.8	7.2
	CA	100	98.8	74.1	11.8	0.0	0.0	15.3	50.6	5.3	1.2	10.7	82.4
	HMC-FC	11.9	67.1	94.1	82.4	27.1	9.5	9.4	10.6	11.8	12.9	3.6	1.2
Low (31)	MNG	80.6	25.8	6.5	22.6	71.0	96.8	100	100	100	100	100	100
	Cereal S	67.7	100	100	100	100	96.8	74.2	51.6	45.2	51.6	61.3	61.3
	Pulses S	100	100	100	93.3	26.7	6.7	6.7	6.7	6.7	6.7	6.7	13.3
	CA	100	100	90.3	16.1	0.0	0.0	6.5	54.8	0.0	0.0	12.9	74.2
	HMC-FC	3.4	41.4	93.1	79.3	37.9	3.4	3.4	10.3	10.3	6.9	3.4	0.0

MNG=mixed natural grass; S=straw; CA = crop aftermath; HMC = homemade concentrate; FC = forage crops

Appendix Table 16. Wealth group household level manure CH₄ emission factor and annual emission rate default values of African livestock

Wealth group	Livestock herd category	Livestock number per HH	Feed digestibility (%)	Temperature range (°c)	EF (kg CH ₄ /hd/yr)	Total CH ₄ /hh /yr
Better	Cattle	19.33	45-55	15-25	1.00	19.33
	Sheep	3.87	45-55	15-25	0.15	0.58
	Horse	1.23	45-55	15-25	1.64	1.84
	Donkey	2.33	45-55	15-25	0.90	2.10
Medium	Cattle	9.95	45-55	15-25	1.00	9.95
	Sheep	2.23	45-55	15-25	0.15	0.33
	Horse	0.42	45-55	15-25	1.64	0.69
	Donkey	1.29	45-55	15-25	0.90	1.16
Low	Cattle	3.16	45-55	15-25	1.00	3.16
	Sheep	0.94	45-55	15-25	0.15	0.14
	Horse	0.18	45-55	15-25	1.64	0.29
	Donkey	0.51	45-55	15-25	0.90	0.46

Source: IPCC (2006)

Appendix Table 17. Wealth groups' rank of the major livestock production constraints in the mixed farming areas of Bale highlands

Wealth groups	Major constraints	Rank given by respondents						Index	Rank
		1 st	2 nd	3 rd	4 th	5 th	6 th		
Better (40)	Feed scarcity	25	20	7	2	2	0	0.407	1
	Low output	0	2	8	9	5	10	0.126	4
	Disease prevalence	1	4	4	8	12	8	0.139	3
	Labor scarcity	1	3	11	6	6	6	0.143	2
	Water scarcity	1	4	3	1	3	1	0.064	6
	Unreliable weather	3	0	2	12	10	4	0.122	5
Medium (85)	Feed scarcity	57	46	19	4	0	0	0.431	1
	Low output	0	2	12	28	21	13	0.129	3
	Disease prevalence	1	5	11	19	29	7	0.129	3
	Labor scarcity	6	5	25	10	11	16	0.149	2
	Water scarcity	1	3	7	6	1	4	0.048	6
	Unreliable weather	4	3	6	19	18	19	0.114	5
Low (31)	Feed scarcity	26	23	3	0	0	0	0.496	1
	Low output	0	2	4	11	2	7	0.123	3
	Disease prevalence	0	1	8	8	9	0	0.139	2
	Labor scarcity	0	2	6	4	7	7	0.117	4
	Water scarcity	0	0	5	1	0	2	0.044	6
	Unreliable weather	0	0	3	6	12	4	0.081	5

Appendix Table 18. Livestock feed production and utilization constraints rank in the mixed farming areas of Bale highlands

Wealth groups	S. N.	Production & utilization Constraints	Ranks given by respondents									Index	Rank
			1 st	2 nd	3 rd	4 th	5 th	6 th	7 th	8 th	9 th		
Better (40)	1	Livestock population	0	4	3	0	0	3	3	12	15	0.063	9
	2	Rainfall shortage	3	2	3	3	4	6	10	4	5	0.094	6
	3	Lack of grazing land	33	5	0	2	0	0	0	0	0	0.195	1
	4	Land degradation	3	18	9	5	3	2	0	0	0	0.160	2
	5	Low feed quantity	0	5	5	6	10	4	6	4	0	0.110	4
	6	Low feed quality	1	6	15	10	3	3	1	0	1	0.142	3
	7	poor extension service	0	0	5	11	8	10	3	1	2	0.106	5
	8	Poor feed market access	0	0	0	1	7	7	7	12	6	0.066	7
	9	Poor storage facilities	0	0	0	2	5	6	10	6	11	0.064	8
Medium (85)	1	Livestock population	0	6	3	2	2	3	12	26	31	0.057	9
	2	Rainfall shortage	4	10	10	3	8	9	17	15	9	0.095	6
	3	Lack of grazing land	69	10	4	2	0	0	0	0	0	0.189	1
	4	Land degradation	9	25	23	13	7	3	3	1	1	0.148	2
	5	Low feed quantity	1	10	10	16	17	22	6	1	2	0.115	5
	6	Low feed quality	2	22	24	23	5	4	2	0	3	0.14	3
	7	poor extension service	0	1	11	21	22	11	4	6	9	0.126	4
	8	Poor feed market access	0	0	0	2	11	15	17	24	16	0.062	8
	9	Poor storage facilities	0	0	0	4	14	18	24	11	14	0.069	7
Low (31)	1	Livestock population	0	1	1	0	1	1	5	8	14	0.049	9
	2	Rainfall shortage	2	2	2	1	4	3	7	8	2	0.089	6
	3	Lack of grazing land	26	4	1	0	0	0	0	0	0	0.195	1
	4	Land degradation	2	11	8	8	1	0	1	0	0	0.156	3
	5	Low feed quantity	0	2	5	4	11	6	2	0	1	0.115	4
	6	Low feed quality	1	11	10	8	0	1	0	0	0	0.162	2
	7	poor extension service	0	0	4	10	8	5	1	0	3	0.11	5
	8	Poor feed market access	0	0	0	0	3	4	10	10	4	0.061	8
	9	Poor storage facilities	0	0	0	0	3	10	5	5	8	0.062	7

Appendix Table 19. Models (formulae) used to estimate different forms of net energy required by the animal

S. n.	Type of energy	Model used	Calculated values for cattle		Calculated values for sheep	
			Growing	Mature	≤1yr	>1yr
1	Net energy for maintenance	$NE_m = Cf_i * (\text{weight})^{0.75}$	17.12	25.33	2.39	3.08
2	Net energy for activity	$NE_a = C_a * NE_m$	6.17	9.12	0.36	0.686
3	Net energy for growth	$NE_g = 22.02 * \left(\frac{BW}{C * MW}\right)^{0.75} * WG^{1.097}$	8.52	9.56	0.145	0.117
4	Sheep (NE of lactation) unknown milk production	$NE_l = \text{Milk} * EV$ (EV= 4.6MJ/kg)				0.157
5	Net energy for work	$NE_w = 0.1 * NE_m * \text{hours}$	13.704	20.264		
6	Net energy for pregnancy	$NE_p = C_{\text{pregnancy}} * NE_m$	1.712	2.533		0.237
7	REM (DE% basis)	$REM = [1.123 - (4.092 * 10^{-3} * DE\%) + (1.126 * 10^{-5} * (DE\%))]$	1.121	1.121	1.121	1.121
8	REG (DE% basis)	$REG = [1.164 - (5.160 * 10^{-3} * DE\%) + (1.308 * 10^{-5} * (DE\%))]$	1.162	1.162	1.162	1.162
9	Y_m (MCF)	Percent of GE in the feed converted to CH_4	3%±1%	4.5%±1%)	4.5%±1.0%	6.5%±1.0%

Source: IPCC (2006); CDR (2011)

Appendix Table 20: Coefficients used to calculate associated energy requirement

S. N.	Coefficients considered	Animal category			
		Growing cattle	Mature cattle	Sheep ≤1year	Sheep >1year
1	Cf_i (MJ/kg day) to calculate NE_m	0.322	0.370	0.236	0.217
2	C_a (activity coefficient, dimensionless)	0.0	0.36	0.024	0.024
3	C_g (coefficient for growth)	1.0	1.2	0.45	0.35
4	C_{work} (coefficient of work) NE_m (MJ/day)	17.13	25.33		
5	EV_{milk} (the energy required to produce 1 kg of milk, MJ kg^{-1})				4.6
6	C_p (coefficient for pregnancy) NE_m (MJ/day)	17.13	25.33	0.077	2.78

Source: IPCC (2006)

Appendix Table 21. Annual rainfall and minimum and maximum temperature data in the mixed farming areas of Bale highlands

Data year	Average minimum temperature	Average maximum temperature	Annual rain fall
1995	7.84	22.14	763.10
1996	7.91	21.98	1007.31
1997	8.31	22.34	896.20
1998	8.40	22.09	926.08
1999	7.91	21.43	916.75
2000	8.09	22.07	802.73
2001	8.36	21.87	819.10
2002	8.95	22.33	648.90
2003	9.00	22.03	891.40
2004	8.77	22.12	777.13
2005	8.62	22.46	855.81
2006	9.06	22.01	840.56
2007	8.87	21.95	857.94
2008	8.56	21.91	827.70
2009	8.96	22.32	748.40
2010	8.98	21.44	1075.95
2011	8.63	21.78	769.20
2012	7.99	21.94	855.30
2013	8.63	21.56	1009.50
2014	8.60	21.57	693.21

Source: compiled from National Meteorological Agency Bale-Robe Branch

Appendix Table 22. Wealth group households' available grazing land use rank in the mixed farming areas of Bale highlands

Wealth groups	Grazing land type	Rank given by respondents					Index	Rank
		1 st	2 nd	3 rd	4 th	5 th		
Better (40)	Communal grassland	7	8	8	13	4	0.216	3
	Private grassland	21	5	3	2	0	0.246	1
	Roadside grazing	2	10	11	6	6	0.180	4
	Fallow land	3	7	6	4	1	0.125	5
	Marginal land	7	10	12	9	2	0.234	2
Medium (85)	Communal grassland	13	12	23	26	5	0.221	2
	Private grassland	35	6	8	2	3	0.218	3
	Roadside grazing	2	3	19	20	7	0.122	5
	Fallow land	15	18	9	2	0	0.172	4
	Marginal land	21	15	24	14	11	0.267	1
Low (31)	Communal grassland	5	6	8	8	1	0.220	3
	Private grassland	10	3	1	0	0	0.159	4
	Roadside grazing	4	7	12	4	2	0.230	2
	Fallow land	4	6	4	0	0	0.137	5
	Marginal land	8	7	6	8	2	0.254	1

Appendix Table 23. Farm level major feeds nutritive value in the mixed farming areas of Bale highlands

Parameters	Feed type	Wealth group			Overall
		Better (40) Mean (SE)	Medium (85) Mean (SE)	Low (31) Mean (SE)	(156) Mean (SE)
ME (MJ/kg DM)	Mixed natural grass	9.39	8.74	8.98	8.96
	Wheat straw	7.52	7.51	7.50	7.51
	Barley straw	8.20	8.16	8.11	8.16
	Emmer wheat straw	7.50	7.48	7.49	7.51
	Teff straw	8.14	7.99	0.00	8.04
	Pulses straw	8.55	8.14	8.34	8.25
	Crop aftermath	6.84	6.84	6.84	6.84
	HMCs	9.78	9.74	9.52	9.70
DCP (g/kg DM)	Mixed natural grass	55.32	46.04	57.72	50.74
	Wheat straw	23.55	24.20	23.21	23.84
	Barley straw	28.57	28.57	28.39	28.53
	Emmer wheat straw	20.95	21.51	21.33	21.33
	Teff straw	29.96	27.27	0.00	28.12
	Pulses straw	49.94	50.12	50.03	50.05
	Crop aftermath	28.75	28.75	28.75	28.75
	HMCs	176.84	174.05	171.53	174.26
RFV	Mixed natural grass	86.79	82.19	94.05	85.73
	Wheat straw	70.42	63.98	57.75	64.39
	Barley straw	65.96	66.92	72.03	67.69
	Emmer wheat straw	57.42	57.97	57.75	57.79
	Teff straw	62.61	61.51	0.00	61.86
	Pulses straw	96.09	95.29	96.67	96.77
	Crop aftermath	53.38	53.38	53.38	53.38
	HMCs	140.89	137.89	136.67	138.42

Appendix Table 24: ANOVA table of household characteristics in the mixed farming areas of Bale highlands

Source of variation		Sum of squares	df	Mean square	F value	Sig.
Respondent age	Between groups	659.55	2	329.77	3.11	0.047
	Within groups	16199.45	153	105.88		
	Total	16858.99	155			
HH family size	Between groups	47.31	2	23.66	5.85	0.04
	Within groups	618.43	153	4.04		
	Total	665.74	155			
Productive age	Between groups	22.98	2	11.49	4.48	0.013
	Within groups	392.17	153	2.56		
	Total	415.15	155			
Unproductive age	Between groups	5.20	2	2.60	1.12	0.33
	Within groups	356.41	153	2.32		
	Total	361.61	155			
Farm experience	Between groups	653.29	2	326.64	3.75	0.03
	Within groups	13311.19	153	87.00		
	Total	13964.48	155			

Appendix Table 25: ANOVA table of household land holding, land use types and cropping pattern (ha HH⁻¹) in the mixed farming areas of Bale highlands

Source of variation		Sum of squares	df	Mean square	F value	Sig.
Land use type						
Grazing land	Between groups	4.27	2	2.133	16.79	0.020
	Within groups	19.49	153	0.127		
	Total	23.76	155			
Cropland	Between groups	90.94	2	45.472	86.94	0.000
	Within groups	79.95	153	0.523		
	Total	170.89	155			
Fallow land	Between groups	0.33	2	0.16	2.32	0.186
	Within groups	10.57	153	0.069		
	Total	10.89	155			
Forage crops land	Between groups	0.27	2	0.14	10.77	0.047
	Within groups	1.96	153	0.013		
	Total	2.23	155			
Rented in/out cropland	Between groups	0.11	2	0.06	0.33	0.730
	Within groups	27.56	153	0.18		
	Total	27.67	155			
Total land holding	Between groups	168.35	2	84.17	18.38	0.000
	Within groups	701.25	153	4.58		
	Total	869.59	155			
Cropping pattern						
Wheat	Between groups	16.56	2	8.28	11.96	0.015
	Within groups	105.83	153	0.692		
	Total	122.38	155			
Barley	Between groups	5.46	2	2.73	16.35	0.013
	Within groups	25.57	153	0.167		
	Total	31.03	155			
Emmer wheat	Between groups	0.41	2	0.204	3.04	0.039
	Within groups	10.21	153	0.067		
	Total	10.62	155			
Teff	Between groups	0.04	2	0.02	0.43	0.679
	Within groups	7.23	153	0.047		
	Total	7.28	155			
Pulses	Between groups	1.62	2	0.81	11.41	0.000
	Within groups	10.89	153	0.071		
	Total	12.51	155			
Oilseed crops	Between groups	0.42	2	0.21	2.56	0.410
	Within groups	9.79	153	0.082		
	Total	8.41	155			

Appendix Table 26: ANOVA table of household level livestock category and herd structure (TLU) in the mixed farming areas of Bale highlands

Source of variation		Sum of squares	df	Mean square	F value	Sig.
Total cattle	Between groups	1733.48	2	866.74	132.73	0.000
	Within groups	998.63	153	6.53		
	Total	2732.12	155			
Cow	Between groups	244.87	2	122.43	122.43	0.000
	Within groups	153.00	153	1.00		
	Total	397.87	155			
Ox	Between groups	268.29	2	134.15	83.32	0.000
	Within groups	246.77	153	1.61		
	Total	515.07	155			
Heifer	Between groups	15.33	2	7.663	25.80	0.000
	Within groups	45.39	153	0.297		
	Total	60.72	155			
Steer	Between groups	17.93	2	8.966	21.55	0.007
	Within groups	63.69	153	0.416		
	Total	81.63	155			
Calf	Between groups	2.67	2	1.335	40.45	0.021
	Within groups	4.97	153	0.033		
	Total	7.65	155			
Sheep	Between groups	2.20	2	1.102	6.68	0.01
	Within groups	25.24	153	0.165		
	Total	27.45	155			
Equines	Between groups	31.82	2	15.91	53.57	0.001
	Within groups	45.44	153	0.297		
	Total	77.26	155			
Horse	Between groups	9.93	2	4.96	35.68	0.046
	Within groups	21.33	153	0.139		
	Total	31.26	155			
Donkey	Between groups	10.99	2	5.498	46.20	0.016
	Within groups	18.16	153	0.119		
	Total	29.16	155			

Appendix Table 27: ANOVA table of household major feed resources and annual dry matter yield (tons) in the mixed farming areas of Bale highlands

Source of variation		Sum of squares	df	Mean square	F value	Sig.
Private grazing	Between groups	72.59	2	36.29	20.74	0.000
	Within groups	268.56	153	1.75		
	Total	341.16	155			
Communal grazing	Between groups	0.001	2	0.0002	0.10	0.900
	Within groups	0.37	153	0.002		
	Total	0.037	155			
Fallow land grazing	Between groups	3.65	2	1.83	4.95	0.008
	Within groups	55.98	153	0.37		
	Total	59.64	155			
Crop aftermath grazing	Between groups	36.39	2	18.19	13.08	0.000
	Within groups	212.33	153	1.39		
	Total	240.72	155			
Cereals straw	Between groups	837.24	2	418.62	22.80	0.000
	Within groups	2809.14	153	18.36		
	Total	3646.37	155			
Pulse straws	Between groups	3.49	2	1.75	4.49	0.012
	Within groups	59.01	153	0.39		
	Total	62.51	155			
Forage crops	Between groups	17.46	2	8.73	10.64	0.016
	Within groups	125.12	153	0.82		
	Total	142.59	155			
Homemade concentrates	Between groups	0.46	2	0.227	56.75	0.042
	Within groups	0.58	153	0.004		
	Total	1.04	155			

Appendix Table 28: ANOVA table of wealth groups' major feeds mean DM (ton), ME (MJ) and DCP (g) content, availability and deficit differences in the mixed farming areas of Bale highlands

Source of variation		Sum of squares	df	Mean square	F value	Sig.
ME content	Between groups	25.76	2	12.88	2146.67	0.000
	Within groups	0.929	153	0.006		
	Total	26.69	155			
DCP content	Between groups	284.14	2	142.07	3738.68	0.000
	Within groups	5.76	153	0.038		
	Total	289.90	155			
RFV (%)	Between groups	1210.24	2	605.12	2373.02	0.000
	Within groups	39.02	153	0.255		
	Total	1249.26	155			
DM availability	Between groups	2039.38	2	1019.69	5073.08	0.000
	Within groups	30.78	153	0.201		
	Total	2070.17	155			
DM deficit	Between groups	6200.83	2	3100.42	18677.23	0.000
	Within groups		153	0.166		
	Total		155			
ME availability	Between groups	113311.00	2	56655.50	54.72	0.000
	Within groups	158418.91	153	1035.42		
	Total	114911.00	155			
ME deficit	Between groups	136611.00	2	68305.5	15.85	0.000
	Within groups	659033.43	153	4307.41		
	Total	136611.00	155			
DCP availability	Between groups	1816464.18	2	908232.09	6015.57	0.000
	Within groups	23100.42	153	150.98		
	Total	1839564.43	155			
DCP deficit	Between groups	40039690.3	2	20019845.1	12615.14	0.000
	Within groups	242807.24	153	1586.97		
	Total	40282497.6	155			

Appendix Table 29: ANOVA table of Household level estimated enteric CH₄ (kg/year) emissions in the mixed farming areas of Bale highlands

Source of variation		Sum of squares	df	Mean square	F value	Sig.
Emission factors						
Mature cattle	Between groups	25.170	2	12.57	245624.24	0.000
	Within groups	0.008	153	0.000		
	Total	25.178	155			
Growing cattle	Between groups	6.542	2	3.27	2068.5329	0.025
	Within groups	0.002	153	0.000		
	Total	6.544	155			
Sheep > 1 year	Between groups	0.137	2	0.069	108536.19	0.010
	Within groups	0.000	153	0.000		
	Total	0.137	155			
Sheep up to 1 year	Between groups	0.069	2	0.034	54538.94	0.020
	Within groups	0.000	153	0.000		
	Total	0.069	155			
Horse	Between groups	0.000	2	0.000		
	Within groups	0.000	153	0.000		
	Total	0.000	155			
Donkey	Between groups	0.000	2	0.000		
	Within groups	0.000	153	0.000		
	Total	0.000	155			
Emission rates						
Mature cattle	Between groups	2209230.68	2	1104615.3	202.99	0.000
	Within groups	832574.93	153	5441.66		
	Total	3041805.61	155			
Growing cattle	Between groups	294637.09	2	147318.55	76.76	0.000
	Within groups	293637.61	153	1919.20		
	Total	588274.70	155			
Sheep > 1 year	Between groups	726.03	2	363.01	4.63	0.000
	Within groups	11995.84	153	78.40		
	Total	12721.87	155			
Sheep up to 1 year	Between groups	199.62	2	99.81	5.26	0.000
	Within groups	2905.61	153	18.99		
	Total	3105.23	155			
Horse	Between groups	7565.40	2	3782.70	51.68	0.000
	Within groups	11199.59	153	73.2		
	Total	18765.00	155			
Donkey	Between groups	5430.00	2	2715.00	63.15	0.000
	Within groups	6577.69	153	42.99		
	Total	12007.69	155			

Appendix Table 30: ANOVA table of household level estimated manure CH₄ (kg/year) emission in the mixed farming areas of Bale highlands

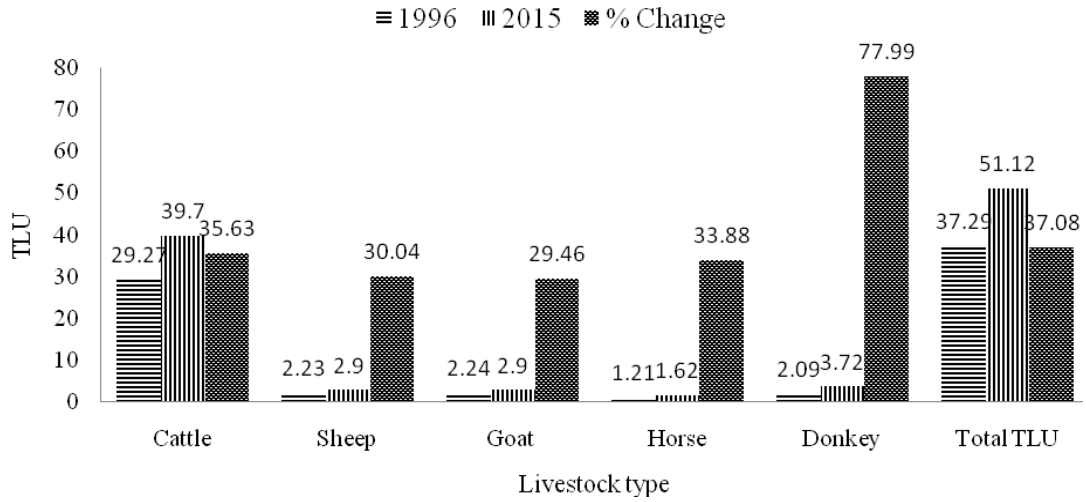
Source of variation		Sum of squares	df	Mean square	F value	Sig.
Cattle	Between groups	4281.34	2	2140.67	188.11	0.000
	Within groups	1741.26	153	11.38		
	Total	6022,61	155			
Sheep	Between groups	5.77	2	2.88	5.68	0.033
	Within groups	77.79	153	0.507		
	Total	83.57	155			
Horse	Between groups	62.80	2	31.40	51.64	0.016
	Within groups	92.97	153	0.608		
	Total	155.77	155			
Donkey	Between groups	43.98	2	21.99	63.19	0.012
	Within groups	53.28	153	0.348		
	Total	97.26	155			

Appendix Table 31: Land use/Land covers classification of the mixed farming districts of Bale Zone

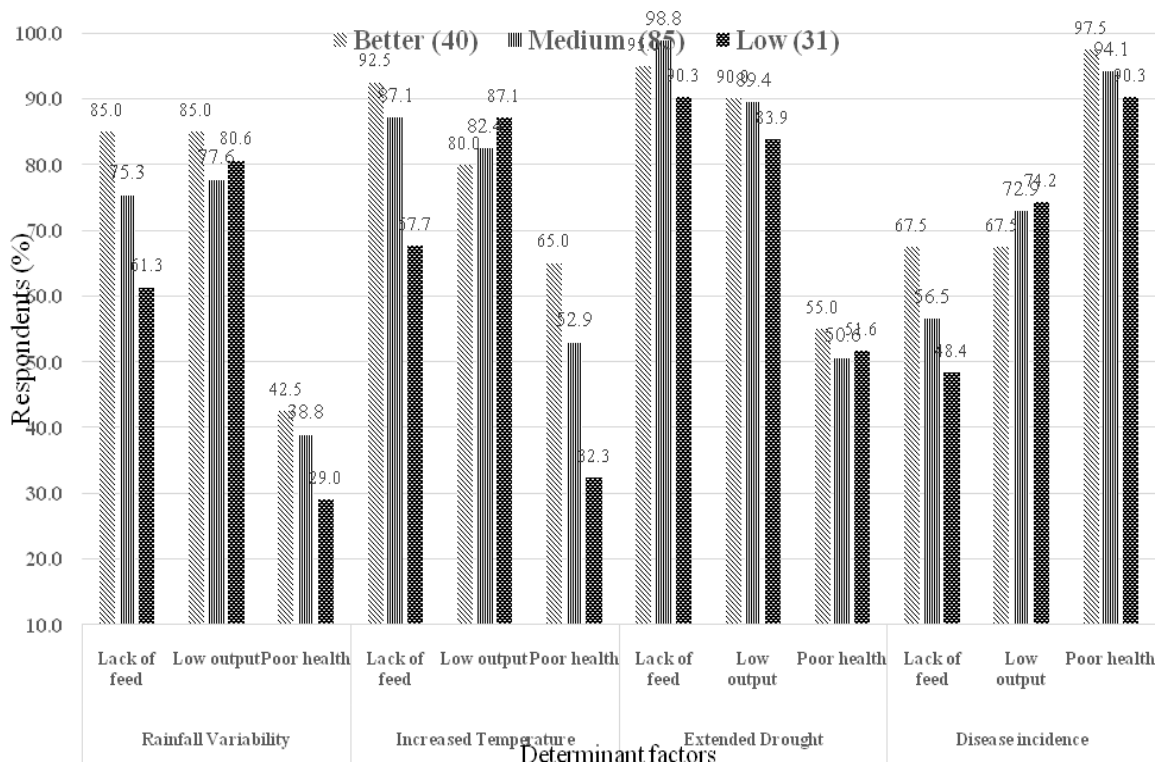
S.N.	Land use/Land cover type	Area (ha) cover	Percent (%) cover
1	Bush-Shrub Land	1535680.19	60.01
2	Cultivation Land	547756.30	21.40
3	Forest Land	352877.22	13.79
4	Grass Land	8181.86	0.32
5	Others*	114553.40	4.48
Grand Total		2559048.97	100.00

* = Afro-alpine, settlement, exposed rock surface and soil surface

8.2. Figures in the Appendices



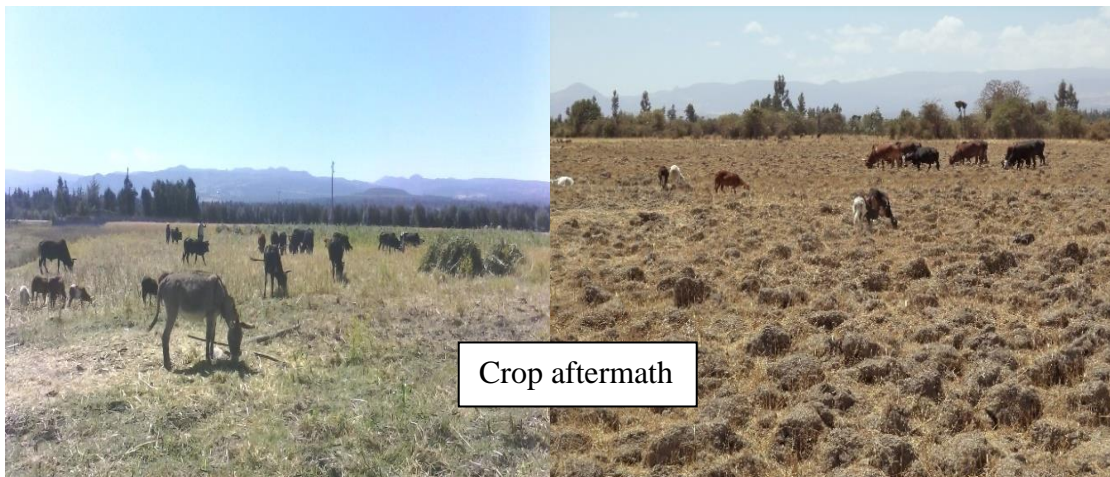
Appendix Figure 1. Bale Zone livestock population (TLU) change between 1996-2015



Appendix Figure 2. Respondent's observation of climate factors direct/indirect implication to livestock production in the mixed farming areas of Bale highlands (%)



Appendix Figure 3. Manure management and utilization types in the mixed farming areas of Bale highlands



Appendix Figure 4. Livestock grazing crop aftermath in dry period in the mixed farming areas of Bale highlands



Appendix Figure 5. Backyard straw feeding methods in the mixed farming areas of Bale highlands



Appendix Figure 6. Livestock under restricted grazing on marginal lands in the mixed farming areas of Bale highlands



Appendix Figure 7. Straw conservation and storage system during surplus period in the mixed farming areas of Bale highlands

8.3. Published Articles

1. The status of livestock husbandry practices and major production constraints in the potential mixed farming system districts of Bale highlands, Southeast Ethiopia. *American-Eurasian Journal of Scientific Research 11 (6): 426-436, 2016*. DOI: 10.5829/idosi.aejsr.2016.426.436.

Available online: <http://www.idosi.org>

Girma Defar, Ashenafi Mengistu and Gebreyohannes Berhane

2. Farmers' perceptions of climate change and its implication on livestock production in mixed farming system areas of Bale highlands, Southeast Ethiopia. *E3 Journal of Agricultural Research and Development Vol. 7(2). pp. 092-0102, April, 2017*.

DOI: [http://dx.doi.org/10.18685/EJARD\(7\)2_EJARD-16-027](http://dx.doi.org/10.18685/EJARD(7)2_EJARD-16-027)

Available online: <http://www.e3journals.org>

Girma Defar, Ashenafi Mengistu and Gebreyohannes Berhane

8.4. Questionnaires Used for the Study

Primary data collection format

Part-I: *General information on household characteristics and resource holding*

Section A: *household characteristics*

1. Household Head Name: _____ Sex: _____ Age: _____ *Kebele* _____
 HH mobile: _____.

2. Marital status (Single, Married, divorced, widowed) and total number of family members' ____ (Male _____, Female _____).

3. Age category of the family members:

	Children (≤ 14 years)	Adult ($\geq 15- 64$ years)	Dependents (>65 years)
Total family members			

4. Education level of the respondent: Tick (X)

Illiterate	Read & write	Primary (1- 6)	Secondary (grade 7- 10)	Preparatory & above

Section B: *farming activities and resource holding*

1. How many years you have been in crop-livestock farming? _____.

2. Land holding and land used for different agricultural activity (*timad*):

	Grazing	Crop	Fallow	Forage crops	Forest	Rented in/out cropland	Total land
Timad							

3. If you have the rented in/out land, what type of crop/s is/are planted? _____
 _____.

4. Fill the table below with the proportion of shared grain and crop residues:

Grain %	Residue %

5. What is the area of land (*timad*) utilized for major food crops you grown in the current year?

	Wheat	Barley	Emmer wheat	Teff	Maize	Pulse	Oil crops	Vegetable	Total land
Short rainy season									
Main rainy season									
Irrigation									

6. Amount of grain yield (*quintal*) and residue obtained from major crops of the current year:

	Wheat	Barley	Emmer wheat	Teff	Maize	Pulse	Oil crops	Vegetable
Short rainy season								
Main rainy season								
Irrigation								
Residue (ton)								

7. Cattle owned and the herd structure (number):

	Lactating cow	Dry cow	Oxen/bull	Heifers	Steers	Calves
Number						

8. Sheep and goat owned and the herd structure (number):

	Ewe/doe	Ram/buck	Weaned female sheep/goat	Male lamb/kid
Sheep				
Goat				

9. Equines owned (number):

	Horses	Mules	Donkey
Number			

Part-II: *Livestock husbandry system and resource utilization*

Section-A: *routine livestock husbandry related activities*

1. Livestock husbandry practice (Encircle): a. extensive, b. intensive, c. semi-intensive

2. Indicate the labour division of the livestock rearing or management (Tick X):

S. N.	Livestock managing activity	Children (≤ 14 years)			Adult ($\geq 15-64$ years)		
		Girls	Boys	Hired	Women	Men	Hired
1	Herding & watering						
2	Milking						
3	Barn cleaning						
4	Stall feeding						
5	Sick animal handling						
6	Breeding (AI/natural)						
7	Tethering on grazing area						

3. For what purpose you are herding the livestock? (Tick X)

	Cow	Traction	Meat	Transport	Saving	Replacement	Sale	Manure	Others
Cow									
Oxen/bull									
Steers									
Heifers									
Shoat									
Equines									

4. What type of housing is used for your livestock? (Tick X)

	Open kraal	Family house attachment	Separate house/shade
Cows and oxen			
Heifer and steer			
Calves			
Shoat			
Horse and mule			
donkey			

5. Ways of livestock manure management and use type? (Tick X)

	Collected & managed	Left in the kraal	Made to dung cake	Discarded	Used as fertilize	Other purpose
Cattle						
Equines						
Shoat						

6. Major sources of livestock drinking water across the seasons (rank 1-6):

	River	Pond	Hand dug well	Spring	Tap water	Others
Dry season						
Wet season						

7. Livestock watering frequency practiced during the dry and wet season: (Tick X)

Season	Livestock	Free available	Once daily	One day interval	More days interval
Dry	Cattle				
	Shoat				
	Equines				
Wet	Cattle				
	Shoat				
	Equines				

8. If there is water scarcity, what measures taken to alleviate the problem? (Encircle the possible answers): a. migration to water sources, b. water conservation, c. destocking, d. others

Section B: *livestock disease and health related issues:*

1. Do you have encountered the death of animals in the course of the 20 years of livestock production experience? 1. Yes 2. No

2. If yes, what are the main causes of your livestock death? (Tick X)

	Sporadic disease	Feed shortage	Drought	Water scarcity	Ecto-parasite	Endo-parasite	Other
Cattle							
Sheep							
Goat							
Equine							

3. How did you treat sick animals? (Encircle): a. scientific way, b. traditionally

4. What are the most common infectious livestock diseases in the area? (Tick X):

Livestock type	Name of livestock disease									
	Anthrax	Black-leg	AHS	Rabbis	FMD	Lymphangitis	Pasteurellosis	Brucellosis	CBPP/CCPP	Others
Cattle										
Sheep										
Goat										
Horse										
Donkey										
Mule										

5. What are the major constraints to treat sick animals in scientific way? (Tick X):

Lack animal health technicians	Lack veterinary clinics	Lack of money	Drugs not available	Others

6. Do you have access to veterinary services in your *kebele*? 1. Yes 2. No

7. If yes, what type of veterinary services found in your *kebele*? (Tick X):

Government	Private	Drug Shop	Others

8. Is there vaccination service in during disease outbreaks? 1. Yes 2. No

9. If no, what is/are the reasons? (Tick X):

Vaccination is expensive	Vaccine is not available	No technician	. Others

Section C: livestock reproduction aspects

1. Indicate accordingly the breeding characteristics exist in the herd for the mentioned livestock species.

Breeding parameters		Cattle	Shoat	Equine
1	Average age at sexual maturity (in years)			
2	Average age at 1 st calving, lambing & kidding (years)			
3	Days open (parturition to conception) (months)			
4	Average calving, lambing & kidding interval (months)			
5	Average calf/lamb/kid born per life time			

2. How many months' female animals stay to come in to heat after parturition? (Tick x)

Livestock category	1-3	3-6	6-9	9-12	More than 12
Cattle					
Shoat					
Equines					

3. How is the growth rate of the animals? (Encircle): a) high b) moderate c) slow

4. What is the main reason for keeping male cattle (ox/bull)? (Encircle): a. mating, b. cultural value, c. draft/work, d. fattening, e. others _____

5. For how long does the lactating cow milked from birth to weaning? (Tick X):

≤ 6 months	6 to 12 months	> 12 months

6. Average daily milk yield per cow per lactation period in liters? (Tick X):

≤ 0.5	0.5 to 1	> 1

7. Rank (1-6) major problems associated with livestock production you have been encountered in the recent years?

	Feed & grazing scarcity	Low output	Disease prevalence	Labor scarcity	Water scarcity	Unreliable weather	Others
Cattle							
Shoat							
Equines							

Part-III: Livestock feed sourcing and feeding system management

Section I: Livestock feed sourcing

1. Which type of grazing land more frequently used by your animals? (Rank 1-5, 1 is most important)

	Communal	Private	Roadside	Fallow	Marginal land
Rank					

2. Feed resources utilized by the herd structure at your farm? (Rank 1-6, 1 is most important):

	Natural grass	Cereal residue	Pulses residue	Crop aftermath	Forage crops	Homemade concentrate	Others
Cows & Oxen							
Steer & heifer							
Calves							
Sheep							
Goats							
Equines							

3. Which feed resources are available during the months of the year at your farm (feeding calendar)? (Tick X)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Natural grass												
Cereal residue												
Pulses residue												
Crop aftermath												
Forage crops												
Concentrates												

4. Where did you get concentrate? a. homemade, b. purchase, c. other (specify)

_____.

5. Which animals more frequently supplemented with concentrates? _____

6. If there is feed shortage, what are the observed problems on your livestock? (Encircle):

a. Weight loss, b. Milk yield reduction, c. Increased mortality, d. others (specify)

_____.

7. What measures taken to alleviate the problem of feed shortage? (Tick X)

Feed preservation	Forage crop production	Buy concentrate	Rent grazing land	Destocking	Others

8. Which animals do you give to other person to overcome feed shortage & what is the agreement?

Type of animal	Agreement
Cow	
Ox/bull	
Steer/heifer	
Shoat	
Equines	

Section B: *crop residues management and utilization*

1. Major crop residues (straws) produced from the crop farm: (Rank 1-7, where 1 is residue produced in large quantity):

Crop type	Wheat	Barley	Emmer wheat	Teff	Maize	Pluses	Oil seeds	Others
Rank								

2. Major crop residues used as feed for your livestock: (Rank 1 - 7 & 1 is more preferred by animal):

Crop straw	Wheat	Barley	Emmer wheat	Teff	Maize	Pluses	Oil seeds	Others
Cattle								
Sheep								
Goat								
Equines								

3. Crop residue management (preservation method & the type of crop residue) tick X:

Ways of residue management	Sources of crop residue			
	Cereals	Maize	Pulses	Oil seed crops
Crop residue stored				
Heap (with shade, no shade)				
Feeding period (dry/wet season)				

4. For what purpose do you use crop residues other than livestock feeding?

Uses type	Sources of crop residue			
	Cereals	Maize	Pulses	Oil seed crops
Fuel				
House plastering				
Left as mulch				
Sold				
Compost making				
Wasted				
Others				

5. Are there large scale (state or investment) farms in the area? 1. Yes 2. No

6. If you produce crop by irrigation, what are the crop produced by irrigation?

Area of used land (<i>timad</i>)	Crop type	Grain yield (<i>quintal</i>)	Total residue yield (kg)

7. Do you practice improved forage crops production ever? 1. Yes 2. No

8. If yes, what are the species of forage crops produced?

Species	Local name of varieties	Area covered by forage (Timad)
Grasses		
Legumes		
Fodder trees		

9. Mention major feed sourcing and feeding system constraints (Rank 1– 9, 1 is most important):

Constraints	Rank	If any opinion
High livestock population		
Rainfall shortage		
Lack of grazing land		
Land degradation & low biomass yield		
Low quantity of feed across seasons		
Low quality of feed across seasons		
Lack of extension services		
Poor access to feed market		
Poor feed storage facilities/techniques		

10. Is there grazing system difference during wet and dry season? 1. Yes 2. No

11. If yes, how? _____

12. Do you think forage plant species decreased for the last 20 years? 1. Yes 2. No

Part-IV: *Farmers perceptions of climate variability*

Section A: *farming type and condition*

1. What type of farming you are practicing? (Encircle): a. Rain-fed, b. Irrigation, c. both

2. Do you have an access to information about agriculture in the recent years?

1. Yes 2. No

3. If yes, from which electronic media you accessed it? (Encircle, possible more than one): a) Radio/TV, b) newspaper, c) academic institutions, d) government office (extension agents)

4. In which fertility category do you classify your farm land & amount in timad? (Tick X)

	Infertile (unproductive)	Less fertile	Fertile
Level of fertility			

5. If your farm land is infertile or less fertile, what is/are the reasons?

_____.

6. How productive (crop & pasture) is your land? (Encircle): a. High, b. Medium, c. Low

7. How productive are your livestock in the course of the last 20 years of farming? (Encircle): a. High, b. Medium, c. Low

Section B: *climate variability perception assessment*

1. Is current years' weather condition the same as the weather of 20 years ago?

1. Yes 2. No

2. What do you say about the seasonal temperature trends over the last 20 years? (Tick X)

	Increased	Decreased	The same	I don't know
Hotness of the days				

3. What do you say about the seasonal rainfall (moisture) over the last 20 years? (Tick X)

	Increased	Decreased	Unpredictable	The same
Rainfall				

4. Is there any variability in timing of rain? 1. Yes 2. No

5. If yes, when did the rain starts? a. early of the season, b. late in the season, c. unpredictable

6. What happen to the land size, productivity of livestock and crop in the last 20 years? (Tick X)

	Increasing gradually	Decreasing gradually	No change
Livestock population			
Livestock productivity			
Cropland size			
Grazing land size			
Grazing land productivity			

7. Have you heard of the word “climate change” ever before? 1. Yes 2. No

8. What do you think is the cause of climate change? (Tick X)

Human actions	Natural process	I don't know	Others

9. Did you think that livestock production have an effect on climate change?

1. Yes 2. No

10. If yes, mention the mechanisms by which the livestock affected climate:

- a. _____,
- b. _____,
- c. _____,
- d. _____,
- e. _____,

11. Your observations of climate change based on the assumed indicators variability for the last 20 years: (Tick X)

Variables (indicators)	Assumed degree of change			
	Increased	Decreased	Constant	Unsure
Rainfall amount				
Rainfall timing (onset to termination)				
Temperature				
Frequency of drought				
Incidence of livestock diseases				
Crop growth cycle (duration)				

12. What happen to your livestock possession and composition for the last 20 years? (Tick X)

	Cattle	Sheep	Goat	Equines
Increased				
Decreased				
No change				

13. Have you faced the livestock water and feed scarcity in the last 20 years?

1. Yes 2. No

14. Which options you were used in times of livestock drinking water shortage? (Encircle, possible more than one): a. hand dug wells, b. migrate to water areas, c. other (specify) _____.

15. Which options you has been used to alleviate feed scarcity? (Encircle, possible more than one): a. alternative feeds, b. cut & carry system, c. taking animals to other places, d. selling animals, e. other _____.

16. Which measures you took within the last 20 years, to adapt the changing climate to keep optimum farm productivity? (Rank 1 - 4, where 1 is most important adaptation measure)

	Change animal species/breed	Decrease animal number	Change crop varieties	Conservation structure	Others

17. Farmers perception's of climate variability coping/adaptation strategies in relation to livestock production:

Perception of climate variability	Perceived effect on livestock	Responses (adjustments) to cope or adapt the effect
Decreased and unpredictable rainfalls	Lack of fodder/feed	
	Low animal output	
	Livestock deaths (poor health)	
Increased temperature	Lack of fodder/feed	
	Low animal output	
	Livestock deaths (poor health)	
Extended frequency of droughts	Lack of fodder/feed	
	Low animal output	
	Livestock deaths (poor health)	
Increasing incidence of animal disease	Lack of fodder/feed	
	Low animal output	
	Livestock deaths (poor health)	

18. In general, how did you express climate change? _____

 _____.

Thank you in advance for your cooperation!