Small-holder farms livestock management practices and their implications on livestock water productivity in mixed crop-livestock systems in the highlands of Blue Nile basin: A case study from Fogera, Diga and Jeldu districts (Ethiopia).

MSc Thesis

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HAWASSA UNIVERSITY

College of Agriculture

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Small-holder farms livestock management practices and their implications on livestock water productivity in mixed crop-livestock systems in the highlands of Blue Nile basin:
A case study from Fogera, Diga and Jeldu districts (Ethiopia).

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I dedicate this thesis manuscript to my wife EMEBET JEMANEH and our children YEMICHAEL, DAGMAWI and LEYOUWORK for nursing me with affection and love and for their dedicated partnership in the success of my life.

STATEMENT OF AUTHOR

First, I declare that this thesis is my own work and that all sources of materials used for this thesis have been duly acknowledged. This thesis has been submitted in partial fulfillment of the requirements for M.Sc. degree at Hawassa University and is deposited at the university library to be made available to borrowers under rules of the library. I solemnly declare that this thesis is not submitted to any other institution anywhere for the award of any academic degree, diploma, or certificate.

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LIST OF ABBREVIATIONS

ACA	Awassa College of Agriculture
AFC	Age at First Calving
AI	Artificial Insemination
ARR	Annual Reproductive Rate
BNB	Blue Nile Basin
CPWF	Challenge Program on Water and Food
CR	Calving Rate
CSA	Central Statistic Authority
CWR	Crop Water Requirement
DM	Dry Matter
EARO	Ethiopian Agricultural Research Organization
EPA	Ethiopian Privatization Agency
ET	Evapotranspiration
ETB	Ethiopian Birr
ET_o	Reference Evapotranspiration
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
GP	Growth Period
Ha	Hectare
HH	Household
HU	Hawassa University
ILCA	International Livestock Centre for Africa
ILRI	International Livestock Research Institute
Kc	Crop Coefficient
LSM	Least Squares Means
LWP	Livestock Water Productivity
m.a.s.l.	Meter Above Sea Level
MoA	Ministry of Agriculture
NBDC	Nile Basin Development Challenge
SAS	Statistical Analysis
SD	Standard Deviation
SE	Standard Error
SGS	School of Graduate Studies
SPSS	Statistical Package for Social Sciences
TLU	Tropical Livestock Unit
USD	United States Dollar

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Small-holder farms livestock management practices and their implications on livestock water productivity in mixed crop-livestock systems in the highlands of Blue Nile basin:
A case study from Fogera, Diga and Jeldu districts (Ethiopia).

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Abstract:

The study pertains to livestock management practices & their implications on Livestock Water Productivity (LWP) in the rain-fed crop-livestock systems in the Blue Nile Basin (BNB). Seven farming systems (Rice-Pulse & Teff-Millet from Fogera), (Barley-Potato, Teff-Wheat & Sorghum farming systems from Jeldu) & (Teff-Millet & Sorghum farming systems from Diga districts) were selected & a total of 220 sample Household (HH) heads were involved. Cattle were the major livestock species accounting for 83% of the total Tropical Livestock Unit. The preference of livestock species was in the order of Oxen, cows, sheep, goats & equines. Invariably across the study areas oxen were reared for the purpose of traction, income source & manure. The main purpose of keeping cows, sheep/ goats & equine were replacement, income sources and transportation, respectively. The main objective of integrating livestock into crop is mainly traction services. Farmers' production objective is not market oriented & they are more focused on assisting crop production. Farmers in most farming systems keep cattle in the traditional Kraal system (enclosure without roofing). This affects animals' physiology in extreme weather conditions thereby lowers LWP. Relatively better (68-83%) housing system (housing with roofing) was exercised in Barley-Potato & Teff-Wheat systems of Jeldu. Most HHs (57-100%) depended on river water sources for livestock drinking. Distance & quality of water were among the major problems raised by farmers. Most (97.3%) sample farmers practice natural mating for their livestock. They also select breeding animals based on their memory instead of performance recording. Much emphasis was put on physical appearance & color, respectively. Culling performed by farmers was very incomplete for it was not accompanied with performance recording. Breeding females were maintained in the herd for older age until reproductive performance nearly ceased. Lower milk yield & shorter lactation lengths, higher age at mating & calving, longer parturition intervals for female animals & higher age at first effective mating for breeding purposes by the bulls, jack & stallion were observed. Variability in performance within species observed between & among farming systems in this study are major indicators of potential to improve productivity & thereby LWP. Major livestock production constraints in the study farming systems were feed shortage, disease occurrence & shortage of initial capital. Higher mortality & low off-take rates for different livestock species were observed. Most important reasons for mortality rates were: disease, bloat & feed shortage. The mere management intervention in the time of harvesting & feeding of the local clovers & sorghum tillers could enable reduce mortality of cattle up to 40% at Jeldu. Average distance to get veterinary services was 9.6 km. Only 21 & 9% HHs get access to improved seeds & credit for livestock improvement, respectively. Mortality & morbidity affects LWP in two major ways: it reduces the efficiencies of the services & productivity of livestock. Secondly when animal dies water invested to feed the animal will be lost. This is important in view of the increasingly scarce agricultural water. Values of LWP across the study systems were lower & the differences among systems were not as such apparent. Lower LWP values were registered for relatively poor HHs (0.08 USD m^{-3}) at Sorghum Diga & Barley-Potato farming systems of Jeldu districts. Highest (0.24 USD m^{-3}) LWP value at HH level was registered for better-off farm clusters. More interesting is a huge gap between the minimum (0.001) & maximum values (0.627 USDm^{-3}) of LWP. In view of this it can be concluded that there is huge potential to improve LWP in mixed crop livestock systems of the BNB. Although understanding the determinants of these variability are important future research policy options that increase farmers access to key livelihood resources is important. Future crop livestock integration must consider not only a short term economic return but long term environmental sustainability. Improving the production potential of local breeds through the different livestock management practices & reducing feed scarcity through food-feed integration adjoined with improved livestock & feed management, better veterinary access & improved extension service could be possible suggestions to lift up the current low livestock productivity and LWP.

1. Introduction

1.1. Problem statement

Livestock are reared by the small holder farmers as means for wealth accumulation and storage food (nutritional security), draught power, manure, and serving towards social cohesiveness besides many times they are used for faunal medicine amongst some ancient societies. In many situations, the "livestock ladder" may allow the poor to escape out from the vicious cycle of poverty. Descheemaeker et al. (2010) observed that the earliest signs of food adequacy are mainly associated with the procurement of a few fowls, followed by small ruminants, bovines etc. Livestock production provides a constant flow of income and reduces the vulnerability of agricultural production especially under the present context of global climate change. Tilahun (2010) reported that the draught animals still provide more than 80% of the power used for farming in Sub-Saharan Africa. Livestock play an important role in nutrient recycling and to maintain the soil fertility by balancing the carbon to nitrogen ratio and redistributing nutrients between and within the agro eco systems. Tilahun (2010) further observed that currently about 53% of the agricultural capital stock, 30% of the GDP and 70% of the human population in Africa depend on livestock. The share could be even higher in major livestock rearing countries like: Ethiopia, Sudan, Nigeria and Tanzania. Moreover, the contribution of livestock to the African economies is expected to rise as the demand for livestock products is expected to increase by 4.2% annually (Tilahun, 2010).

Almost the entire rural population of Ethiopia are directly or indirectly associated with livestock husbandry practices. According to CSA (2011) the livestock sector within the country has a great potential to assist the economic development of the country, the estimated livestock population comprises of approximately: 52.13 million Cattle; 24.2 million Sheep; 22.6 million Goats; 1.96 million Horses; 6.4 million Donkeys; 0.37 million Mules; 0.99 million Camels; 44.89 million Poultry; and 4.99 million Beehives (CSA 2011). Livestock are distributed throughout the country, with the highest concentration in the highlands. However, the rearing of livestock always has been largely a subsistence activity.

Ethiopia has an immense potential for increasing livestock production, both for local use and for export purpose. However, expansion and productivity was constrained by inadequate and imbalanced nutrition, sporadic disease outbreak, scarcity of water, lack of appropriate livestock extension services, insufficient and unreliable data with which to plan the services, and inadequate information on how to improve animal performance, marketing, processing and ways of suitable integration with crop and natural resources for sustainable productivity and environmental health (Aynalem et al., 2011).

Water, for agricultural activities besides consumption of human and animals is increasingly becomes a limiting factor. It is a scarce resource in most parts of Ethiopia including the BNB. Mekete (2008) and Semira (2009) reported that this is especially crucial during the eight dry months, in most parts of the country, extending from October to May. The observation of Semira (2009) further indicates that livestock products play an important role in social food security issues of the inhabitants. However, they are often overlooked in planning research and interventions that involve livestock's efficient uses of the scarce water resources.

The study of Zinash et al. (2003) reveals that on an average a TLU of livestock consumes about 25 liters of water on a daily basis. But this constitutes only small fraction of its daily water requirement. Peden et al. (2007); Amare et al. (2009 a;b) and Van Breugel et al. (2010) suggested that the water consumed directly by livestock amounts to only 2% of the total water used to provide products and services under small-scale mixed farming systems. Studies by Peden et al. (2003) indicate that the prime user of water resources (for livestock production) is for the production of feed. On the other hand, the key constraint to livestock production in Ethiopia is attributed to seasonal feed shortage, the production of which is often dependent on rainfall. Therefore, with increasing demand for livestock products it is anticipated that there will be increase of pressure on already scarce water resources.

Thus, there is an urgent need to improve agricultural productivity and proper management of already scarce water resources for livestock production. Proper management of scarce resources is important to secure both the livelihood of smallholders and the sustainability of the environment as a whole (Molden et al., 2010).

Water productivity measures the ability of agricultural systems to convert water into food and feed; this can be defined as the ratio of agricultural outputs to the volume of water depleted for its production (Molden et al., 2010). There are two general driving factors of livestock water productivity: the impact of livestock on water resources depletion in the process of feed production and the efficiency with which the different livestock management practices help to convert this invested water, to produce feed, into useful products. The present research focuses on the livestock management aspects. It hypothesizes that smallholders' livestock management practices are system specific and dependent on both biophysical and social cultural factors. Therefore, a closer look and understanding on how the livestock management is practiced and what it implies in terms of water productivity, ecosystem services and livelihood capital of smallholder farmers is crucial steps in designing a comprehensive strategy to improve LWP.

1.2. General Objective

- § The overall objectives of this work were to investigate how livestock management across the system varies and how it affects livestock water productivity.

1.2.1. Specific objectives

- § To describe the current livestock management practices in different farming systems of the Blue Nile Basin;
- § To analyze and contextualize implications of current livestock management on livestock water productivity, ecosystem services and livelihood capital and;
- § To identify system specific intervention options that could improve livestock water productivity, livelihood and ecosystem services.

1.3. Research questions

The present research attempts to answer the following research questions:

1. How do current livestock management practices vary across selected smallholder farming systems?
2. How does livestock management influence livestock water productivity (LWP)?
3. What are the impacts of emerging livestock management practices on LWP?

2. Literature Review

2.1. Livestock in rain fed system: what for the livestock water productivity?

2.1.1. Beneficial Output and Livestock Water Productivity

Livestock water productivity (LWP) is defined as the ratio of livestock products and services (such as meat, milk, traction, hides, manure) expressed in monetary units to the water depleted in producing them (Amare et al., 2009a; Tilahun et al., 2009; Peden et al., 2007) (Figure 1).

LWP can be assessed at different scales including animal (Solomon et al., 2009), household (Amare et al., 2009b), farming system (Amare et al., 2009a;b), and the catchment or basin scale (Cook et al., 2009). Reported values of LWP vary from 0.3 to 0.6 USD m^{-3} for animals (Solomon et al., 2009) and from 0.1–0.6 USD m^{-3} for farming systems (Amare et al., 2009a;b). Semira et al. (2011) and Mekete (2008) also suggested LWP values of 0.07-0.09 and 0.06-0.08 USD m^{-3}, respectively. The same authors also reported the beneficial output values of 7488-9422 and 4377-6600 ETB /HH /year, respectively.

Agricultural development including better animal husbandry and sustainable utilization of ecosystem elements and improved livelihoods could be achieved through improving the LWP. The observation of Tilahun et al. (2009) and Peden et al. (2007) suggested that improving feed sourcing, enhancing animal productivity and conserving water could be some of the major strategies.

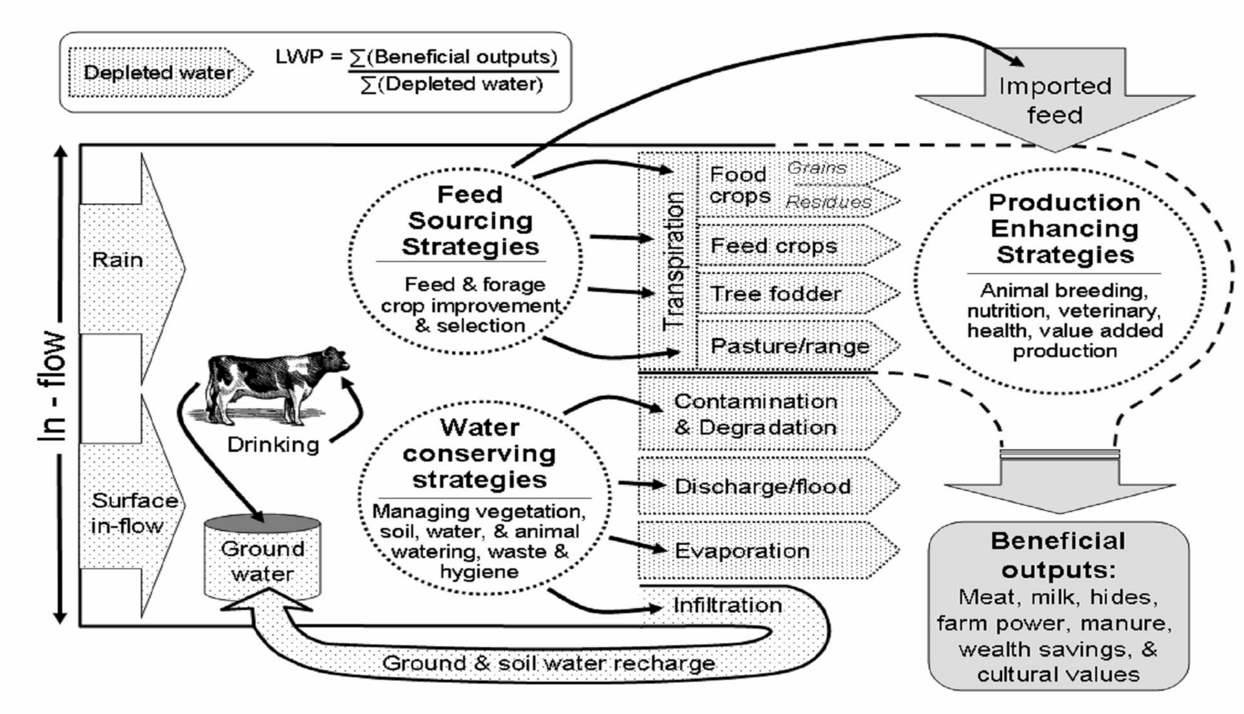

Figure 1: Simplified framework for assessing livestock-water productivity can help identify options to reduce water depletion associated with animal keeping and increase goods and services derived from them (Peden et al., 2007).

2.1.2. Does only crop-livestock integration/association matters?

Mixed crop-livestock systems dominate in the BNB and are important in terms of area and contribution to people's livelihood (Descheemaeker et al., 2011; Amare et al., 2009a). In these systems, there are complementarities of the inputs and outputs of the crop and animal enterprises thus assisting the resource challenged farm households in securing their livelihood. Mixed crop-livestock production is carried out primarily to maximize the returns from their limited land and capital resources and minimizes the risks associated with crop production through diversification of the various sources of income. The question here is whether the prevailing agricultural practices and integration/association of crop livestock objectively targets efficient use of already limited water resources (Figure 1). Descheemaeker et al. (2010) also reported that livestock can play critical roles to support the communities involved in the mixed crop-livestock production systems through a range of products and services. The major products obtained from livestock include draught power, meat, milk, eggs and manure. It was further elaborated by Ali et al. (2011) that these livestock derived products and services serve as a financial reserve thus offering an alternative source of income in the face of uncertain crop production.

The studies by Rao and Hall (2003); (cited by Semira (2009) indicate that integration of food-feed crops in mixed systems can contribute significantly to assist in both human and animal nutrition. It also optimizes the usage of transpired water within the cropping system. Strategies to increase the dual purpose efficiency of these crops are aimed towards enhancing the nutritive value of the crop residues and to integrate food-feed legumes with cereal crops. The use of crop residues, coupled with the cultivation of fodder crops and purchased feed, can facilitate the transition from open grazing to a system of stall-feeding. The observation of Amare et al. (2011a) indicates that improvements in water productivity of livestock are positively correlated with its share (on percentage basis) of crop residues in a diet.

Similar observations were also made by Descheemaeker et al. (2011), they suggested that productivity of livestock is strongly linked to the water productivity of the feeds they consume. In a study by Amare et al. (2011a), it was learned that feeding concentrate to livestock depleted the least volume of water followed by feeding crop residues. But as feed is only one part of the livestock water productivity equation, further questions as to whether:

- Farmers' production objectives in the different systems support the ideas and practices for efficient uses of water productive feeds?

- The current herd composition and structure support the principles of efficient uses of the water productive feeds?
- Are there sufficient grass root level veterinary services to tackle problems of livestock mortality and morbidity, whereby a few livestock can equivalently produce what many are producing now?
- Current practices encourage multiple uses of livestock such as cows for traction and milk, horses for transport and cultivation?

2.1.3. Overview of livestock productivities: Challenges and opportunities to improve livestock water productivity

The dominant livestock species in the study area include cattle (*Bos indicus*), sheep (*Ovis aries*), goats (*Capra hircus*), donkey (*Equus asinus*) and horse (*Equus caballus*). They serve multiple roles such as source of milk, meat and traction besides social bonding amongst the communities. Their present productivity most often reported as low. However there is still immense scope to improve their economic contribution, which may be improved by within breed selection, proper husbandry and veterinary practices. Production and reproduction performance of indigenous cattle breeds are generally low and differences were observed both between and within the breeds themselves. This may be attributed to their poor genetic potential, inferior husbandry systems, lack of capital and inputs by the households. Results of a study by Zewedu (2004) indicated that the birth weight, milk yield, age at first calving and calving interval for Fogera to be 22.45 kg, 313 kg, 38.5 months and 474 days, respectively while these values for *Horro* breeds were 18.3 kg, 216 kg, 53 months and 494 days, respectively.

According to Solomon (2007) some of the important sheep breeds of the BNB are *Horro*, *Washera* and *Farta*. The indigenous sheep breeds are year round breeders and mating is largely not controlled and the current off-take rate in small ruminants is very low (Markos, 2006). The annual off-take rate for sheep in the country is estimated at 33% (EPA, 2002) with an average carcass weight of about 10 kg, which is the second lowest amongst the sub-Saharan countries (FAO, 2004). Asfaw and Mohammed (2008) also observed that the off-take rate of small ruminants in Ethiopia to be between 25-35%. According to Kassahun (2000), the birth, 90 days and yearling weights of *Horro* sheep is 2.43, 8.21 and 19.7 kg, respectively. Mengiste (2008) reported that the birth weight, 90 days and yearling weight of Washera sheep to be 2.7, 11.9, 23.6 kg, respectively. However, the weights vary within the different agro ecologies of the BNB. Better husbandry and breeding systems which improves productivity per unit livestock could be employed thereby assisting the economic improvement of the raisers. This can help in decreasing the livestock population and optimizing the usage of the scarce resources in the BNB. Keeping large numbers of unproductive animals in the herd would induce burden on the already overused grazing land and the ecosystem at large and thus it affects the productivity of the animals.

As human population increases the size of crop land increased at the expense of grazing lands and animals are marginalized. According to Asaminew (2007) the pasture land holding for *Bahir-Dar Zuria* and *Mecha* districts was 0.65 and 0.6 ha, respectively. As reported by Peden et al. (2007) rearing optimal numbers of productive animals, exercising proper livestock production with strategies like animal breeding, balanced nutrition, veterinary intervention, value added production, maintaining soil cover by proper vegetation, capitalizing on crop and feed resources that are efficient in their water use would enhance the productivity and off-take of animals and thus improves an overall values of LWP. It is very important to rear only those livestock species which are well adapted to the prevailing agro ecology and according the available resources. Having limited but productive number of animals would also help us to relocate some portion of land for ecosystem services to ensure system sustainability and optimum utilization of the already scarce water resources. However, the capacity of a farmer to exercise the above management options would be impaired by lack of capital (access to resources), alternative breed, and proper extension services at farm and landscape level.

2.1.4. Overview of livestock services provision: Challenges and opportunities to improve livestock water productivity

According to EARO (2000), livestock power is a sustainable option in the present day farming system. The report from ESAP (2002) indicates that draft power contributes significantly to the agriculture and livelihood of the smallholder farmers. The draft power being is sometimes the only source of power to meet the day to day activities of smallholders. Earlier, Gryseels et al. (1984) found a significant correlation between livestock numbers and food security. However, the potential of livestock in the BNB area has not been properly utilized due to diseases like Trypanosomiasis and to seasonal shortage of feed and fodder (Belete et al., 2010; Zewedu, 2004). The efficiency of livestock can further be enhanced when they are properly fed and taken care of and the feed issue illustrates the crop-feed-livestock – water continuum. The feed issue links livestock service provision and water. Probably efficient and multiple uses of livestock is another important entry points to improve LWP.

For example experience in Ethiopia and elsewhere in tropics have shown that crossbred bullocks have superior draft power when compared to the indigenous cattle as they are stronger than the latter and hence can be used as a single traction (EARO, 2000). With limited modification of working schedule such as early morning and late evening work, periodic "work and short rest cycle" they can meet the small farmers' demand. The research work in the highlands of Ethiopia reveals that even crossbred cows can be profitably used both for draft and milk production Mengistu et al. (1999). If judiciously used they can compliment if not totally replace oxen for draft purpose. According to EARO (2000), rearing of oxen for draft purpose is rarely efficient. Studies suggest that even during the peak period, they are used for only about 75% of the possible time. Preliminary results indicate that oxen work on the average for 131 days in a year at *Ginchi* (Black soil area) and *Holetta* (Red soil area). Since animals are giving services only for limited days, but contrastingly fed throughout the year, this indicates low LWP values compared to the potential.

In Ethiopia the use of equine power has been an integral part of the highland agricultural production system (transportation, plowing and threshing). It was stated by CSA (2011), that the country has 8.73 million equine, the majority of which are found in the highlands. In the BNB, donkey is the work animal which has the most to offer. The donkeys are mainly used in transporting both pre and post harvested agricultural materials including water (Semira, 2009). In some parts of the BNB the equines are also used for ploughing purpose in case one of the oxen is incapacitated. In the lowlands of *Horo-Gudru*, close to the Abay Gorge, donkeys are used for ploughing as cattle cannot be kept in the area due to trypanosomiasis (Adugna, 2012 personal communication). Out scaling and improving such dual role of the equines would help improve the LWP in an area (Amare et al., 2009a).

In the current agricultural setting, expansion of cultivated area, better cropping pattern, labor savings, and increased yields and thus crop and feed water productivity can be achieved by improving animal traction (ILCA, 1990). In general, the draftablity of the animals is related to its nutrition, health and other husbandry aspects. Improving the condition of the animals would therefore enable the animals to deliver to their optimal potential, while at the same time for potential tradeoffs with costs of water for feed production. Understanding this trade off and adopting optimum practice will make big differences in improving LWP.

2.1.5. Mortality and morbidity as a cause for low water productivity

Although indigenous livestock breeds are fairly well adapted to the tropical environments, the majority of animals are raised under an extensive husbandry. Livestock diseases of economic importance in BNB include Foot and Mouth Disease (FMD), Blackleg, Anthrax, Lumpy skin disease, Contagious Bovine Pleuropneumonia (CBPP), Trypanosomosis, Mastitis, and Dermatophilosis and Tuberculosis (Zewedu, 2004). Mulugeta (2005) indicated that proper veterinary facilities are out of reach of most of the residents in highlands of Ethiopia. The mortality and poor productivity may be both attributed to preventable and non preventable causal factors. A sick animal is often a burden than an asset to small holders due to their inefficient usage of input invested in terms of attributes like water. For example lamb and kid mortality is the most important constraint limiting productivity of small ruminants in BNB. According to Duguma et al. (2005), lambs born during the dry season have a poor survival rate. This is mostly a fallout of poor nutritional status of ewes; leading to lowered milk production, thus higher ewe and lamb mortality. Markos (2006) reported that birth weight affects the survival rate and pre-weaning growth of lambs. Abebe (1999) observed that a substantial proportion (40%) of deaths in the highlands of Ethiopia occurred during March to May when feed supply is usually limiting. In his work at Debre-Birhan Markos (2006) reported that 33.1% and 19.2% mortality rates for *Horro* and *Menz* sheep, respectively indicating difference in pre-weaning mortality could be attributed to breed X environmental interactions. According to Mengiste (2008) the yearling mortality rate of Washera sheep at Western *Gojam* is 10.1% (BNB). It was also noted in the study by Kassaw (2007) that the mortality of equine at Fogera district to be 4.1%.

The mortality of animals seriously impacts LWP (Descheemaeker et al., 2010). Also diseased and stressed animals lead to low livestock productivity, as production and service delivery is depressed while sick animals still consume feed and water.

2.1.6. Livestock herding and watering practices

Water is used by all life forms to maintain the day to day maintenance requirements, various physiological usages besides production. According to Jagdish (2004) water requirements of livestock varies with environments, type of feed, species, age, body weight, exercise, status of health, the water content of the feed, milk yield, severity of heat, amount of DM intake, etc. According to Belete et al. (2010), cattle are watered once a day and the distance to watering points ranges from 100 meters to 5 km in Fogera. He also added that all age and sex group of cattle are herded and watered together.

In a study conducted at *Mieso* district (Oromia), Kedija et al. (2008) observed that 78% of the households obtain water from rivers, animals moved 1-30 km daily; hence, more time will be spent in search of water daily and this has influence on grazing resulting in loss of body weight and substantial decrease in milk production. The distance travelled by the animals for their feed is also closely associated with their feed demand and thus negative implication on LWP (Descheemaeker et al., 2010). The observation of Zewdie (2010) also is that 95% of farmers obtain water for their livestock at *Debre-Birhan* area from Rivers. Therefore, additional stress at any point is expected to hinder the overall efficiency of the animals.

Descheemaeker et al. (2009) concluded that in most parts of the BNB livestock watering points are not synchronized with feed availability. Particularly in the dry seasons livestock must trek long distance in search of drinking water. In parts where there are watering points over grazing is common to notice. In areas where drinking water is not accessible feed may not be efficiently used. This means also by distributing drinking water availability, in time and space, efficient uses of existing feed can be enhanced and at the same time energy spent on walking in search of water and feed can be reduced; this has positive implications for LWP.

3. Materials and Methods

3.1. Location and biophysical characterization of the study sites

The highlands of the Blue Nile Basin (BNB) cover two major eco-physiographic regions, parts of the central highlands and the western highlands of Ethiopia. This research work was undertaken in Fogera; Jeldu and Diga of the Nile Basin under the auspices of Nile Basin Challenge (NBDC). These districts were initially selected by the NBDC prior to the commencement of this research and therefore this work adopted the same sites (Figure 2).

Fogera district is located in Amhara Regional State: North western parts of Ethiopia. It lies at 1774-2410 meter above sea level (m.a.s.l.) and has mean rainfall of 1200 mm and minimum and maximum temperature 11^{o}C and 27 ^{o}C, respectively. Jeldu district is located in Oromia Regional State: Western part of Ethiopia. It is situated between 1800-3000 m.a.s.l. and has average annual rainfall of 938mm. The mean minimum and maximum temperature in Jeldu is about 9 ^{o}C and 27 ^{o}C, respectively. Diga district is located in Oromia Regional State: Western Ethiopia. Its altitude ranges between 1338 and 2100 m.a.s.l. and has average annual rainfall of 1936 mm. The mean minimum and maximum temperature is 15^{o}C and 27^{o}C, respectively. Data from district Agricultural office suggests that in 2010, the livestock population in Fogera, Diga and Jeldu are about 120,367 TLU, 43,661 TLU and 122,181 TLU, respectively. Cropping systems are diverse. In Fogera district, rice-pulse and teff-millet farming are major farming systems while in Jeldu district, the farming system are barley-potato, teff-wheat and sorghum based. In Diga district Sorghum and Teff-millet based farming systems dominate (Amare et al., 2011b).

3.2. Household survey and data analysis

3.2.1. The household survey

In a single visit (ILCA, 1990) a multi stage stratified random sampling technique was employed to select farm households. First a watershed was selected within the three districts and stratified into different farming systems (Figure 2). Then households within kebeles[1] in each stratum were randomly selected. Farm households were clustered into 3 wealth categories (Poor, Medium and Better-off) depending on land and cattle holdings (Appendix Table 17). Number of kebeles selected from each system depended on the proportion of the kebele areas in the sample watershed.

Structured questionnaire (Appendix 1) covering data on farm household characteristics, resources ownership (land & livestock, feed), farming practices, livestock species composition, livestock management, productivity, off-take, mortality, feeding system, types of feed, marketing, and institutions, etc. were prepared, pretested and implemented.

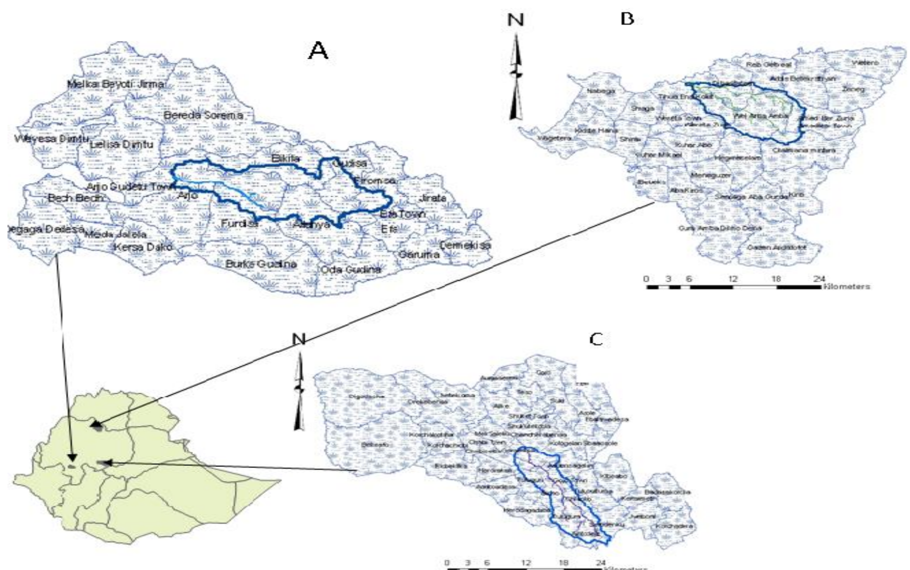

Figure 2: A) Diga B) Fogera and C) Jeldu Districts with their Kebeles, selected watershed and sample Kebeles within the watersheds

[1] Kebele is the smallest administrative unit in Ethiopia

3.2.2. Estimating Livestock Water Productivity

Livestock water productivity (LWP), as defined earlier is the ratio of livestock beneficial outputs and services to water depleted to produce livestock feed (Peden et al., 2007) as indicated in equation 1 below.

$$LWP = \frac{\sum_{j=1}^{n} OjPj}{\sum_{1=j}^{n} Kc * ETo(Gj) + \sum_{j=1}^{n} Kc * ETo\ (\beta j)}.$$

In which *Kc*, is crop factor; *ETo* is reference evapotranspiration and *LWP* is livestock water productivity; *Oj* is the livestock beneficial output of type *j*; *Pj* is the price of output *j*; *Gj* and *βj* are grazing and arable land uses of type *j* from where the livestock feed is collected. The following subsections give details of steps and procedures that were used in estimating depleted water and livestock beneficial outputs given on equation 1 above (Amare et al., 2009a).

a) Estimating depleted water

As the drinking water for livestock is not more than 2% of the total water for livestock production (Peden et al., 2007), only the amount of water used for feed production were accounted as depleted water. Depleted water was computed from the amount of water that was lost through evapotranspiration (ET). The results were analyzed using CROPWAT (FAO, 2003) software and FAO NewLockClim database was employed.

ETcrop = Kc x ETo

Where:

ETcrop: Crop water requirement in mm per unit of time

Kc : Crop coefficient (Crop factor)

ETo : Reference crop evapotranspiration in mm per unit time

To arrive at the total depleted water, the evapotranspiration for each crop grown and grazing pasture were estimated. The following data sources and steps were applied to work out.

1. Data on land use, crop group and type and the area covered by each crop type were collected from farmers' interview and the district agricultural and rural development office.

2. Harvest index value from literature was used to estimate the amount of crop residues from grain yield.

   2.1. Crop residues yield (kg) = Conversion factor * grain yield (kg/yr). Conversion factors established by FAO (FAO, 1987) and other sources from literature were used.

3. The amount of crop residue or grass that would be utilized by livestock was calculated by applying a use factor% developed by (Adugna and Said, 1994; FAO, 1987).

   3.1. Used for feed (kg) = Total residue or grass available(kg) * use factor%

4. Evapotranspiration and total water requirement

Using the Kc factors for the different crop types and reference evapotranspiration (ETo) ETcrop was calculated as follow:

   4.1. ETcrop = (ETo in farming system * Kc factors)

   4.2. Total water requirement

      4.2.1. GP = Growing Period for each crop and feed resource were obtained from literature and district agricultural office.

4.2.2. Total Crop Water Requirement (CWR)/ m^3/ annum = (ETm * GP) * area (m^2)

4.2.3. Residues CWR/ m^3/ annum = (Total CWR/ m^3/ annum * harvest index) * use factor%

4.2.4. Grass CWR/ m^3/ annum = (Total CWR/ m^3/ annum * % total grass yield) * use factor%

5. The sum of residues and grass CWR/ m^3/ annum were considered as depleted water to calculate the livestock water productivity.

b) Estimating beneficial outputs

In the present study livestock products and services were estimated from primary and secondary data. Year 2010 market values for products and services in the study area were used to quantify the benefits and services in monetary terms.

Information regarding the livestock numbers and density were generated from the interviews with the farmers' and district Agricultural and rural development office. The total number of livestock was converted to Tropical Livestock Unit using TLU conversion factors for different livestock species: Total TLU = Livestock Nr * TLU factor and the Live Weight = TLU * 250 (ILCA, 1990; 1 TLU is equivalent to the weight of zebu cow of 250 kg), appendix Table 38 the TLU converter for each species of livestock.

1. Livestock Outputs

1.1. Milk Yield

To calculate the total milk yield the following data were generated

1.1.1. Total milk production = (total number of milking cows* (milk yield in liter per day*30)* length of lactation period))

1.1.2. Milk Value (ETB) = Total milk yield * price per liter (ETB)

1.2. Livestock off-take

To estimate the total off-take values of animals we used the number of sold, given to others and slaughtered animals per household in a year and the current market price in the study areas. For ruminants: market values from sale and estimated current price for gifted-out and for HH consumption. For equine: we used current market price for gifted-out and sold ones.

1.3. Total Manure

The quantity of total manure produced per year per household was calculated based on the number of TLU and quantity of manure produced daily from each TLU on dry matter basis. We used literature values for dry weight daily dung production of 3.3 kg day^{-1} TLU^{-1} for cattle and 2.4 kg day^{-1} for equines and sheep and goats to estimate total dung produced in different farming systems. The nutrient content of dung (e.g. Nitrogen, Phosphorus and Potassium) was estimated based on average chemical composition for Ethiopia of 18.3 g N kg^{-1}, 4.5 g P kg^{-1} and 21.3 g K kg^{-1} on a dry weight basis (Amare et al., 2006) (Appendix Table 39), This was converted to fertilizer equivalent monetary values using the current local price of fertilizer. To estimate the value obtained from manure the current fertilizer market price was used.

1.3.1. Total Manure = TLU * (kg manure per day/ TLU * 365.25 days)

1.3.2. Manure Value (ETB) = Total Manure (kg) * price/kg (ETB).

1.4. Traction (threshing, ploughing and transportation) services

The time utilized for different services of animals such as threshing, ploughing and transportation and the local price of the different classes of livestock for the respective services were considered to estimate the value of such services.

1.4.1. Traction animal Nr * Traction Values (ETB) * Time spent

2. Finally the total value of beneficial outputs was derived from the values of products and services calculated from the above procedures.

2.1. Beneficial Outputs (USD) = Values for services + Value for products

3.2.3. Statistical analysis

Both descriptive and inferential procedures were used to analyze the data collected from the survey work. The descriptive part included mainly percentage values summarized in the form of tables and figures as appropriate. The software Statistical Package for Social Sciences ((SPSS) version 16.0, 2007)) and Excel for windows 2003 were used to enter and analyze the data. ANOVA tests were done using GLM procedures of SAS (Statistical Analysis Systems version 9.0) to assess the effects of farming systems on most response variables. Effects of wealth class on beneficial output and livestock water productivity was also accessed separately using the GLM procedures of SAS.

An index was calculated to provide overall ranking of the preferred livestock species reared according to merit with the formula: Index= sum of [4 X number of HHs ranked 1st + 3 X number of HHs ranked 2nd + 2 X number of HHs ranked 3rd + 1 X number of HHs ranked 4th] for preferred type of livestock reared divided by sum of [4 X number of HHs ranked 1st + 3 X number of HHs ranked 2nd + 2 X number of HHs ranked 3rd + 1 X number of HHs ranked 4th] for all preferred livestock kept.

Differences between group means were expressed as least Squares Means (LSM) $\pm$ SE. Significant differences were compared using Duncan's Multiple range Test (Duncan, 1997).

Model 1: $Y_{ijk} = \mu + F_i + \varepsilon_i$. Where,

Y_{ijk} = Dependant variable

(Milk yield, lactation, TLU…)

μ = The overall mean

F_i = Effect of ith Farming system (*1-7: =Rice-Pulse & Teff-Millet from Fogera. Barley-Potato, Teff-Wheat & Sorghum from Jeldu. Teff-Millet & Sorghum from Diga districts).*

ε_i = Random error term

Model 2: $Y_{ijk} = \mu + W_i + \varepsilon_i$. Where,

Y_{ijk} = Beneficial output or LWP

μ = The overall mean

W_i= Effect of jth Wealth category (1-3, 1= Better-off, 2= Medium, 3= Poor): based to LS & land holdings.

ε_i = Random error term

4. Results and Discussion

4.1. *Key Livelihood Assets*

4.1.1. Land holding and land use pattern

The average land holding values are presented in Table 1. It indicates that the overall average land holding of the respondents was 2.2 hectares per household (HH). The mean values for the study areas were 1.5, 2.4 and 2.7 hectares per HH at Fogera, Jeldu and Diga districts, respectively. Lowest and highest land holdings were recorded in Rice-Pulse Fogera and Sorghum Diga farming systems. The overall land holding per HH observed is lower than reported by Getachew (2002) in *Ginchi* highlands and Asaminew (2007) for Bahir Dar Zuria and Mecha districts of the BNB. The differences could be due to differences in population size. Unlike the differences across districts variations between farming systems within the districts were not as such apparent.

Table 1: Least squares means ± standard errors of land holding in (ha) and % land in each farming systems.

Districts	Farming system	N	Crop land (ha)	Grazing land(ha)	Total land holding(ha)	%of grazing land to crop land
Fogera	Rice-Pulse	30	1.3±0.1^{a}	0.1+0.02^{a}	1.4±0.1^{a}	7.14
	Teff-Millet	32	1.4±0.1^{a}	0.2±0.03^{a}	1.5±0.1^{a}	13.30
Jeldu	Barley-Potato	31	1.4±0.1^{b}	0.3±0.06^{a}	2.2±0.2^{b}	13.63
	Teff-Wheat	30	1.9±0.0^{a}	0.7±0.08^{a}	2.7±0.2^{a}	25.93
	Sorghum	30	1.7±0.1^{ab}	0.3±0.06^{ab}	2.3±0.1^{ab}	13.04
Diga	Teff-Millet	35	1.8±0.2^{a}	0.2+0.06^{a}	2.6+0.2^{a}	7.69
	Sorghum	32	2.2±0.2^{a}	0.4±0.08^{a}	2.9±0.3^{a}	13.79
For all farming systems		220	1.67±0.11	0.31±0.06	2.23±0.17	13.50

Comparisons were made for farming systems under the same district.

Framers in the study areas allocate land to different use and cover type. Crop production covers major holding areas while grazing land is among those with lower share. Allocation of grazing land within a household depends on farming system and across the study areas the share of grazing land ranges between 7 and 25% in rice and teff wheat farming systems, respectively (Table 1). The average pasture land owned per HH as observed in this study was lower than what is reported by Asaminew (2007) for Bahir Dar and Mecha districts of the BNB.

The results therefore, indicate that more animals are maintained on a small plot of grazing land and the bulk of the feed comes from crop residues. This has two major implications: as a result of overgrazing of the small grazing land, poor biomass productivity can be a norm. Secondly the fact that livestock depend on crop residues for feed mean they share the water input with grain, and thus may theoretically imply good LWP. But, this potential is limited by poor feed quality of crop residues. Its crude protein value does not exceed much over the maintenance requirement (Amare et al., 2010).

4.1.2. Livestock holding and species composition

The average numbers of livestock holdings per HH is presented in Table 2. It shows that TLU values ranged between 5.61 and 9.25 per HH. The highest value was estimated for Teff-Wheat farming system. More numbers of livestock were observed in the Jeldu district compared to the other two districts.

Table2: Least squares means ± standard errors of LS holdings in (TLU hh^{-1}) of the sampled HHs in the study areas.

Districts	Farming system	Livestock species						Over all
		Cattle	**Sheep**	**Goats**	**Donkey**	**Horse**	**Poultry**	
		LSM ±SE	LSM ±SE	LSM ±SE	LSM ±SE	LSM ±SE	LSM ±SE	LSM ±SE
Fogera	Rice-Pulse (n=32)	5.13 ± 0.59^{ab}	0.18 ± 0.07^{c}	0.03 ± 0.01^{b}	0.24 ± 0.06^{ab}	0.04 ± 0.04^{c}	0.00 ± 0.00^{b}	5.61 ± 0.67^{b}
	Teff-Millet (n=30)	5.96 ± 0.62^{ab}	0.03 ± 0.02^{d}	0.17 ± 0.04^{a}	0.35 ± 0.07^{a}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	6.52 ± 0.61^{b}
Jeldu	Barley-Potato (n=31)	4.47 ± 0.57^{b}	0.75 ± 0.12^{a}	0.03 ± 0.01^{b}	0.13 ± 0.05^{b}	1.64 ± 0.27^{a}	0.02 ± 0.01^{a}	6.99 ± 0.91^{b}
	Teff-Wheat (n=30)	6.67 ± 0.66^{a}	0.48 ± 0.09^{b}	0.02 ± 0.02^{b}	0.26 ± 0.08^{ab}	1.79 ± 0.19^{a}	0.02 ± 0.00^{a}	9.25 ± 0.83^{a}
	Sorghum (n=30)	4.95 ± 0.46^{ab}	0.22 ± 0.06^{c}	0.05 ± 0.03^{b}	0.28 ± 0.09^{ab}	0.53 ± 0.15^{b}	0.01 ± 0.00^{a}	6.04 ± 0.59^{b}
Diga	Teff-Millet (n=35)	5.43 ± 0.58^{ab}	0.22 ± 0.05^{c}	0.04 ± 0.02^{b}	0.22 ± 0.04^{ab}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	5.90 ± 0.61^{b}
	Sorghum (n=32)	5.67 ± 0.71^{ab}	0.11 ± 0.03^{c}	0.01 ± 0.01^{b}	0.28 ± 007^{ab}	0.00 ± 0.00^{c}	0.00 ± 0.00^{b}	6.07 ± 0.77^{b}
For all farming systems (n=220)		**5.47±0.23**	**0.28±0.03**	**0.05±0.01**	**0.25±002**	**0.55±0.07**	**0.01±0.00**	**6.61±0.28**

TLU= Tropical Livestock Unit (250 kg), Means followed by different superscripts differ significantly ($p < 0.05$), means are compared across columns. (Comparisons were made among all farming systems).

Livestock species composition varies across the study systems but consistently cattle were the major livestock species (Figure 3). The result of the present study was in good agreement with the findings of Belete (2006) from Fogera area.

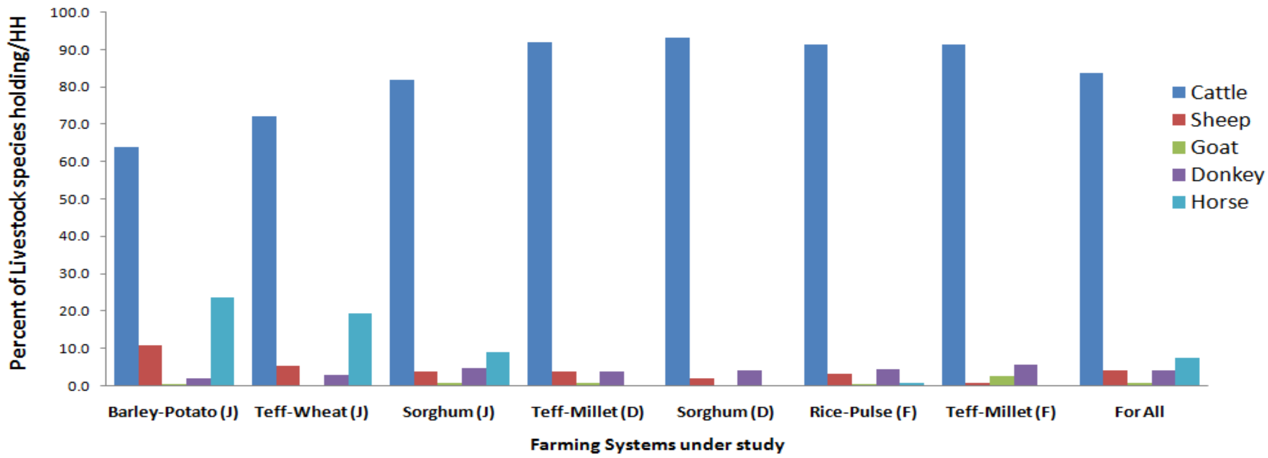

Figure 3: Proportions of different livestock species in the study areas (TLU.)

The composition of herd generally suggests that farmers depend mainly on crop husbandry and cattle rearing, the latter being a power house for the former. The mean TLU holding of small ruminants per HH was estimated at 0.33. The mean value for Barley-Potato and Teff-Wheat systems of Jeldu district were 0.78 and 0.50 TLUs, respectively. This suggests the important role small ruminants are playing in the higher altitude. Our result agrees with the observation of Amare et al. (2009a) for Barley-based systems of Gumera watershed at Fogera in the BNB. Similar trends were observed for mean holdings of horses in the study area.

Appendix Table 1 further indicates that the proportions of oxen and steers constituted a lion share (51%) and wide ranges was observed between farming systems (48-60%) probably which can be accounted for by to intensification of crop production practices. The rearing of different species of livestock is one of the coping mechanisms to optimize the use of available resources and thereby distributing the risks associated with a particular livestock species. The point here is as to whether the differences in herd composition will strongly affects the level of LWP and also to understand the optimum combination of livestock species to achieve higher LWP value.

4.1.3. Human resources

The average family size in Fogera, Jeldu and Diga districts is presented in Table 3. The overall mean value for the study areas was 6.73 persons per family which is higher than the national average 4.6 persons per family CSA (2011). Values for Fogera, Jeldu and Diga districts were 5.97, 7.48 and 6.42 persons, respectively.

The average HH size observed in this study is less than the reports of Asaminew (2007) from *Bahir Dar Zuria* and *Mecha* districts. The author of this study further noted that higher proportion of children's (<15 years of age), (Table 3).

Depending on proximity to town some farming system showed relatively better level of school attendances. In a similar study Mekete (2008) reported similar trend at Alewuha and Golina areas, Wollo. Addissu et al. (2007) also reported similar trend for Fogera area. Education plays an important role in smallholders' farm activity decision. For example literate HH heads are more likely to learn fast and participate in the use of improved agricultural technologies; such technical innovations including sound livestock management systems. Therefore, the relative literacy level (Table 4) observed (especially at Diga and Jeldu) can provide an opportunity to implement sound livestock management and agricultural practices to improve LWP.

Table 3: Least squares means ± standard deviations of HH size, age category, and farm labor force (n) per household in the study area

Districts	Farming system	House hold size				Age of respondents (years)	**Farm Labour Force** (years)	Farm Experience (Number)	Sex of HH head	
		<15 years of age	15-60 years of age	>60 years of age	Total HHs				Male	Female
		LSM ±*Sd*	LSM ±*Sd*	LSM ±*Sd*	LSM ±*Sd*	LSM ±*Sd*	LSM ±*Sd*	LSM ±*Sd*	%	%
Fogera	Rice-Pulse (32)	3.0 ±1.5	2.5±1.3	0.1±0.3	5.6±2.1^{c}	42.1±2.6^{ab}	3.3±1.5^{b}	23.87±13.58^{ab}	83.3	16.7
	Teff-Millet (30)	3.5 ±1.8	2.7±1.4	0.1±0.3	6.3±2.1^{bc}	43.6±2.3^{ab}	3.7±1.3^{b}	24.4±13.6^{ab}	96.9	3.1
Subtotal (n=62)		***3.3±1.7***	***2.6±1.3***	***0.1±0.3***	***5.9±2.2***	***42.9±1.7***	***3.5±1.4***	***24.1±13.6***	***90.7***	***9.3***
Jeldu	Barley-Potato (31)	4.0±2.3	2.5±1.6	0.3±0.5	6.8±2.7^{bc}	42.1±3.1^{ab}	3.9±1.4^{b}	21.19±14.99^{ab}	93.5	6.5
	Teff-Wheat (30)	4.5±2.8	3.6±1.9	0.4±0.7	8.5±3.6^{a}	48.4±2.5^{a}	4.9±2.1^{a}	29.00±13.75^{a}	96.7	3.3
	Sorghum (30)	4.1±2.1	2.8±1.4	0.2±0.6	7.2±1.9^{ab}	45.1±2.7^{ab}	4.0±1.2^{b}	24.07±13.79^{b}	96.7	3.3
Subtotal (n=91)		***4.2±2.4***	***3.0±1.7***	***0.3±0.6***	***7.5±2.9***	***45.2±1.6***	***4.3±1.7***	***24.7±14.4***	***95.6***	***4.4***
Diga	Teff-Millet (35)	3.3±1.7	2.7±1.5	0.2±0.5	6.2±2.1^{bc}	42.7±2.8^{ab}	3.7±1.4^{b}	24.2±14.72^{ab}	96.7	3.7
	Sorghum (32)	3.3±1.9	3.3±1.8	0.1±0.2	6.6±3.0^{bc}	37.8±2.1^{b}	3.9±1.9^{b}	19.15±11.0^{b}	90.6	9.4
Subtotal (n=67)		***3.3±1.8***	***3.0±1.6***	***0.1±0.4***	***6.4±2.6***	***40.3±1.8***	***3.8±1.6***	***21.7±13.2***	***91.0***	***9.0***
Overall (n=220)		**3.7±2.1**	**2.9±1.6**	**0.2±0.5**	**6.7±2.7**	**43.1±0.9**	**3.9±1.6**	**23.68±13.8**	**92.7**	**7.3**

N = number of respondents; Sd = Standard Deviation; HH = Household, Comparisons were made across column for all farming systems (Letters with different superscript differs significantly, $p<0.05$).

Table 4: Educational level (literacy level) of respondents (household heads) across the study sites (Percentage)

Districts	Educational status of the household heads						
	Farming system	Illiterate (%)	Read-Write (%)	1-4 grade (%)	5-8 grade (%)	9th grade and above (%)	Total (%)
Fogera	Rice-Pulse (n=32)	43.3	10.0	23.3	16.7	6.7	100
	Teff-Millet (n=30)	50.0	16.6	25.0	9.4	-	100
Jeldu	Barley-Potato (n=31)	32.3	3.2	29.0	25.8	9.7	100
	Teff-Wheat (n=30)	43.3	13.3	16.7	20.0	6.7	100
	Sorghum (n=30)	40.0	-	36.7	13.3	10.0	100
Diga	Teff-Millet (n=35)	31.4	5.7	34.3	14.3	14.3	100
	Sorghum (n=32)	28.1	6.3	28.1	28.1	9.4	100
Overall (n=220)		**38.2**	**7.7**	**27.7**	**18.2**	**8.2**	**100**

Probably what is more important than the family size is the active labor force available so as to enable timely sowing, harvesting and proper herd management which ultimately contributes to LWP. Table 3 indicates the overall average person equivalent labor value is about 3.9. There is variation between system implying differences in on timely practices of agricultural activities and therefore better productivity; given resources are not limiting factors. Compared to other farming systems, better labour force was registered in the Teff-Wheat farming systems of Jeldu. It was also observed that the availability of farm hands was strongly correlated with the family sizes in the study area. Hence, HHs with larger family sizes are able to have the capacity to perform the required livestock management interventions which may be important to increase LWP.

4.2. Crop livestock integration and its implication for LWP

4.2.1. Kraal shifting to increase crop land fertilization

The shifting of the livestock in night kraals was observed in the study areas. Kraals help in utilization of the dung which helps in fertilizing the agriculture plots and therefore assisting in cop production. Kraals are shifted on a regular basis. The results of Table 5 indicate that the kraals are shifted once in 4.4 and 8.5 days during the wet and dry seasons, respectively. According to the key informants and observations made in this study, the kraal shifting was more common in the Sorghum and Teff-Millet farming systems of Diga district. Respondents in these areas indicated that the reason for the shifting was to improve soil fertility thereby ensuring better productivity. In Burkina Faso, central Mali, the Niger and central Nigeria, overnight kraaling of cattle herds is often used to fertilize the crop fields. Animals are kept on a small portion of the field and moved after several nights (Powell, 1986).

In a mixed crop livestock systems crop residues are normally fed to the livestock. This mean also nutrient moved to another compartment. This in long term depletes soil fertility unless recycled through manure application. One of the principles of increasing water productivity is improving the plant water uptake through sufficient soil nutrient application. When there is sufficient nutrient in the soil, plants grow vigorously and take up water for photosynthesis (Amare et al., 2009a). This ensures higher biomass yield and crop water productivity. As crop residues are used for animal feed, under higher crop water productivity scenario the LWP will be also higher, particularly when animal fed on crop residue are supplemented with high quality feed sources. The problem is that there are always competing uses for scarce resources like manure and thus the opportunity for recycling the nutrient to the crop fields are slim.

Table 5: Least squares means ± standard errors of kraal shifting in wet and dry seasons.

Districts	Farming system	Wet Season Kraal shifting		Dry Season Kraal shifting	
		N	LSM ±SE	N	LSM ±SE
Fogera	Rice-Pulse	-	-	4	7.0±3.5[c]
	Teff-Millet	6	3.7±0.4[b]	8	7.1±3.3[c]
Jeldu	Barley-Potato	-	-	2	14.0±0.0[b]
	Teff-Wheat	2	4.5±2.5[b]	1	14.0±0.0[b]
	Sorghum	3	7.0±0.0[a]	3	20.0±6.8[a]
Diga	Teff-Millet	23	4.6±0.2[b]	33	5.4±0.3[c]
	Sorghum	12	3.8±0.4[b]	15	8.3±0.9[c]
For all farming systems		**46**	**4.4±0.2**	**66**	**8.5±0.5**

Superscripts with different letters indicate significant difference at ($p<0.05$), compressions were made across column for all farming systems.

4.2.2. Crop by-products as a source of animal feed and its implication

The use of crop residues as animal feed was observed in the studied systems. This process helps in efficient uses of resources regardless of the critics on nutrient removal, particularly in areas where manure is not used to enrich soil nutrient. As illustrated in Table 6 crop residues and natural pasture are the major feed resources described. Although there are variability across systems: residues of cereal (maize, sorghum, teff, rice, finger millet, wheat, barley), and pulse crops (faba-bean, field pea, grass pea, plant weeds etc.) are major feed sources which is in line with the observation of Seyoum et al. (2001) for wheat based crop livestock systems of Ethiopia.

All of the respondents indicated (Table 6) the use of crop residues for livestock feeding. A properly piled crop residues was observed at Fogera and Jeldu, while at Diga there was a lot of wastage due to poor storage techniques, termite attack and inefficient feeding. The differences across systems can be accounted for by differences in feed shortage and associated care farmers are doing. Hence, improving the collection, storage and feeding techniques of crop residues may be a step towards sustainable agricultural production, nutrient recycling and therefore improved LWP.

Table 6: Reported feed resources in the study area (percent of total respondents, 220)

Districts	Farming Systems	Feed resources (%)					
		Communal grazing land	Private grazing land	Crop residue	Hay	Improved forage	Non-conventional feeds*
Fogera	Rice	76.7	63.3	100	13.3	13.3	80.0
	Teff Millet	93.8	46.9	100	40.6	6.3	75.0
Jeldu	Barley	3.2	64.5	100	35.5	19.4	77.4
	Teff Wheat	16.7	93.3	100	43.3	13.3	90.0
	Sorghum	-	66.7	100	10.0	-	73.3
Diga	Teff-M	*34.4*	*59.4*	*100*	-	*6.3*	*62.5*
	Sorghum	48.6	62.9	100	-	14.3	62.9
Overall		39.5	65.0	100	20.0	10.5	72.7

*Non-conventional feeds; local brewery residues; roasted/ boiled grain/surplus, pea/faba bean haulms

4.2.3. Livestock as source of cash to purchase crop production inputs

The objectives of livestock integration are not only the use of traction and manure. The results of this study illustrated that farmers use cash income from livestock sale to settle household expenses and purchase farm inputs. About 46.7-83.3% of respondents indicated that they utilize the money obtained from sales of their livestock and their products for the purpose of HH expenses. About 23.3-86.7% of the respondents expend for the purposes of purchase of farm input in the form of improved seeds and fertilizer. As discussed earlier, better livestock productivity (e.g weight gain) and associated off take rate can increase farmers' income for better investment in fertilizer. These ultimately improve crop water productivity and LWP. Many of the respondents (59.4-91.4%) expend for schooling and health care (Appendix Table 2). This is in line with the report by Anteneh et al. (2006) at North Shewa Zone and Yoseph (2008) at Central Ethiopia.

4.3. Livestock Husbandry Practices

4.3.1. Preference and purpose of keeping livestock

Results from Tables 7a indicated that cattle were the most important component of herd in the study areas. In the study areas, the major objective of livestock keeping is draught power and this is consistent with Descheemaeker (2010). Although sufficient draught power is one of the determinant factors for timely performances of cropping activities and therefore positive influences on crop water productivity and LWP, contrastingly the fact that oxen are usually providing services for only fraction of a year whereas fed throughout the year might have reduced their benefits and water cost ratio: lower LWP. Therefore, mechanism for improving the service efficiencies of draught power must be sought. In general, the result of this study was consistent with Mukasa-Mugerwa (1989) in the central highland of Ethiopia and Yitaye et al. (2001) in southern region, Laval and Assegid (2002) in West *Wollega* and Asaminew (2007) in *Bahirdar-Zuria* and *Mecha* districts.

Table 7a: Preferred livestock types reared by the study respondents in the BNB

Preferred type of Livestock	Rank 1st	Rank 2nd	Rank 3rd	Rank 4th	Index	Ranks
Oxen	173	39	5	3	0.37	1st
Cow	39	161	17	3	0.31	2nd
Small ruminants	7	13	125	75	0.18	3rd
Equines	1	7	73	140	0.14	4th
Total	220	220	220	220		

Index= sum of [4 X number of HHs ranked 1st + 3 X number of HHs ranked 2nd + 2 X number of HHs ranked 3rd + 1 X number of HHs ranked 4th] for each preferred type of LS divided by sum of [4 X number of HHs ranked 1st + 3 X number of HHs ranked 2nd + 2 X number of HHs ranked 3rd + 1 X number of HHs ranked 4th] for all preferred livestock kept.

Table 7b: Purpose of keeping oxen by the study respondents in the study areas

Purpose of keeping oxen	Rank 1st	Rank 2nd	Rank 3rd	Rank 4th	Index	Ranks
Plow and thresh	219	3	0	0	0.43	1st
Income source	1	128	62	9	0.25	2nd
Manure	0	69	94	25	0.21	3rd
Insurance/Meat/Prestige	0	11	55	79	0.11	4th
Total	220	211	211	113		

Index= sum of [4 X number of HHs ranked 1st + 3 X number of HHs ranked 2nd + 2 X number of HHs ranked 3rd + 1 X number of HHs ranked 4th] for each purpose of keeping oxen divided by sum of [4 X number of HHs ranked 1st + 3 X number of HHs ranked 2nd + 2 X number of HHs ranked 3rd + 1 X number of HHs ranked 4th] for all purpose of keeping Oxen.

Table 7a indicated that the respondents prioritized oxen, cows, small ruminants and equines in the descending order. The trend was similar in the different farming systems but the proportions of the index values differed. The results from Table 7b indicated that oxen were reared primarily for draught power, income from sales, manure production and insurance. As it is indicated in Appendix Table 3a, cows were mainly reared as a mother for the replacement of male calves (bullocks); heifers and bull calves, besides milk production, while hardly few respondents indicated that the farmers reared cows solely for the purpose of obtaining manure. Meat and dowry/prestige from oxen/cow ranked 4th. The result obtained in this study is similar with that noted by earlier authors Solomon (2004), Zewedu (2004) and Asaminew (2007).

Appendix Table 3b indicates multi-functional roles of ruminants. The small ruminants are reared for income generation, meat and replacements in the descending order. The results as obtained in this study are in agreement with that obtained by Tesfaye (2008) for the Menz and Afar sheep.

Appendix Table 3c indicated that equines were primarily raised for transportation of both people and agricultural inputs and outputs. The results are similar with the reports of Yitaye (1999) and Solomon (2004). The different types of livestock species provide multipurpose benefits to the community and play important roles towards optimal utilization of available resources and have also positive contribution towards LWP.

4.3.2. Housing of Livestock

The purposes of housing in the study areas were to protect livestock from theft and from extreme weather. Table 8 and Appendix Figure 2 indicated that in the Teff-Millet (Fogera), Sorghum (Diga and Jeldu), and Teff-Millet (Diga) systems the common types of animal houses were kraal, there was no as such permanent cattle housing. Most of the farmers in the Barley-Potato and Teff-Wheat of Jeldu district had permanent houses (housing with roofing) for their livestock. However, about 47% of the respondents in the rice-pulse system have livestock houses attached to the house they live in.

Farmers house small ruminants, equine and cattle in order of preference. However, the decision depends on the number of species each HH owns which is similar with the reports of Mekete (2008) for *Golina* and Asaminew (2007) for *Bahirdar-Zuria* and *Mecha* districts. Housing type depends on the weather conditions of the different farming systems, even in relatively hotter farming systems of Diga and Jeldu (Sorghum based) and Fogera (Rice based); housing of animals especially during the rainy season seems to be quite important.

The general discussion made with farmers at Barley-Potato and Teff-Wheat farming systems revealed that animal performance is severely affected if not properly housed during the night. The cattle housing found in these farming systems were similar with other previous reports (Getachew, 2002; Solomon, 2004). This indicates that, improvement in LWP is not only limited to feed sourcing and feeding techniques, but all rounded livestock management practices needs to be ensured.

Table 8: Livestock housing in the study areas indicated in percentage

Districts	Farming system	Cattle			Sheep and goats			Equine		
		Separate house with roof	Kraal without roofing	Attached to the house	In the house with people	Separate house with roof	Attached to the house	Separate house with roof	Kraal without roofing	Attached to the house
Fogera	Rice-Pulse	10 (33.3)	6 (20.0)	14 (46.7)	5 (50.0)	1 (10.0)	4 (40.0)	4 (33.3)	-	8 (66.7)
	Teff-Millet	10 (31.3)	20 (62.5)	2 (6.3)	6 (30.0)	6 (30.0)	8 (40.0)	7 (44.8)	-	9 (56.3)
Jeldu	Barley-Potato	21 (67.7)	3 (9.7)	7 (22.6)	4 (13.8)	11 (37.9)	14 (48.3)	13 (54.2)	-	11 (45.8)
	Teff-Wheat	25 (83.3)	5 (16.7)	-	3 (12.0)	10 (40.0)	12 (48.0)	18 (69.2)	-	8 (30.8)
	Sorghum	8 (26.7)	21 (70)	1 (3.3)	2 (12.5)	2 (12.5)	12 (75.0)	7 (36.8)	-	12 (63.2)
Diga	Teff-Millet	1 (2.9)	33 (94.3)	1 (2.9)	12 (42.9)	2 (7.1)	14 (50.0)	3 (14.3)	6 (28.6)	12 (57.4)
	Sorghum	7 (21.9)	22 (68.8)	3 (9.4)	6 (37.5)	1 (6.3)	9 (56.3)	1 (7.14)	1 (7.14)	12 (85.7)
Overall		**82 (37.3)**	**110 (50.0)**	**28 (12.7)**	**38 (26.4)**	**33 (22.9)**	**73 (50.7)**	**53 (40.2)**	**7 (5.3)**	**72 (54.6)**

Numbers in bracket indicate percentages and numbers out of the bracket indicates the number of respondents

4.3.3. Water source, watering practices and its implication

Table 9 and Appendix Figure 3 illustrate the main source of water for livestock drinking. It shows that in the study areas rivers, ponds and wells are major sources of drinking water for livestock. During the dry season 41.9, 96.7 and 98.5% of the HHs from Fogera, Jeldu and Diga districts use water from rivers, while about 11.3 and 27.4% of HHs at Fogera provide water from wells and ponds. This general trend of water sourcing is in good agreement with Zewdie (2010) who undertook similar studies for Debre-Birhan area. The quality of water and the distance traveled to reach are major concerns. Similar observations were made by Descheemaeker et al. (2009) in the BNB. The poor quality of water leads to pathogens and helminthes infestation among the animals thereby to disease outbreaks, higher morbidity and mortality, and lower productivity.

According to key informants in the studied farming systems watering frequency in the studied farming systems varied between seasons. In dry season even though animal's need for frequent watering increases it is not possible to get more than once per day since rivers are far from the grazing points. As a result, the seasonal availability and distance of water sources have implications on watering frequency of different classes of livestock in the different farming systems. During the dry months, watering points dry up and livestock must track long distance. This incurs energy cost which implies also significant amount of water invested in feed. For example as indicated on Table 10 the majority of the HHs trek their livestock between 0.5-2 km to reach the watering point in the Fogera, Jeldu and Diga districts during the dry season. The table further indicates that some respondents track nearly 5 km in search of water during the dry season.

Table 9: Major sources of water for livestock in the Blue Nile Basin (% of respondents)

Districts	Farming Systems	Sources of water in dry season					Sources of water in wet season			
		N	Well	River	Pond	Still Water	Well	River	Pond	Still water
Fogera	Rice-Pulse	30	13.3	56.7	16.7	13.3		50.0		50.0
	Teff-Millet	32	9.4	28.1	37.5	25	3.1	84.4	3.1	9.4
Jeldu	Barley-Potato	31		100.0				93.8		6.2
	Teff-Wheat	30		93.3		6.7	3.3	63.3	3.3	30.0
	Sorghum	30		96.7		3.3	3.3	60.0	3.3	33.3
Diga	Teff-Millet	35		97.1		2.9		82.9		17.1
	Sorghum	32		100.0				93.8		6.3

Table 10: Distances covered by the different livestock species to get drinking water (%)

Districts	Farming Systems		Wet season			Dry season		
			Distance to watering point (km)			Distance to watering point (km)		
		N	<0.5	0.5-2.0	2-5	<0.5	0.5-2.0	2-5
Fogera	Rice-Pulse	30	60.0	36.6	3.3	46.7	43.3	10.0
	Teff-Millet	32	6.3	75.1	18.0		78.1	21.9
Jeldu	Barley-Potato	31	9.7	67.7	22.7		66.7	31.7
	Teff-Wheat	30	33.3	63.3	3.3	20.0	76.6	3.3
	Sorghum	30	20.0	73.3	6.7	16.7	66.7	16.7
Diga	Teff-Millet	35	14.3	57.1	26.6	14.3	50.8	34.5
	Sorghum	32	12.5	56.1	31.2	6.3	61.5	31.3

Source: Own survey, 2011

4.3.4. Breeding systems

Table 11 depicts dominant breeding systems in the study areas. It indicates that natural mating was the most common method for cattle breeding. The results further indicate that 93.3-100% of the respondents in all study systems have no sufficient access to artificial insemination (AI) services.

No one of the respondents had access to AI for their livestock in Teff-Wheat and Sorghum (Jeldu), Teff-Millet and Sorghum farming systems of Diga districts. However, results of the discussion with farmers further indicated that the respondents of Barley-Potato and Teff-Wheat (Jeldu), Rice-Pulse and Teff-millet (Fogera) farming systems agreed that crossbred animals (cows) had better milk production and traction ability (males) than the existing native cattle. They appear to select livestock (cattle) based on physical appearance, coat color and the animals with above average performing parents usually. The observations are similar to those reported by Nuru and Dennis (1976) and Dereje (2005) for North Eastern Ethiopia. Some of the farmers used the libido as a criterion of selection for males. The question as to which of these selection criteria can be key indicators to better productivity and higher LWP might be interesting to understand in the future. The works of Amare et al. (2010) in Indo-Ganga basin of India substantiate farmers' idea regarding higher performances of cross breed animal. They concluded that under sufficient quality and quantity of feed, cross breed animals improves LWP. But lack of access to AI, market, veterinary services and initial capital generally limits these opportunities in all study areas.

Table 11: Mating systems used in the BNB (%)

Districts	Farming system	Mating Systems			
		Natural Mating		AI	
		N	%	*N*	%
Fogera	Rice-Pulse (30)	28	93.3	2	6.7
	Teff-Millet (32)	30	93.8	2	6.3
Jeldu	Barley-Potato (31)	29	93.6	2	6.5
	Teff-Wheat (30)	30	100	-	-
	Sorghum (30)	30	100	-	-
Diga	Teff-Millet (35)	35	100	-	-
	Sorghum (32)	32	100	-	-
For all farming systems (220)		**214**	**97.3**	**6**	**2.7**

N = Number of respondents, AI = Artificial Insemination, Numbers in brackets indicate proportion of respondents,

Almost 83% of the respondents under the studied farming systems exercise the selection of male and female animals (coat color, body size, length of naval flap, milk yield for females and body size for male) were mentioned as selection criteria by study respondents. This is in line with the findings of Zewedu (2004) for indigenous animals in North-Western Ethiopia.

Wet season and harvesting seasons are characterized by greater vegetation cover, and hence provide better roughage and crop aftermath supply to livestock. This results in higher milk yields and breeding efficiency. Most respondents were aware of the visible signs of estrus in cattle. Most farmers revealed that survival of the neonates is better during the rainy season while some indicated that the survival was better in both rainy and harvesting season. This may be attributed to better body condition of the dams during these seasons which ensure adequate milk production for the calves thereby ensuring better nutrition, immunity and survival. Markos (2006) has observed similar pattern for small ruminants.

Generally, number of studies revealed that livestock which are better adapted under the prevailing conditions are selected by default. Usually such animals are poor yielders. The results of a study by Addissu et al. (2010), indicated that the adaptive traits predominated over productive traits in the presently operative community based breeding of Fogera breed of cattle. Therefore, increased LWP is required to achieve desirable levels of production by rearing both adaptive and relatively productive animals depending on existing situation.

As illustrated on Table 12, the overall average age of culling cows was about 9 years (8-10); which is consistent to the observations of Mukasa-Mugerwa et al. (1989). The studies also indicate that in case of emergencies (both financial and agricultural) the farmers tend to sell the growing stock first, these observations are in accordance to the report of Tesfaye (2008). Generally, it was reported that breeding females were maintained in the herd for older age until reproductive performance nearly ceased. This is due to the important role that cows play in the HH or might be the strategy of the owners to avert risks by maintaining the surviving adult females rather than depending on young replacement females whose survival may be low at times because of diseases (Dereje, 2005). Solomon et al. (2009) clearly indicated that with older age LWP decreases. Therefore, future research must identify optimum ages of culling and policy measures must create awareness to farmers in this regard.

The overall average lifetime calf production in cows was estimated to be 6 ranging from 5-8, which was similar with the estimates by Dereje (2005). However, the present result was slightly higher than the results of Mukasa-Mugerwa et al. (1989) for Ethiopian zebu. The wider gap in the life time calf production within crop livestock system generally implies the potential to improve livestock life time productivity even by selection and crossing of local breeds. This significantly and positively impacts LWP.

Table 12: Least squares means ± standard errors of productive lifetime and age of culling (years) for cows.

Districts	Farming system	Productive lifetime		Age at culling	
		N	LSM ±SE	N	LSM ±SE
Fogera	Rice-Pulse	27	11.7±0.5[a]	27	9.9±0.6[a]
	Teff-Millet	32	11.2±0.4[a]	32	8.5±0.5[a]
Jeldu	Barley-Potato	29	11.7±0.5[a]	29	8.8±0.6[a]
	Teff-Wheat	29	11.9±0.4[a]	29	10.0±0.5[a]
	Sorghum	30	12.8±0.7[a]	30	9.8±0.7[a]
Diga	Teff-Millet	35	11.1±0.7[a]	35	8.4±0.5[a]
	Sorghum	30	11.6±0.6[a]	30	8.9±0.6[a]
For all farming systems		**212**	**11.7±0.2**	**212**	**9.2±0.3**

Comparisons were made across column for all farming systems, letters with different supper scripts show significant (p<0.05) difference.

Table 13 summarizes the weaning practices in the study farming systems. The table illustrates that 25% of the total respondents practice weaning of their calves. The weaning age for calves ranges from 8.7–15.0 months in Teff-Millet Diga and Teff-Millet Fogera, respectively. The overall average weaning age of calves was estimated to be 10.9 months which was slightly lower than the results obtained by Asaminew (2007) for calves reared in *Bahir Dar Zuria* and *Mecha* districts and Samuel (2005) for *Yerer watershed*. The study has also confirmed that the average weaning ages of calves in the Teff-Millet and Rice-Pulse farming systems of Fogera district were higher than the results obtained by Asaminew (2007). The study further indicates that higher proportion of the respondents in the Rice-pulse farming system practice weaning followed by Teff-millet -Fogera and Sorghum farming system of Diga. A study by Yitaye et al. (2007) on Fogera calves indicated that in order to prevent the negative effect of long time suckling on the reproductive performance of the dam, forage dry matter intake of calf and the milk that will be available for human consumption or sale, it was suggested to wean calves prior to eight months of age. Quite interesting is to see nearly 100% differences in weaning age within mixed farming systems. This is a big opportunity to improve the life time productivity of an animal and thereby it's LWP. Probably a relevant work in the future will be to understanding the determinants of age of weaning. In this regard the farmers argue that weaning at a very early age leads to poor growth of the calf unless it is managed well by providing additional feed supplements. Findings by Samuel (2005) for similar study in *Yerer* areas and Yitaye et al. (2007) for Fogera areas also support this argument.

Table 13: Least squares means ± standard errors of culling and weaning age in (years) for male cattle and calves and percentage of weaning performed by the herder by farming system.

Districts	Farming system	Age of culling breeding male in years		Who weans the calf (%)			Age at weaning (months)	
		N	LSM ± SE	N	Dam	Herder	N	LSM ± SE
Fogera	Rice-Pulse	27	5.2±0.3[b]	28	53.6	46.4	22	13.0±0.9[b]
	Teff-Millet	31	6.0±0.4[a]	32	62.5	37.5	24	15.0±1.2[a]
Jeldu	Barley-Potato	*27*	5.4±0.3[a]	26	84.6	15.4	26	9.3±0.7[c]
	Teff-Wheat	*29*	4.9±0.2[a]	24	57.5	12.5	23	10.7±0.6[c]
	Sorghum	*29*	5.6±0.2[a]	30	90.0	10.0	25	9.6±0.6[c]
Diga	Teff-Millet	*35*	5.9±.2[a]	35	85.7	14.3	21	8.7±0.5[c]
	Sorghum-Maize	*29*	5.5±0.2[a]	32	65.6	34.4	25	9.4±0.9[c]
For all farming systems		**207**	**5.5±0.1**	**207**	**75.4**	**24.6**	**165**	**10.9±0.4**

N = number of respondents; * = mean value. Compared along the column for all farming systems at ($p<0.05$).

4.3.5. Record keeping in livestock

Recording is a basis for proper livestock husbandry. Records help assist to make important decisions at all times thereby ensures proper interventions. The observations by Azage (2000) and Markos (2006) indicated that livestock development in the country has been handicapped to a greater extent due to lack of reliable records. The findings from the present study suggests that 87-100% HHs do not keep any record pertaining to their livestock but few households to some extent try to keep scanty records (Appendix Table 4). During field work it was also learnt that some literate farmers understand the importance of records. However, the numbers of such individuals are very few. Simple recording tools can be developed and the farmers can be trained in utilization of this information to make decision for better livestock management and thereby optimize the utilization of the available resources in the study area.

4.4. Productive performances of livestock

4.4.1. Daily milk yield

Table 14 indicated that the estimated mean daily milk yield significantly differ ($p<0.05$) among the study farming systems. Highest and lowest milk yield was recorded from the Rice-Pulse Fogera and in Teff-Millet farming systems of Diga, respectively. The overall average yield was about 1.57 liters/ day. These values were higher than reported by Asaminew (2007) from *Bahir Dar Zuria* and *Mecha* districts but similar with the national average of 1.50 liters/ day described by (CSA, 2011). Observations during the study made at Alember (Fogera) showed the potential to improve milk yield up to 8 liters per day from Fogera X Fresian crosses. It is clear that higher milk yield needs more feed. But Amare et al. (2011a) from their work in India reported that the milk produced outweighs the water cost in feed production and thus improves LWP.

The present study also indicated a broad range between the lowest and highest milk yield (Table 14). The study also indicates that if properly managed the cattle have a potential for an extra 800 ml of milk /day, however there are differences attributed to genetics and non-genetic factors (feeding, health care and management).

There is a significant relationship between season and milk yield of cattle. This can be attributed to feed availability and environmental stresses. The availability of fodder is usually scanty during the dry season whereas there are plenty of grasses in the wet season. Proper management and storage of excess fodder in the form of silage or hay can help to reduce the feed gap during the dry months and thereby ensure adequate nutritional requirements throughout the year.

4.4.2. Lactation length

Table 14 indicates that the overall average lactation length of the native cows was 8.62 months. This value is higher than the national average (CSA, 2011). The present results are in agreement with the reports of Belete (2006). Differences ($p<0.05$) in lactation lengths were observed among the farming systems. Accordingly, differences of ± 2 months were observed between the study areas of Fogera and Diga districts. The difference in lactation length between Jeldu and Fogera was observed to be ± 1.34 month. The differences in lactation length across farming system can be accounted for by both to feed, management and genotype related factors. Hence, yield can be attributed to both genetics and managerial factors as indicated before.

Table 14: Least squares means ± standard errors of milk yield in Liters and Lactation length in months.

Districts	Farming system	Milk yield of local cows		Lactation Length of local cows	
		N	LSM ± SE	N	LSM ± SE
Fogera	Rice-Pulse	28	1.90 ± 0.13^{a}	28	9.82 ± 0.45^{a}
	Teff-Millet	32	1.59 ± 0.11^{ab}	32	9.77 ± 0.62^{a}
Jeldu	Barley-Potato	26	1.86 ± 0.14^{ab}	28	8.18 ± 0.45^{b}
	Teff-Wheat	29	1.65 ± 0.11^{ab}	29	8.79 ± 0.48^{ab}
	Sorghum	30	1.55 ± 0.06^{b}	30	8.37 ± 0.46^{ab}
Diga	Teff-Millet	35	1.08 ± 0.08^{c}	35	7.73 ± 0.34^{b}
	Sorghum-Maize	29	1.53 ± 0.12^{b}	30	7.80 ± 0.51^{b}
Overall		**209**	**1.57±0.04**	**212**	**8.62±0.19**

Means with different superscripts within the same column (for all farming systems) are statistically different ($p < 0.05$).

4.4.3. Age of Livestock to fit service and Slaughter

Age at which livestock start providing services and also production determines the life time productivity and thus LWP values (Amare et al., 2010). Appendix Table 5 indicate that the average marketing age of cattle in the study areas was 3.49±0.10 years while the average age of bull to commence traction services was estimated to be 3.88±0.05 years. Differences among the study areas were also observed. For example in the Sorghum farming system of Jeldu, cattle reach marketable age earlier ($p<0.05$) than those in the farming systems under Fogera and Diga districts. In the Diga district cattle are slow growers compared to those reared in Fogera and Jeldu districts. This is in contrast to the relatively good feed availability in Diga. Probably infestation of tsetse fly in Diga can explain the differences. Generally they reach market age at the age of 6 to 12 months later than in the Fogera and Jeldu districts respectively.

Even though the overall average age of slaughter in this study was comparable to the results obtained by Samuel (2005) for the *Yerer* watershed; it was also noticed that the average slaughter age of cattle at sorghum farming system of Jeldu was lower than the results reported by the same author. Similarly this study revealed a significant ($p<0.05$) difference among farming system in the age at which the bulls reach and fit for plowing. Example could be between the Sorghum and Teff-Millet farming systems of Diga.

Appendix Table 6 indicates that the overall average marketable age for sheep and goat was 9.2 and 9.5 months, respectively. However, the values obtained in the present study was lower than those reported by Tesfaye (2008) for Menz sheep where the average market ages of rams and ewes were 11.3 and 11.9 months, respectively. The age of slaughter for sheep from the present study is higher than the values reported by Samuel (2005) in *Yerer* Watershed. However, differences were also observed between the study farming systems. The study also indicated that small ruminants in the Sorghum and Teff-Millet farming systems of Diga district have a higher slaughter age than the other farming systems under study. Surprisingly, small ruminants reared at Sorghum farming systems of Diga reached their market and slaughter age earlier ($p<0.05$) than those reared at Teff-Millet farming system of Diga district. On the average the slaughter age for small ruminants in the Diga district was at yearling age while in the other farming systems the small ruminants are marketed at an earlier age.

4.5. Reproductive Performance of Livestock in the Study Areas

4.5.1. Age at first mating and calving for cattle

Table 15 indicate that the overall estimated average age at first service of the heifers was 45.5 months while the age at first calving was estimated to be 55.5 months. The study also indicated that the results differed ($p<0.05$) considerably among the study farming systems.

The average estimated ages at first service of the heifers and subsequent age at first calving was shortest at the Sorghum farming system of Jeldu followed by those reared in Sorghum farming system of Diga, Teff-Millet farming system of Diga and Teff-Millet farming system of Fogera. The result of the overall age at first calving in the present study was slightly lower than the values reported by Asaminew (2007).

As reported by Ruiz-Sanchez et al. (2007), early maturing heifers are better milk producers and have lower cost of maintenance, with a positive implication on LWP. The overall estimated average age at first calving as presented in Table 15, indicated that the values were higher than what has been reported by Addissu (1999) for Fogera breed reared at the *Metekel* Ranch. The difference can be attributed to better management interventions delivered in the ranch. However, the values estimated in present study are similar to the values reported for *Horro* cattle reared at *Bako* agricultural research centre (Gizaw et al., 1998) and also at West *Wellega* (Alganesh et al., 2003).

Improved management levels along with optimum nutrition, housing and health care improves the growth rate of the heifers. This assists the animals to come in to heat at an early age, thereby lowering the age at first service, calving and enhances life time productivity of the animals. However, the results in the present study are higher than the optimal values reported by Nilforooshan and Edriss (2004). The results indicated that introduction of exotic blood may be an option to improve the reproductive traits of the cattle, thereby help to improve the productivity of cattle and improved LWP.

Appendix Table 5-7 also indicate that the estimated age at first service for the bulls, rams, bucks, jack and stallion and slaughter ages for bulls and small ruminants. The result for the bulls is in agreement with the observations of Alganesh et al. (2003) for *Horro* bulls. The age at first service of the bulls and equines are quite high indicating delayed maturity thereby leading to more investment and lower efficiency to available feed and water. This may be attributed to inadequate attention and nutrition paid by the smallholders to the males compared to the female animals.

Table 15: Least squares means ± standard errors of age at 1st mating/calving and calving interval for cattle in months.

Districts	Farming system	Age at 1st mating for heifers		Age at 1st calving		Calving interval	
		N	LSM ±SE	N	LSM ±SE	N	LSM ±SE
Fogera	Rice-Pulse	27	44.96 ± 1.54^{bc}	27	55.37 ± 1.63^{b}	27	22.48 ± 0.90^{ab}
	Teff-Millet	32	47.44 ± 1.38^{ab}	32	59.44 ± 1.34^{a}	32	24.22 ± 1.00^{a}
Jeldu	Barley-Potato	29	44.07 ± 1.29^{bc}	29	53.03 ± 1.30^{bc}	29	19.83 ± 1.03^{bc}
	Teff-Wheat	30	43.66 ± 1.15^{bc}	29	52.66 ± 1.15^{bc}	29	19.93 ± 0.86^{bc}
	Sorghum	29	41.20 ± 1.25^{c}	30	50.20 ± 1.25^{c}	30	20.63 ± 0.80^{b}
Diga	Teff-Millet	35	50.91 ± 1.44^{a}	35	61.11 ± 1.34^{a}	35	22.29 ± 0.76^{ab}
	Sorghum	30	45.20 ± 1.79^{bc}	30	55.12 ± 1.79^{b}	30	17.30 ± 1.01^{c}
Overall		**212**	**45.51±0.56**	**212**	**55.47±0.58**	**212**	**21.00±0.36**

N = number of respondents; SE = Standard Error; AFC = Age at first calving. Means with different superscripts within the same column for all farming systems are statistically different ($p < 0.05$).

Average calving interval in the present study was estimated to be 21.0 months. The values however varied between the study areas and was lowest in the Sorghum farming system of Diga and was highest at the Teff-Millet farming system of Fogera. The differences may be attributed to non genetic differences only and hence can be lowered by proper and balanced nutrition besides other management interventions. However, the age at first calving is lower than the values reported by Alganesh et al. (2003) for *Horro* cattle.

The overall average age of first service for ewes and does was comparable to the reports of Solomon et al. (1995) for *Horro* ewes and lower than the values reported by Mukasa-Mugerwa et al. (1994) for Menz sheep. The overall average age at first kidding and lambing in the study areas were lower than the values assessed by Otte and Chilonda (2002).

4.5.2. Annual reproductive rates (ARR)

The overall average ARR which was calculated as a function of litter size and parturition interval for sheep and goats in the study farming systems are presented in Appendix Table 8. The values are comparable to that reported by Samuel (2005) for sheep in the *Yerer* area but higher for goats. The results of the present study are higher than the values reported by Gatenby (1986) and Wilson (1989) for Menz sheep. However, lower values for the trait were reported by Mukasa-Mugerwa (1981) for the sheep and goats raised at *Yerer* area. This higher ARR may be due to higher reproductive performance particularly with high prolificacy and fecundity of the small ruminants (*Horro* and *Washera* sheep) and goats in the study areas. The values of the reproductive traits in this study were encouraging. The observations in the present study also indicate significantly higher calving rate at Sorghum farming system of Diga. There is a further scope of improving the same through both genetic and management interventions, thereby leading to an improved LWP.

4.5.3. Life time reproductive performances of different livestock species

The overall estimated average life time reproduction of cows, does, ewes, mares and Jennies are presented in Appendix Table 9. It indicates the average estimated number of off-springs delivered by a cow, doe, ewe, mare and jenny. This result as obtained is in agreement with the results published by ILCA (1990) for African domestic livestock. The average total numbers of offspring's is an indication of the productivity of the livestock and also is fall out of optimum physiological activity, thereby highlighting the efficiency of utilization of invested water.

4.5.4. Livestock Off-take rates

The results of the overall off-take rates for cattle, sheep, goats, donkey and horse are presented in Table 16. There was significant difference ($p<0.05$) in the off take values of cattle among the study farming systems. Higher off-take rates for cattle were observed in Teff-Millet Fogera and Sorghum farming systems of Jeldu. Off-take rates for sheep in Rice-Pulse –Fogera, Sorghum farming system –Diga were significantly higher than ($p<0.05$) off-take rates of sheep in Teff-Millet –Diga. The findings of the present study were in agreement with the observations of Samuel (2005) but lower than EPA (2002). However, Niftalem (1990) reported an annual off-take of 18.4 and 7.3% in sheep flocks raised in highlands of Ethiopia which could be attributed to both livestock sales and home consumption. These lower off-take values for different livestock in the study areas have two implications: the low growth rate of the animal and sharp increase in population and thus adversely affect LWP.

Table 16: Least squares means ± standard errors of off-take rates (%) for cattle, sheep /goats and equine in the study area.

Districts	Farming system	Off-take rates									
		Cattle		Sheep		Goats		Donkey		Horses	
		N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE
Fogera	Rice-Pulse	29	6.0 ±1.45[ab]	10	35.5 ± 11.5[a]	4	40.3 ± 14.2	13	3.8 ± 3.8[b]	-	-
	Teff-Millet	32	10.8 ± 2.1[a]	2	15.0 ± 15.0[ab]	17	17.2 ± 3.8	20	19.2 ± 7.5[a]	-	-
Jeldu	Barley-Potato	29	3.9 ± 1.3[bc]	29	19.3 ± 3.5[ab]	4	12.5 ±12.5	6	0.0 ± 0.0[c]	24	5.6 ± 2.7[a]
	Teff-Wheat	29	8.4 ± 2.0[ab]	23	15.9 ± 3.7[ab]	2	41.7 ± 25.0	11	4.8 ± 3.4[b]	26	3.7 ± 2.2[a]
	Sorghum	29	10.6 ± 2.2[a]	12	22.2 ± 9.1[ab]	4	16.7 ± 9.6	13	11.5 ± 7.9[ab]	13	0.00
Diga	Teff-Millet	34	6.8 ± 1.8[ab]	19	8.00 ± 3.9[b]	7	14.7 ± 7.7	14	5.3 ± 5.3[b]	-	-
	Sorghum	31	9.7 ± 3.4[ab]	13	25.6 ± 10.5[a]	2	25.0 ± 25.0	19	0.0 ± 0.0[c]	-	-
Overall		213	8.1 ± 0.80	113	18.6 ± 2.4	40	20.2 ± 3.4	96	7.7±2.3	64	3.1±1.8

N = number of respondents; SE = Standard Error, Means with different superscripts across the same column (for all farming systems) are statistically different (p< 0.05).

4.6. Livestock service delivery

Table 17 indicates that, in the study area, an ox is used for an average of 132 days for ploughing purpose. The values however range between 123 days in the Sorghum farming system of Jeldu district and 140 days at Teff-Millet farming systems of Fogera district. The average numbers of days oxen are used for the purpose of threshing was about 7 days. The values range between 3 days at Teff-Wheat farming system at Jeldu to 12.5 days at Rice-Pulse farming systems of Fogera. It was also observed that equines (horses) were used for threshing purpose especially in the Barley-Potato, Teff-Wheat and Sorghum farming systems of Jeldu. The studies indicated that on average the horses were used for 3-5 days for threshing purpose. There was significant ($p<0.05$) difference in the number of days oxen were used for plowing purpose which of course varied according to the prevailing farming system. In the Teff-Millet farming system (Fogera) oxen were used for considerably higher number of days while they were used for least number of days in the Sorghum farming system of Jeldu, however, no significant differences were observed among the rest of the farming systems. Significant ($p<0.05$) differences were also observed in the number of days oxen were used for threshing in the studied farming systems. Oxen were used for 11-13 days in Fogera while they were used for only, 3-5 days in the rest of the farming systems.

From the present study it can be concluded that oxen were grossly underutilized. Results obtained in this study were similar with the reports of EARO (2000) which was 131 days in the highland of *Ginchi*. However, lower values were reported by Gryseels and Anderson, (1986). The findings of the present study are in line with the observations of Semira (2009) at *Lenchedima* watershed. This may be attributed to the use of oxen for draught purposes only in the cropping and harvesting seasons. Normally oxen are kept for more number of days without any appreciable work. This indicates also huge water cost of keeping draught oxen at the farm throughout the year (Agymang et al., 1991).

Table 17: Least squares means ± standard errors of number of days the Oxen were used for different activities.

Districts	Farming system	Oxen			
		Plowing		Threshing	
		N	LSM ± SE	N	LSM ± SE
Fogera	Rice-Pulse	30	134.8±4.8[ab]	30	12.5±1.3[a]
	Teff-Millet	30	140.0±5.1[a]	31	11.1±0.9[a]
Jeldu	Barley-Potato	27	134.3±6.9[ab]	11	4.6±0.6[b]
	Teff-Wheat	29	130.6±4.0[ab]	23	3.1±0.4[b]
	Sorghum	30	123.4±6.3[b]	27	3.7±0.3[b]
Diga	Teff-Millet	35	131.5±5.1[ab]	35	5.2±0.5[b]
	Sorghum	30	131.8±4.1[ab]	30	5.1±0.6[b]
For all farming systems		**210**	**132.4±1.9**	**187**	**6.8±0.4**

Comparisons were made among the different farming systems along the column, significant at ($p<0.05$)

Considering the size of land holdings, the characteristics of the terrain and the economic conditions of the farmers' animal power is likely to continue to play an important role on smallholder farms of the BNB. Research experiences in the highland of Ethiopia suggest that the use of crossbred dairy cows for milk production and traction as an option to alleviate the existing farming problems, which would allow for a better feed utilization by the different classes of livestock available at the farm (Mengistu et al., 1999). Adoption of this technology would enable smallholder farmers to keep less number of more productive cattle that could increase overall farm productiveness and reduce the livestock pressure on the land leading to sustainable resource utilization and improvement in livelihood and better ecosystem services. Appendix Table 10 indicates that donkeys were used for several purposes which included marketing, transporting crops to home and fetching water. The present study also identified that donkeys were used for 173 days in a year. The results of this study are in good agreement with observation of Semira (2011) in the *Lenche Dima* watershed.

Generally it can be concluded that the service currently rendered by the livestock is by far lower than the potential they can offer. If multiple uses with accompanying technologies could be put in place farmers need obviously less livestock for the traction and threshing. This reduces the volume of water invested in feed and increase LWP.

4.7. Beneficial Outputs and Water Productivity of Livestock

4.7.1. Livestock beneficial outputs

In this study, beneficial livestock outputs estimated at the HH level include milk (from cow), manure from all livestock except poultry, agricultural power (from cattle and horses (ploughing, threshing)), draft and pack (donkeys, horses and sale of all livestock). The overall total mean milk production on annual basis per HH was 479.99±38.08 liters. Poor, medium and better-off HHs reported that they obtained 173.31±32.65, 432.53±54.34 and 829.13±76.97 liters of milk annually (Appendix Table 11). The result is in agreement with the reports of Zewedu (2004). The amount of milk produced per HH on an annual basis was ($p<0.05$) significantly higher in better-off HH when compared to the medium and poor HHs. This may be attributed to better availability of feed resources; better management of the cattle besides the numbers of cattle owned by the HH and suggests potential for improvement even with selective breeding of local cows. Similar to the milk production Table 18 indicates that the overall total value of milk (in US dollar) significantly differed ($p<0.05$) among the wealth categories.

There were no significant differences among the wealth categories in Teff-Millet system of Diga in terms of total off-take indicating non market oriented production of livestock. Appendix Table 11 indicates that the amount of manure obtained and nutrient recycled (nitrogen, phosphorus and potassium) back to the soil varied between the farming systems ($p<0.05$) and between farm clusters within a farming system. This can be attributed to differences in TLU holdings ($p<0.05$). The results of the present study are in good agreement with the works of Semira (2011).

The overall contribution of services to the total beneficial outputs was about 54% (50.8, 53.3, and 55.4%) for poor, medium and better-off farm HHs which was mainly contributed by cattle & equine, but it could reach 58.3% at Barley Potato farming system. Such results revealed that the main purpose of livestock integration into cropping system is services rather than milk, meat & manure production. The total beneficial output for the studied farming systems was 828 USD. The value rates were 322, 714 & 1436 for the poor, medium & rich HHs. The overall mean beneficial output obtained in the current study (828 USD) was higher than what was reported for the crop livestock systems of Ethiopia by Descheemaeker et al. (2011). Then if the livestock integration objectives in smallholder farming system are mainly services provision (Descheemaeker, 2009) and farmers' production are not market oriented and no market to transform this: what is the incentive for farmers to invest in new technologies. How much water can we save only by improving livestock service efficiencies?

Table 18: Least squares means ± standard errors of beneficial output values in (USD/ HH /year) for the study farming systems.

Farming systems	Wealth category	Output per year and units of measure					
			Milk value (USD/HH)	Off-take value (USD/HH)	Manure value (USD/HH)	Value of services (USD/HH)	Total Beneficial output in (USD/HH)
		N	*LSM ± SE*	*LSM ± SE*	*LSM ± SE*	*LSM ± SE*	*LSM ± SE*
Rice-pulse/Fogera	Poor	10	86.56±39.01[b]	32.24±21.54[b]	34.96±6.21[c]	86.24±29.51[c]	239.99±70.04[c]
	Medium	10	156.24±45.39[ab]	72.35±32.62[b]	107.62±11.05[b]	298.47±77.11[b]	634.68±119.49[b]
	Better-off	10	224.74±41.83[a]	210.08±40.79[a]	204.35±7.31[a]	718.71±75.55[a]	1357.88±93.44[a]
Average for Rice-Pulse Fogera		***30***	***155.85±25.72***	***104.89±23.03***	***115.64±13.72***	***367.80±60.64***	***744.18±101.34***
Teff-Millet/Fogera	Poor	11	58.74±24.70[b]	118.29±27.13[ab]	66.37±7.51[c]	223.64±45.37[c]	467.03±63.27[c]
	Medium	10	81.53±32.04[b]	88.24±29.83[b]	116.11±4.27[b]	428.71±38.04[b]	714.58±55.53[b]
	Better-off	11	247.06±61.19[a]	242.03±61.59[a]	232.64±16.95[a]	798.61±66.33[a]	1520.34±105.79[a]
Average for Teff-Millet Fogera		***32***	***130.59±28.42***	***151.43±26.95***	***139.07±14.17***	***485.37±52.23***	***906.46±93.04***
Barley-Potato/Jeldu	Poor	12	12.87±9.58[b]	21.32±9.36[b]	46.00±7.65[c]	157.53±38.5[c]	237.73±40.76[c]
	Medium	9	92.92±27.41[b]	68.94±26.34[b]	122.36±9.23[b]	406.41±55.86[b]	690.63±57.46[b]
	Better-off	10	281.03±47.86[a]	267.55±96.74[a]	231.66±28.22[a]	1026.94±136.60[a]	1807.17±268.28[a]
Average for Barley-Potato Jeldu		***31***	***122.61±26.96***	***114.58±36.85***	***128.06±17.16***	***510.24±82.69***	***875.49±149.56***
Teff-Wheat/Jeldu	Poor	10	105.89±32.38[b]	69.71±28.12[b]	88.01±16.13[c]	249.88±57.26[c]	513.57±100.90[c]
	Medium	9	178.43±40.09[ab]	134.51±33.95[ab]	174.93±10.18[b]	504.84±53.55[b]	992.71±93.64[b]
	Better-off	11	328.88±91.71[a]	210.92±47.68[a]	270.48±17.28[a]	890.69±104.89[a]	1700.97±219.96[a]
Average for Teff-Wheat Jeldu		***30***	***209.41±40.23***	***140.93±24.19***	***181.02±16.55***	***561.33±66.99***	***1092.69±128.58***

Table 18: Least squares means ± standard errors of beneficial output values in Cont'

Farming systems	Wealth category	Output per year and units of measure					
			Milk value (USD/HH)	Off-take value (USD/HH)	Manure value (USD/HH)	Value of services (USD/HH)	Total Beneficial output in (USD/HH)
		N	*LSM* ± SE	*LSM* ± *SE*	*LSM* ± *SE*	*LSM* ± *SE*	*LSM* ± *SE*
Sorghum/Jeldu	Poor	10	30.00±16.29[c]	52.35±25.59[b]	58.02±5.84[c]	203.18±22.13[c]	355.46±37.81[c]
	Medium	10	154.85±69.37[ab]	103.35±42.06[ab]	116.70±10.20[b]	321.29±51.13[b]	668.64±101.30[b]
	Better-off	10	192.57±66.05[a]	234.29±72.14[a]	199.76±11.46[a]	669.41±76.75[a]	1296.04±138.09[a]
Average for Sorghum Jeldu		***30***	***125.81±33.82***	***130.00±31.49***	***124.83±12.02***	***397.96±47.76***	***773.38±91.95***
Teff-Millet/Diga	Poor	12	33.82±9.64[c]	55.78±20.39[a]	53.99±7.49[c]	113.73±28.55[c]	257.33±48.56[c]
	Medium	11	105.78±15.63[b]	92.82±33.98[a]	117.22±10.39[b]	359.25±54.23[b]	675.08±88.03[b]
	Better-off	12	164.41±27.51[a]	39.80±21.07[a]	199.19±14.17[a]	703.43±73.91[a]	1106.84±100.18[a]
Average for Teff-Millet Diga		***35***	***101.21±14.25***	***61.95±14.58***	***123.65±12.06***	***393.08±52.32***	***679.88±75.69***
Sorghum/Diga	Poor	11	16.85±11.44[b]	39.31±16.69[b]	37.25±6.72[c]	122.89±23.31[c]	216.29±41.68[c]
	Medium	9	82.35±30.71[b]	97.71±33.00[a]	109.09±9.95[b]	360.78±71.34[b]	649.95±96.28[b]
	Better-off	12	201.91±36.82[a]	123.63±51.95[a]	215.90±18.48[a]	776.47±103.19[a]	1317.91±132.21[a]
Average for Sorghum Diga		***32***	***104.67±21.63***	***87.35±22.62***	***124.45±15.66***	***434.89±66.24***	***751.37±101.69***
Overall	**Poor**	**76**	**47.6±8.8[c]**	**55.3±8.6[b]**	**54.6±3.7[c]**	**163.9±14.8[c]**	**322.9±25.1[c]**
	Medium	**68**	**121.7±15.3[b]**	**93.7±12.4[b]**	**122.8±4.3[b]**	**380.7±22.5[b]**	**714.8±35.4[b]**
	Better-off	**76**	**233.1±21.3[a]**	**185.0±22.9[a]**	**222.0±6.8[a]**	**795.9±36.3[a]**	**1436.1±63.7[a]**

Comparisons were made within column, for the wealth categories within farming systems separately and for all (different typology) at ($p<0.05$)

4.7.2. Livestock water productivity

Tables 19 and 20 revealed that there were no significant differences in LWP among the study districts and systems. Lower LWP values were recorded among the resource poor households in the Sorghum farming system of Diga, Barley-Potato farming system of Jeldu and Rice-Pulse farming system of Fogera district. However, our result for all farming system (0.12 and 0.21 USD m^{-3}) for the poor and better-off HHs, respectively is higher than reported (0.07, 0.09 USD m^{-3}) for the better-off and poor HHs by Semira (2011). The results from Table 20 further illustrated variations among farm households in the same wealth cluster: poor HH's, from the Sorghum and Teff-Wheat farming systems of Jeldu, Teff-Millet farming system of Diga and Teff-Millet farming system of Fogera districts. More interesting is a huge gap between the minimum (0.001) and maximum values (>0.6 USD /m^{-3}) of LWP. It can therefore be suggested that there is huge gap between the potential and actual LWP. The results further indicated that the highest LWP (USD/ m^{-3}) at HH level was reported among the better-off HHs. This may be ascribed to differences in access to resources. Therefore policy options that capacitate poor farm households' access to resources must be implemented.

Table 18, further indicated that the beneficial livestock outputs and services assessed in terms of monetary values was highest in Teff-Wheat farming system of Jeldu followed by Teff-Millet farming system of Fogera, while the lowest value was assessed in Teff-Millet at Diga district. But LWP value is the function of both depleted water and beneficial outputs and thus beneficial outputs alone does not determine LWP (Amare et al. (2009a).

The prevailing climatic parameters and the resultant reference evapotranspiration (which itself is a climatic parameter derived from temperatures, rainfall, humidity, wind speed and sun shine hour data of a given locality) can play a major role in the determination of the amount of depleted water (Appendix Table 12) in a given agro ecology and farming system and hence affected the water productivity in general and livestock water productivity in particular. The types of crops cultivated and the cropping pattern prevailing under particular agro ecology as well as the type and productivity of the grazing lands and herd composition in the different farming systems may play their part, in determining the LWP values for particular agro ecology.

Two major points can be drawn from the present study of LWP: LWP in all study areas is low because of poor returns from the livestock sector including slow growth and high mortality as in the observations by Asfaw and Mohammed (2008) which account to low off take and ultimately total beneficial outputs. Obviously, high evapotranspiration and low biomass yield also contributed a lot. On the other hand, there are LWP study results based on data from controlled experiment which suggests higher value LWP as indicated in Solomon et al. (2009). From this it can be concluded that there are ample opportunities to improve LWP. Descheemaeker et al. (2010) indicated that prevailing poor veterinary coverage, un organized and poor extension services, traditional livestock management practices, agronomic practices for cultivation of fodder processing of the feed resources and marketing intelligence and support affect the LWP either directly or indirectly and if improved can surely promote livestock sector and associated livelihoods and ecosystem health.

Table 19: Least squares means $\pm$ standard errors & ranges of LWP estimates of HHs of different wealth categories in the studied farming systems (USD m^{-3} water)/HH

Wealth Category	N	LWP		
		LSM $\pm$ SE	Minimum	Maximum
Poor households	76	0.12 ± 0.01^{c}	0.001	0.361
Medium households	68	0.16 ± 0.01^{b}	0.012	0.423
Better-off households	76	0.21 ± 0.01^{a}	0.081	0.627
Average for all farming systems	**220**	**0.16 ± 0.01**	**0.031**	**0.470**

Compressions were made among the wealth categories; letters with different superscript within column shows significant differences at $p<0.05$.

Table 20: Least squares means ± standard errors & ranges of LWP estimates for different farming systems (USD m^{-3} water)/HH

Farming Systems	Wealth Category	N	LWP		
			LSM ± SE	Minimum	Maximum
Rice-Pulse	Poor	10	0.09 ± 0.02^{b}	0.009	0.207
	Medium	10	0.14 ± 0.03^{ab}	0.011	0.301
	Better-off	10	0.20 ± 0.02^{a}	0.122	0.301
Averages for Rice-Pulse		***30***	***0.15±0.02***	***0.047***	***0.270***
Teff-Millet	Poor	11	0.19 ± 0.03^{ab}	0.074	0.349
	Medium	10	0.14 ± 0.02^{b}	0.082	0.259
	Better-off	11	0.21 ± 0.01^{a}	0.151	0.265
Averages For Teff-Millet		***32***	***0.18±0.01***	***0.102***	***0.291***
Barley-Potato	Poor	12	0.08 ± 0.01^{b}	0.002	0.130
	Medium	9	0.14 ± 0.01^{b}	0.093	0.189
	Better-off	10	0.24 ± 0.05^{a}	0.118	0.627
Averages for Barley-Potato		***31***	***0.15±0.02***	***0.071***	***0.315***
Teff-Wheat	Poor	10	0.11 ± 0.02^{b}	0.007	0.183
	Medium	9	0.19 ± 0.02^{a}	0.079	0.286
	Better-off	11	0.19 ± 0.03^{a}	0.136	0.431
Averages for Teff-Wheat		***30***	***0.16±0.01***	***0.074***	***0.300***
Sorghum	Poor	10	0.12 ± 0.02^{b}	0.027	0.245
	Medium	10	0.16 ± 0.03^{ab}	0.068	0.371
	Bette-off	10	0.19 ± 0.03^{a}	0.114	0.350
Averages for Sorghum		***30***	***0.16±0.02***	***0.070***	***0.322***
Teff-Millet	Poor	12	0.13 ± 0.03^{b}	0.001	0.361
	Medium	11	0.19 ± 0.03^{ab}	0.124	0.423
	Better-off	12	0.23 ± 0.03^{a}	0.114	0.483
Averages for Teff-Millet		***35***	***0.19±0.02***	***0.080***	***0.422***
Sorghum	Poor	11	0.08 ± 0.02^{b}	0.021	0.216
	Medium	9	0.17 ± 0.03^{a}	0.082	0.344
	Better-Off	12	0.22 ± 0.03^{a}	0.081	0.379
Averages for Sorghum		***32***	***0.16±0.02***	***0.061***	***0.313***

Compressions were made among the wealth categories within the same farming systems separately; letters with different superscript within column shows significant differences at $p<0.05$.

4.8. Major Constraints to Livestock Production and Productivity

Generally livestock production and productivity are affected by several factors. The present study revealed that (Table 21) the major constraints are feed shortage, livestock diseases, and shortage of initial capital and poor genetic makeup of the livestock. Lack of drinking water, limited information on animal husbandry practices, labor shortage and poor market access, predators and flooding were also among the constraints mentioned by the respondents. Results of the present study were in line with the observations of Asaminew (2007) who reported the major constraints for livestock production in *Bahir Dar Zuira* and *Mecha* districts.

The mortality rate of cattle, sheep, goats, donkey & horses were 7.6, 11.9, 4.2, 8.9 & 9.9%, respectively (Table 22). These high mortality rates of livestock observed in current study are in agreement with previous findings by different authors (Markos, 2006; Mengiste, 2008; Asfaw and Mohammed, 2008) for different species of livestock.

Appendix Table 13 also indicates that livestock diseases are the major limiting factor in the farming system of Diga and Fogera districts. Nutritional problems like bloat and lack of feeds besides diseases are other contributing factors affecting livestock production. Interventions by the extension agents can assist in minimizing the livestock mortality and morbidity especially those associated with consumption of local clovers and sorghum tiller. The death due to bloat and cyanide (from sorghum) poisoning account to nearly 40% mortality in Jeldu district.

Appendix Table 14 also suggest that lack of veterinary services, un-affordability of medicines besides lack of medicines and skilled technician were some of the major constraints limiting livestock production. Veterinary clinics are generally few and are inaccessible for most of the farming community. The present finding is also compared with that reported by Mekete (2008); Belete et al. (2010). The most important diseases were Trypanosomiasis, Anthrax, Ticks, Foot and mouth, Black leg and internal parasites (Appendix Table 15a-c).

Notorious weeds *Asracantha lingifolia* locally known as *(*Amykila) at Fogera and *Karaaba* in local language at Diga districts are encroaching into the grazing lands thereby replacing the natural pasture grasses (Appendix Figure 5). Appendix Table 16 also indicates that hardly 50% of the farmers have access to extension service and only a few get accesses to improved seeds and micro credit facilities. From field observation and discussion with farmers, it was realized that among those respondents who were provided with the credit facilities only a few used the money for the purpose it was disbursed. It seems the extension group focuses mainly on the crop and natural resources area only. To benefit more from the system, the livestock component also have to be given due attention as equally as the other components as far as the extension of technologies are concerned.

Table 21: Major Livestock production constraints as ranked by the HHs in the BNB and presented in index value.

Constraints	Fogera				Jeldu						Diga				For all farming systems	
	Rice-Pulse		Teff-Millet		Barley-Potato		Teff-Wheat		Sorghum		Teff-Millet		Sorghum			
	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Feed shortage	0.27	1st	0.33	1st	0.34	1st	0.36	1st	0.34	1st	0.25	2nd	0.27	2nd	0.30	1
Disease occurrence	0.21	3rd	0.24	2nd	0.16	2nd	0.18	2nd	0.26	2nd	0.26	1st	0.28	1st	0.23	2
Shortage of capital	0.05	6th	0.10	3rd	0.16	2nd	0.03	3rd	0.17	3rd	0.17	3rd	0.18	3rd	0.14	3
Poor genotype	0.03	7th	0.09	5th	0.12	4th	0.13	3rd	0.09	4th	0.06	5th	0.06	5th	0.08	4
Lack of drinking water	0.09	4th	0.05	4th	0.08	4th	0.06	4th	0.03	6th	0.07	4th	0.03	6th	0.06	5
Limited knowhow	0.05	6th	0.08	6th	0.07	5th	0.11	5th	0.07	5th	0.04	6th	0.06	5th	0.06	5
Shortage of labour	0.08	5th	0.10	3rd	0.05	6th	0.00		0.03	6th	0.06	5th	0.07	4th	0.05	7
Flooding	0.22	2nd	0.00		0.00		0.00		0.00		0.00	-	0.00	8th	0.04	8

Index= sum of (8 X number of HHs ranked 1st + 7 X number of HHs ranked 2nd + 6 X number of HHs ranked 3rd 5 X number of HHs ranked 4th + 4 X number of HHs ranked 5th + 3 X HHs ranked 6th + 2 X HHs ranked 7th + 1 X HHs ranked 8th) for particular constraint divided by sum of (8 X number of HHs ranked 1st + 7 X number of HHs ranked 2nd + 6 X number of HHs ranked 3rd + 5 X number of HHs ranked 4th + 1 X number of HHs ranked 5th … 1 X HHs ranked 8th) for constraints.

Table 22: Least squares means ± standard errors of mortality rates for cattle, small ruminants and equine in the study areas (%)

Districts	Farming system	Mortality rates									
		Cattle		Sheep		Goats		Donkey		Horses	
		N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE	N	LSM ± SE
Fogera	Rice-Pulse	29	5.3 ± 2.1[b]	10	2.8 ± 2.1[b]	4	9.7 ± 5.7[a]	13	7.7 ± 7.7	-	-
	Teff-Millet	32	3.8 ± 1.2[b]	2	0.0 ± 0.0[b]	17	3.4 ± 1.9[a]	20	4.2 ± 2.9	-	-
Jeldu	Barley-Potato	29	9.2 ± 2.8[ab]	29	12.6 ± 4.0[a]	4	0.0 ± 0.0[b]	6	0.0 ± 0.0	24	9.7 ± 2.7[b]
	Teff-Wheat	29	7.3 ± 1.6[b]	23	11.2 ± 4.1[a]	2	8.3 ± 8.3[a]	13	15.4 ± 10.4	26	8.3 ± 2.9[b]
	Sorghum	29	9.9 ± 2.1[a]	12	7.5 ± 2.9[a]	4	0.0 ± 0.0[b]	11	15.2 ± 9.4	13	14.1 ± 8.4[a]
Diga	Teff-Millet	34	7.6 ± 2.2[b]	19	19.4 ± 6.4[a]	7	7.6 ± 5.1[a]	14	3.6 ± 3.6	-	-
	Sorghum	31	10.4 ± 2.3[a]	13	10.4 ± 5.9[a]	2	0.0 ± 0.0[b]	19	13.2 ± 7.5	-	-
Overall		**213**	**7.6 ±0.8**	**113**	**11.9 ± 2.1**	**40**	**4.2 ± 1.4**	**96**	**8.9 ± 2.6**	**64**	**9.9 ± 2.7**

N = number of respondents; SE = Standard Error, comparisons were made among all farming systems across column.

5. CONCLUSION AND RECOMMENDATIONS

5.1. CONCLUSION

The study was conducted to characterize the overall livestock management practices & their implications on Livestock Water Productivity (LWP) in the rain-fed crop livestock production systems in the Blue Nile Basin (BNB). Accordingly, 7 farming systems (Rice-Pulse & Teff-Millet from Fogera), (Barley-Potato, Teff-Wheat & Sorghum farming systems from Jeldu) & (Teff-Millet & Sorghum farming systems from Diga districts) were selected for this study and a total of 220 sample HH heads were involved.

In the study areas teff, barley, wheat, rice, finger millet, maize, sorghum based farming systems were dominant. Cattle were the major livestock species accounting for 83 % of the total TLU. Oxen, cows, sheep, goats & equines were preferred livestock in their order of importance. The main objective of integrating livestock into crop is mainly for traction services. Across the study areas oxen were reared for the purpose of traction, income source & manure. The main purpose of keeping cows, sheep/ goats & equine were replacement, income sources and transportation, respectively. Farmers' production objective is not market oriented and they are more focused on assisting crop production activity.

Most farmers in all farming systems use crop residues for animal feed. However, lack of proper collection, handling, storage and poor utilization was observed in the Diga district. Although crop residues use is essential means to enhance resources use efficiencies, its poor feed quality is usually a major concern.

Most (97.3%) sample farmers practice natural mating for their livestock. They also practiced selection of breeding animals based on their memory instead of performance recording. Much emphasis was put on physical appearance & color, respectively. The fact that the present LWP approaches to estimate benefits from livestock do not include benefits from color; it is difficult to judge if these practices are contributing to efforts of LWP improvement. Culling performed by farmers was very incomplete for it was not accompanied with the livestock performance recording. It was reported that breeding females were maintained in the herd for older age until reproductive performance nearly ceased.

Nearly 100% differences in weaning age within mixed farming system (8.7-15 months) were observed. This is a big opportunity to improve the life time productivity of an animal and thereby it's LWP. Probably a relevant work in the future will be to understand the determinants of age of weaning.

Production and reproduction traits including services delivered by livestock were low and variable among the different farming systems. Lower milk yield & shorter lactation lengths, higher age at mating & calving, longer parturition intervals for female animals and higher age at first effective mating for breeding purposes by the bulls, jack & stallion were observed. Variability between minimum and maximum values observed in this study are major indicators of potential to improve production and reproduction traits and therewith LWP.

Major livestock production constraints in the studied farming systems were feed shortage, disease occurrence & shortage of initial capital. Higher mortality and low off-take rates for different livestock species were observed. Most important reasons for this huge mortality rates were disease, bloat & feed shortage. The mere management intervention in the time of harvesting & feeding of the local clovers & sorghum tillers could enable reduce mortality of cattle up to 40% at Jeldu. Average distance to get veterinary services was 9.6 km. Only 21 & 9% HHs get access to improved seeds & credit for livestock improvement, respectively. Surprisingly 15% of the respondents converted it in to practice. Mortality and morbidity affects LWP in two major ways: it reduces the efficiencies of the services and productivity of livestock. Secondly when animal dies water invested to feed and the animal will be lost. This is important in view of the increasingly scarce agricultural water.

Values of LWP across the study systems were lower and the differences among systems were not as such apparent. Lower LWP values were registered for the relatively poor HHs at the rate of 0.08, 0.08 & 0.09 USD m^{-3} at Sorghum farming system of Diga, Barley-Potato farming system of Jeldu & Rice-Pulse farming system of Fogera districts respectively. Highest (0.24 USD m^{-3}) LWP value at HH level was registered for better-off farm clusters in Barley-Potato farming system. More interesting is a huge gap between the minimum (0.001) and maximum values (0.627 USD m^{-3}) of LWP. It can be concluded that there is huge potential to improve LWP in mixed crop livestock systems of the BNB.

5.2. RECOMMENDATIONS

1. **The objectives of crop livestock integration** should not be only short term economic return and only service provision oriented. Integration must take environment into account.
2. **Enhancing animal productivity and reducing herd sizes**: Establish community based veterinary services & other infrastructural facilities, upgrading the genetic potential of native breeds by introduction of selective breeding, community based livestock improvement schemes and better husbandry techniques.
3. **Improve off-take rates reduce mortality and morbidity rates and this improves LWP**
4. **Improve access** to watering point, feed conservation practices, pasture and grazing land management; delivery of improved fodder/housing, indoor feeding, cut and carry system, and tethering of livestock, should be encouraged for the betterment of livestock production, productivity and thereof LWP.
5. It would be imperative if future research can explore on how much water can be saved only by focusing on improvement of livestock service efficiencies and also policy incentive mechanisms to transform current livestock production objectives.
6. To improve LWP, crop residues based feed sourcing needs to be supplemented by high quality feed: research results and policy measures that can improve farmer access to improved feed needs to be put in place.

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7. Appendices

Appendix 1 Household questionnaire

Household Questionnaire to Study Small-holder Farms Livestock Management Practices and their Implications on LWP in Mixed Crop-Livestock Systems of the Highlands of Blue Nile Basin: A case study from Fogera, Diga and Jeldu Districts (Ethiopia).

Questionnaire Number_________________________

Introduction and informed consent

Good morning/ Good afternoon!

My name is ________________________ I came from International Livestock Research Institute (ILRI), which has been conducting research on rainwater management strategies in the Nile Basin of Ethiopia. Currently ILRI is conducting research on implications of livestock management practices and feed sourcing on rainwater use efficiency in Blue Nile Basin of Ethiopia. You are randomly selected to provide information for this research. The information you provide will help us gain insights for better ways of managing livestock to improve livestock water use efficiency.

The interview may take between **2 - 3 hours** to complete. Any information you provide will be strictly confidential and will not be used for any purpose outside this research. Information provided in this survey will not be attributed directly to you and will be used only for descriptive and analytical purposes in a form that will not reveal your identity or the identity of your organization.

Consent given Yes ☐ No ☐

[If the answer is "No" to this question, end the interview now]

SECTION 1: IDENTIFICATION *(enumerators to fill in the names, supervisor to provide the codes)*

Date of Interview: Dd/Mm/Year _______________/____________/______________________________

Region: ____________________________ Recode: ____

Woreda:____________________________ Wocode:____

Farming system____

Kebele: ____ Kebelecode: __________________________

Household Head full Name: ___________________________ Sex_____ Age______ Education__________

Farm experience_____________________________________ Marital status (*Single, Married*) _____________

Gps Longitude ____

Gps Latitude ____

Altitude (m)____

Landscape position according to the farmer (Upper/Medium/Low)___________________________

Enumerator's Full Name: ____

Supervisor's full Name: ____

Date Entered: DD/MM/Year __________________/____________/________________

Entered By ____ Decode: ________________

SECTION 2: HOUSEHOLD CHARACTERISTICS

2.2. Household members: number and age of member including household head.

Total numbers of house hold members including HH head____________________________

Age Category (in years)	No. of members in the household *		
	Male	*Female*	Total
< 6 years old			
6-9 years old			
10-15 years old			
15-60 years old			
> 60 years old			

*Include all persons living permanently in the household and taking food from the same kitchen.

SECTION 3: LIVESTOCK RESOURCES, PURPOSE OF KEEPING and OFF-TAKE

3a) Number of livestock owned at the beginning of the year for 2003 and changes in inventory during the year 2003 E.C.

Animal holdings: (**Cattle**_______ **Sheep**_______ **Goat** ___________ **Donkey**__________ **Horse**________ **Mule** ____**Chicken** M/F__________)

Animal Species	**Sub-group**	**Beginning** stock 2003E.C (n)	**Died/Lost** in 2003 E.C (n)	**Bought** in /gift in 2003 E.C (n)	Purpose Bought [1] (n)	**Gift** out/**sold/slaughtered**[2] in 2003 E.C (n)	If **sold** why[3] (n)	**Born** in 2003 E.C. (n)	Market value/animal [4]
Cattle	calf (<12 months)								
	1st yr heifer (13-24 months)								
	1st yr steer (13-24 months)								
	2nd yr heifer								
	2nd yr steer								
	3rd yr heifer								
	3rd yr steer								
	mature cow: dry								
	mature cow: pregnant								
	mature cow: lactating								
	Ox								
Sheep	lamb (<12 mths)								
	1st year								
	Mature ewe: dry								
	Mature ewe: Lactating								
	Ram/wether								
Goat	Kid								
	1st year								
	Mature doe: dry								
	Mature doe: Lactating								
	Mature buck								
Donkey	Foals								
	1st year								
	2nd year								
	3rd year								
	Jenny								
	Jack								
Horses and Mules	Foals								
	1st year								
	2nd year								
	3rd year								
	Mares								
	Stallion								
Chicken	M&F								

[1] **If bought:** **1**= Replace animal that died, **2**= start breeding (first animal) **3**= increase herd size, **4**= Breed improvement, **5**=Fattening, **6**= other (specify)[2] **Reason out:** **1=**Gifted out,
[1] **If bought:** **1**= Replace animal that died, **2**= start breeding (first animal) **3**= increase herd size, **4**= Breed improvement, **5**=Fattening, **6**= other (specify)[2] **Reason out:** **1=**Gifted out,
2= Sold, **3=**Slaughtered, **4**=Died

[3] **If sold:** **1**=to meet household expenses + clothing, **2**=business; **3**= Culling (**3a**=*unproductive*, **3b**= *old*, **3c**= *diseased*, **3d**= *Bad temperament*), **4**= Fattened, **5**=others (specify)

[4] **Market values for** (*Sold*, *slaughtered*, *gifted*, *died*)

3b) Rank purposes of keeping livestock and preferences (Give values for most (1) and least 3, 4 …preferred)

Attributes	***Oxen***	***Cows***	***Sheep***	***Goat***	***Equine***	***Remarks***
Preference/ importance Rank ⇨						
Product/services rank ⇩						
Meat					*not applicable*	
Milk					*not applicable*	
Work/draft (Plow and thresh…)			*not applicable*	*not applicable*		
Transport			*not applicable*	*not applicable*		
Income source/saving						
Manure						
Hides/skin					*not applicable*	
Security/Insurance						
Prestige status						
Dowry						
Calf production/replacement						
Other (specify)						

SECTION 4: LIVESTOCK PERFORMACE AND MANAGEMENT PRACTICES

4a) Livestock production and productivity

Animal Species	Breed Type	Average age at 1st Service(**mating**)/ months		**Age** at first **parturition** (months)	**Parturition** interval (Months)	**No** of offspring /parturition	**Productive** herd life at your farm in years		Total **number** of young in life time		Average **lactation** length for old/young in **month**		Average milk **yield** per day				**Breeding** animal **culling** age (years)			
													Wet		***Dry***					
		Male	Female								*Wet*	*Dry*	Morning	Afternoon	Morning	Afternoon	Male		Female	
							Min	*Max*	*Min*	*Max*							**Min**	**Max**	**Min**	**Max**
Cattle	Local																			
	Cross																			
Goats	Local																			
Sheep	Local																			
Horses	Local																			
Donkey	Local																			

4b) Livestock beneficial output utilization

Products	**Home consumption**	**Sold**	**Gifted out + reason***	**Calf feeding**	**Used as fertilizer on crop fields**	**Used as dung cake /fuel**	**Used for house plastering & threshing field pasting**
	Proportion (%)	***Proportion (%)***	***Proportion (%)***	***%***	***Proportion (%)***	***Proportion (%)***	***Proportion (%)***
Milk (L/day)							
Butter (kg/week)							
Cheese (kg/week)							
Manure (kg/day)							
Hides							
Skin							

*: **1**=Gift to religious; **2**=Feast/social sacrifice; **3**= given to sick persons; **4**= Given to relatives after fasting accomplishment; **5**= Given to relatives in the nearby town

4c) Traction power, threshing and transport

Animal group and performed activities		**Services types**																	
		*Time elapsed for **Ploughing** power*						*Time elapsed for **Threshing***						*Time elapsed for **Transports***					
		Hrs/day		day/month		Months/year		Hrs/day		Days/months		Months/years		Hrs/day		Days /months		Months/year	
		O^1	R^2	O^1	R^2	O^1	R^2	O^1	R^2	O^1	R^2	O^1	R^2	O^1	R^2	O^1	R^2	O^1	R^2
Oxen /steer	Traction (plow, thresh, transport?)																		
Cows/heifer	Threshing/ploughing?																		
	Transport crops to market																		

Donkey	Transport crops to home																		
	Transport to fetch water																		
	Transport to the mill house																		
Horse	Transport (human/merchandise)																		
Mule	Transport (human/merchandise)																		

[1]O= own animal [2], R = rented animal/ "***Wenfel*", "*Jigi*"** and other social collaborative working arrangements

- Number of animals performing the activities together at once: **Threshing____________________**
- Estimated value (birr/day) for group of animals: **Threshing_________________ Ploughing____**

Time of starting and ending of ploughing for different seasons (months): ____

4d) Livestock service by crop type

Animal labor	**Pair of Oxen in days (timad)**	**Services required/hectare**															Remarks
		Teff	**Barley**	**Wheat**	**Maize**	**Sorghum**	**Millet**	**Chickpea**	**F. Bean**	**Pea**	**H. Bean**	**Noug**	**G. nut**	**Sesame**	**Rice**	**Pepper**	
Ploughing	1st plow																
	2nd plow																
	3rd plow																
	4th plow																
	Final plow (seeding)																
Threshing *	# of Heap/hectare for																
	# of days for threshing																
	# of animals used per day																

* (Animals: oxen, cow, heifer, donkey, horses…)

- Average wage rate (man days) in the locality (Birr/day) _______________________
- Average daily rate for animal traction rental in the locality (Birr/day) **Oxen** plow/thresh _________/________, **Donkey** _______, **Horse** _______, **Mules** ______

4e) Livestock management activities and division of labor, Rank: a) **more** b) **Medium** c) **Low** d) Not at all e) Others (specify)

Activities		**Husband**	**Wife**	**Children**	**Hired labor**
Livestock Herding/feeding and Watering					
Milking					
Livestock Product Processing – butter/ghee, cheese…					
Manure collection and Barn/shed Cleaning					
Coral shifting and barn maintenance					
Animal management (Health care (medication), calf/kid/lamb management, stall-feeding (supplementary feeding) and Breeding…)					
Selling	Livestock				
	Livestock product				
	Dung cake				

4f) Selling priority if the cattle/sheep/goat is sold because of finance shortage (Rank as needed in their priority, 1st, 2nd, 3rd …)

4f1) ***Cattle***: Cow_____, Castrates_____, Infertile_____, Heifer______, Old cow_____, Bull______, Calf___________

4f2) ***Small ruminants***: Ewe/doe____, Castrates____, Infertile____, *Keb*_____ Old ewe/doe____, Ram/buck____, Lamb/kid___

- For what purpose is the cash obtained from selling livestock and livestock products used? ________________
- Who decides on the expenditure?____

- Which animal is mostly sold ____
- **4g) Livestock Breeding**

4.g1) Estrus/heat detection in cows?
a) Yes b) No

4.g2) In which seasons/months do more cows show estrus?____
____
____

4g3) Do you select superior male and female animals for breeding?
a) Yes b) No

4g4) What Breeding/mating practice/system do you employ?

a) Natural Mating/uncontrolled/open
b) Natural Mating/Controlled
c) Artificial insemination
d) A and B
e) A, B and C

4g5) If mating is uncontrolled, what is the reason?

a) Animals graze together
b) Lack of awareness
c) Lack/insufficient number of breeding males
d) Others (specify)

4g6) How do you select breeding males?

1. Pedigree history 2. Physical appearances 3. Growth rate 4. Service efficiency 5. Combination of the above (mention) ____6.Others (specify) ____________________________

4g7) Which season of the year you prefer for birth (calving/kidding/lambing) for different species of animals & what are the reasons? ____

____

4g8) Do you practice Calf/lamb/kid WEANING?

a) Yes b) No

4g9) If yes, Reason for weaning____

4g10) If No, why____

4g11) Weaning age for *calf*____________________*Lamb*_________*Kid*_________________________

4g12) Do you practice culling?

a) Yes b) No

4g13) Culling reason

a) Disease b) Old age c) Infertility d) Poor physical appearance and poor young bearing e) Lack of feed/grazing (mitigate feed shortage) f) Bad temperament g) Poor traction and unwilling to train for traction

4g14) Do you practice castration?

a) Yes b) No

4g15) If yes, reason for castration?

a) Control breeding b) Improve fattening c) Better temperament d) Better price e) others (Specify)

4g16) Do you exercise Cross breeding? a) Yes b) No, If yes (Local * best local/ Local * exotic)

4g17) If no, what are the major problems in getting cross breeding services?

a) Places are too far b) It is often difficult to get the inseminator c) Payment for crossbreeding is too much d) I don't hear about crossbreeding

4g18) If yes, for what reason you want cross breeding services?

a) To get more milk b) To get more draught power c) Others (specify)______________

4g19) How do you herd your animals during grazing

a) Separately b) Mixed with other species c) Not herded

4g20) In which season do you herd your animals Separately?___________________________________

4g21) what is the reason for herding your animals separately?_________________________________

4g22) At what age on average your different species of animals reach to market or slaughter in years?

(Cattle________Sheep_________Goat__________`)

4g23) Average years a bull trained and fit for cultivation: Local__________Exotic/crossed_________

4g24) Average years donkey/horse and mule start servicing___________/__________/________________

4g25) Do you have an experience of keeping records in your farm pertinent to livestock rearing? a) Yes b) No

SECTION 5: Livestock housing, Livestock movement

5a) Housing type for different species of livestock (tick**)**

Type of housing used during the night	Cattle	Small ruminants	Equine	Poultry
Separate house or isolate pen				
Attached to the house				
In-the house with people				
Kraal / coral at the crop field)				

5b) Which species are privileged for housing? *Rank them with priority:*

a) Cattle_____ b) Sheep____ c) Goat____ d) Equines______ e) Others (specify)____________________

5c) Do you move your animals to other places?

a) Yes b) No

5f) Reason of movement____

5g) Season of movement (months) to go______________________Months to go back________________________

5h) Types of animals to be moved and the number____

5i) Way of movement and perceived benefit obtained____

5j) Cost per animal for hosting____

SECTION 6: Manure production, management, storage and use;

6.1. Manure production and its usage

Which Types of animal	End products[1]	Place of collection [2]	Processing activities [3]	Storage means [4]	Daily number of baskets/'*enkib' collected*
Cattle					
Goat					
Sheep					
Equine					
Poultry					
Other					

[1] **End product:** 1= manure; 2= compost; 3= cake; 4=plaster; 5=other (specify),_____________________

[2] **Place of collection:** (**M**ultiple **A**nswer is possible) 1=grazing land; 2=stall; 3=other (specify)______________________________

[3] **Processing activities: MA** 1=mixing with straw; 2=drying; 3=other (specify)______________________________

[4] **Storage: MA** 1=pit; 2=heap; 3=in situ/corral; 4=other (specify)____

6.2) Do you practice night corralling? a) Yes b) No, if yes!

- **Why**?____
- **In which field and for how long?**____
____
- **When**____
- **How is shifting of corals**____
- **Sequence of the crop type for corralling**_______________________________
____
____

SECTION 7: Major constraints of Livestock development/improvement?

7a) Major livestock production constraints (Direct ranking): 1= major problem…

Problems	Rank constraints
Feed shortage	
Disease	
Poor genotype	
Lack of market access	
Drinking water scarcity	
Labor shortage	
Shortage of initial capital	
Limited knowhow	
Predator	

7b) Major Constraints of Veterinary interventions?, *Rank them according to their priority.*

a) Distance to health center______________ b) Lack of drugs _____________ c) Un affordability of the service __________ d) Lack of skilled technicians______________ e) Awareness problem ___________________

7b1) Distance in km or travel per hour to the animal health center from your home____________ (km) or __________ (hrs)

7c) Reason for most deaths for livestock (1st: Major problem…)

Constraints	*Rank as needed with priority*	*Remarks*
Disease		
Poisoning/bloat with legume & others		
Hunger		
Accident		
Predator		
Unknown		

7d) Seasonal calendar of animal mortality

Animal Species	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*June*	*July*	*Aug*	*Sept*	*Oct*	*Nov*	*Dec.*
Cattle												
Sheep												
Goat												
Equine												
Poultry												

*** Mortality [+ low; ++ high; +++ very high]**

7e) **Major livestock health problems, their importance and effect in your area** (tick as needed and prioritize)

Health problems		**Affected species**								**Importance ***	**Effect ****
		Cattle		***Small ruminants***		***Equine***		***Poultry***			
Scientific name	**Vernacular names/**Local names	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**	**Wet season**	**Dry season**		
Black leg											
FMD											
Liver fluke											
Pneumonia											
Tick											
Skin disease											
Internal parasite											
Anthrax											
Trypanosomiasis											
Bloat											

****: 1= Low, 2= medium, 3= high, 4= very high:*** *****: 1= Mortality, 2= Morbidity***

SECTION: 8 **Costs of purchased inputs for livestock production during 2001-2003 E.C.**

Item	Unit	Quantity	Value in (birr)			Remarks
			2001	*2002*	*2003*	
Feed (Dry fodder, Green fodder)						
Supplements (Salt lick, Concentrates; Oil cakes, bran**)**						
Medicine (Treatment, Vaccine, de-worming**)**						
Artificial insemination						
Bull/ram/buck service						
Herding cost						
Cost of animal housing?						

SECTION 9: LIVESTOCK PRODUCTION SUPPORT SERVICES

What type and by whom you get services

Types of services	Yes/ No	Organization /experts	How Often?	If not get service tell constraints
Extension advice on livestock management (breed improvement, culling, housing …)				
Health/Veterinary service (Vaccination, de-worming, treatment)				
Artificial Insemination				
Improved fodder Seeds, production and feeding systems				
Credit for livestock production				

9.1 Have you put the information in to practice

a)Yes b) No

9.2. Reason for not putting the information in to practice? ______________________________

Appendix 2 Check list for key informants and District MoA

Check list for Key informants

1. What are the major constraints of livestock production and productivity in your area?
2. What are the indicators for wealth ranking according to the local community standards?
3. What are the common/major disease and parasites that affect the Livestock in the dry/wet seasons? Rank them , Disease type, occurring month, Possible causes
4. Discuss the issues of credit facilities, access to modem farm inputs (fertilizer, improved seeds, pesticides, herbicides, improved breeds/AI, and veterinary drugs) and marketing?
5. What livestock and water management activities should be undertaken for optimum and sustainable production? (Comment on the livestock type, number, housing, breeding, feeding).
6. Do farmers in your area use livestock for dual purposes (cows/horses for traction/ploughing)?
7. How do livestock management system and your production objectives help maintain your livestock in the occurrence of disaster such as drought, disease, shortage of land and water etc? ____
8. Do farmers in your locality give preference to different livestock species for drinking water/which season/for which species do they give priority and why____
9. What is the minimum wage per day in your area?
10. Do farmers cull oxen at certain season of year (slack period) in your area?_____________________
11. What are wealth ranking criteria in your locality? For poor, medium and better-off farmers_______

Appendix Table 1: Least squares means ± standard errors of cattle herd structure (TLU hh^{-1}) HH^{-1} in surveyed farming systems.

Species	Fogera		Jeldu			Diga		Over all
	Rice-Pulse (N=30)	Teff-Millet (N=32)	Barley-Potato (N=31)	Teff-Wheat (N=30)	Sorghum (N=30)	Teff-Millet (N=35)	Sorghum (N=32)	(N=220)
	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE
Cattle	5.13 ± 0.59^{ab}	5.96 ± 0.62^{ab}	4.47 ± 0.57^{b}	6.67 ± 0.66^{a}	4.95 ± 0.46^{ab}	5.43 ± 0.58^{ab}	5.67 ± 0.71^{ab}	5.47 ± 0.23
Oxen & Steer	2.71 ± 0.36^{a}	2.85 ± 0.33^{a}	2.66 ± 0.34^{a}	3.25 ± 0.33^{a}	2.53 ± 0.23^{a}	2.67 ± 0.35^{a}	2.77 ± 0.34^{a}	2.78 ± 0.12
Cow & Heifer	2.09 ± 0.24^{ab}	2.70 ± 0.35^{a}	1.51 ± 0.23^{b}	2.88 ± 0.34^{a}	2.09 ± 0.29^{ab}	2.34 ± 0.25^{ab}	2.55 ± 0.39^{ab}	2.31 ± 012
Calf	0.33 ± 0.05^{b}	0.41 ± 0.06^{ab}	0.30 ± 0.05^{b}	0.54 ± 0.06^{a}	0.33 ± 0.06^{b}	0.42 ± 0.05^{ab}	0.35 ± 0.06^{b}	0.38 ± 0.02
% ox & steer	*52.83*	*47.82*	*59.51*	*48.73*	*51.11*	*49.17*	*48.85*	*50.82*
% cow & Heifer	*40.74*	*45.30*	*33.78*	*43.18*	*42.22*	*43.09*	*44.97*	*42.23*
% of calf	*6.43*	*6.88*	*6.71*	*8.10*	*6.67*	*7.73*	*6.17*	*6.95*

N = number of respondents; SE = Standard Errors; TLU = Tropical Livestock Unit. a,b,c = means with different superscripts within a row are significantly different($p<0.05$).

Appendix Table 2: Livestock as a source of procurement of farm inputs (%) of respondents (220)

District	Farming systems	Used for Household expense		For farm expense		For schooling & health	
		Yes	No	Yes	No	Yes	No
Fogera	Rice-Pulse	83.33	16.67	23.33	76.67	66.67	33.33
	Teff-Millet	71.88	28.13	50.00	50.00	78.13	21.88
Jeldu	Barley-Potato	58.06	41.94	80.65	19.35	83.87	16.13
	Teff-Wheat	46.67	43.33	86.67	13.33	83.33	16.67
	Sorghum	63.33	36.67	46.67	53.33	76.67	23.33
Diga	Teff-Millet	65.71	34.29	77.14	22.86	91.43	8.57
	Sorghum-Maize	71.88	28.13	53.13	46.88	59.38	40.63
Over all		**67.27**	**32.73**	**60.00**	**40.00**	**77.27**	**22.73**

Appendix Table 3a: Purpose of keeping cow by the study respondents in the BNB

Purpose of keeping cow	Rank 1st	Rank 2nd	Rank 3rd	Rank 4th	Index	Ranks
Replacement	158	46	2	0	0.38	1st
Milk	55	152	5	2	0.34	2nd
Manure	1	7	122	40	0.17	3rd
Income/Prestige/Dowry	0	9	84	98	0.11	4th
Total	214	214	213	140		

Index = sum of [4 for rank 1 + 3for rank 2 + 2 for rank 3+1for rank 4] for particular purpose divided by sum of [4 for rank 1 + 3for rank 2 + 2 for rank 3+1for rank 4]for all purpose of keeping cows.

Appendix Table 3b: Purpose of keeping sheep and goats by the study respondents in the BNB

Purpose of keeping sheep & goat	Rank 1st	Rank 2nd	Rank 3rd	Index	Ranks
Income source	115	41	23	0.46	1st
Manure	3	42	65	0.16	3rd
Meat/Replacement	47	82	76	0.38	2nd
Total	165	165	164		

Index= sum of (3 X number of household ranked 1st + 2 X number of households ranked 2nd + 1 X number of households ranked 3rd) given for purpose of keeping small ruminants divided by sum of (3 X number of households ranked 1st + 2 X number of households ranked 2nd + 1 X number of households ranked 3rd) for all purpose of keeping small ruminants.

Appendix Table 3c: Purpose of keeping equines by the study respondents in the BNB

Purpose of keeping equines	Rank 1st	Rank 2nd	Rank 3rd	Index	Ranks
Transportation	144	9	2	0.50	1st
Income/Replacement	10	92	84	0.33	2nd
Manure	2	47	52	0.17	3rd
Total	156	148	138		

Index= sum of (3 X number of household ranked first + 2 X number of household ranked second + 1 X number of household ranked third) given for purpose of keeping equine divided by sum of (3 X number of household ranked first + 2 X number of household ranked second + 1 X number of household ranked third) for all purposes.

Appendix Table 4: Exercises of record keeping in Livestock husbandry (%) of respondents (220)

District	Farming systems	Do you keep records regarding your livestock	
		Yes	No
Fogera	Rice-Pulse	6.67	93.33
	Teff-Millet	0.00	100.00
Jeldu	Barley-Potato	6.45	93.55
	Teff-Wheat	13.33	86.67
	Sorghum	0.00	100.00
Diga	Teff-Millet	2.86	97.14
	Sorghum-Maize	6.25	93.75
Over all		**5.00**	**95.00**

Appendix Table 5: Least squares means $\pm$ standard errors of slaughter age and age bulls fit for service in years

Districts	Farming system	Slaughter age for cattle		Age of bulls fit service (plowing)	
		N	LSM $\pm$SE	N	LSM $\pm$SE
Fogera	Rice-Pulse	26	3.37 ± 0.28^{b}	26	3.90 ± 0.17^{bc}
	Teff-Millet	32	3.61 ± 0.24^{ab}	31	4.26 ± 0.12^{ab}
Jeldu	Barley-Potato	30	3.30 ± 0.24^{bc}	30	3.57 ± 0.13^{dc}
	Teff-Wheat	29	3.28 ± 0.26^{bc}	30	3.45 ± 0.11^{dc}
	Sorghum	30	2.60 ± 0.12^{c}	29	3.57 ± 0.10^{d}
Diga	Teff-Millet	35	4.20 ± 0.23^{a}	34	4.35 ± 0.12^{a}
	Sorghum	29	3.97 ± 0.34^{ab}	28	3.95 ± 0.16^{bc}
Overall		**208**	**3.49 ± 0.10**	**208**	**3.88 ± 0.05**

Means with different superscripts across column for all farming systems are statistically different ($p< 0.05$).

Appendix Table 6: Least squares means ± standard errors of slaughter age of Sheep and goats in months in the study farming systems.

Districts	Farming system	Slaughter age for Sheep		Slaughter age for Goats	
		N	LSM ± SE	N	LSM ± SE
Fogera	Rice-Pulse	11	7.73 ± 0.92^{b}	9	6.78 ± 0.83^{bcd}
	Teff-Millet	6	7.67 ± 0.99^{b}	20	8.80 ± 0.64^{bc}
Jeldu	Barley-Potato	27	7.11 ± 0.63^{b}	5	5.40 ± 0.75^{cd}
	Teff-Wheat	27	7.52 ± 0.76^{b}	11	5.0 ± 0.86^{d}
	Sorghum	21	7.95 ± 0.74^{b}	4	7.82 ± 0.71^{bcd}
Diga	Teff-Millet	27	13.81 ± 0.94^{a}	20	14.40 ± 1.01^{a}
	Sorghum	20	10.30 ± 1.00^{b}	10	9.50 ± 1.09^{b}
Overall		**139**	**9.15±0.39**	**79**	**9.53±0.50**

Means with different superscripts across column for all farming systems are statistically different ($p < 0.05$).

Appendix Table 7: Least squares means ± standard errors of age at which equines reach and fit for services (years).

Districts	Farming system	Age donkeys fit services		Age horses fit services	
		N	LSM ±SE	N	LSM ±SE
Fogera	Rice-Pulse	17	1.67 ± 0.20^{b}	-	-
	Teff-Millet	21	1.83 ± 0.27^{b}		-
Jeldu	Barley-Potato	6	2.25 ± 0.48^{ab}	22	2.86 ± 0.16^{a}
	Teff-Wheat	14	2.36 ± 0.23^{ab}	17	2.99 ± 0.25^{a}
	Sorghum	15	2.75 ± 0.18^{a}	26	3.04 ± 0.17^{a}
Diga	Teff-Millet	27	2.22 ± 0.26^{ab}	-	-
	Sorghum	19	1.95 ± 0.20^{ab}	-	-
Overall		**119**	**2.12±0.10**	**65**	**2.95±0.12**

Means with different superscripts within the same column (for all farming systems) are statistically different ($p < 0.05$).

Appendix Table 8: Least squares means ± standard errors of calving annual reproductive rate (%) in sheep/ goat and cow.

Farming systems	Calving Rate	ARR for Sheep	ARR for Goats
	LSM ± SE	LSM ± SE	LSM ± SE
Barley Potato, Jeldu	66.41 ± 3.65^{b}(29)	194.81 ± 14.98 (26)	171.24 ± 36.05 (3)
Teff-Wheat, Jeldu	65.07 ± 3.39^{bc}(29)	174.76 ± 12.74 (24)	135.19 ± - (1)
Sorghum, Jeldu	62.44 ± 3.17^{bc}(30)	175.43 ± 19.42 (11)	206.16 ± 33.54 (5)
Rice-Pulse, Fogera	56.27 ± 2.15^{cd} (27)	205.76 ± 36.42 (7)	185.88 ± 42.53 (3)
Teff-Millet, Fogera	52.54 ± 1.86^{d}(32)	152.08 ± - (1)	245.63 ± 15.51 (19)
Sorghum, Diga	76.41 ± 3.79^{a}(30)	224.50 ± 21.36 (14)	270.37 ± 0.00 (2)
Teff-Millet, Diga	57.19 ± 2.39^{cd}(35)	173.77 ± 13.61 (24)	235.27 ± 21.94 (13)
Over all mean ± SE	62.18 ± 1.2 (212)	187.80 ± 6.98 (107)	228.34 ± 10.64 (46)

Numbers in brackets indicate number of observation; Means with different superscripts within the same column (farming systems) are statistically different ($p < 0.05$).

Appendix Table 9: Least squares means ± standard errors of lifetime young production (number) by the different livestock species.

Districts	Farming system	Number of young produced in life time									
		Cow		Ewe		Doe		Jenny		Mare	
		N	LSM ±SE	N	LSM ±SE	N	LSM ±SE	N	LSM ±SE	N	LSM ±SE
Fogera	Rice-Pulse	27	5.8±0.3	7	24±3.8	3	17.2±7.4	9	14.0±0.9	-	-
	Teff-Millet	32	5.1±0.3	1	9.5±9.5	17	19±2.1	16	10.4±1.3	-	-
Jeldu	Barley-Potato	29	5.6±0.2	25	10.2±0.9	3	13.2±4.2	4	8.1±1.4	19	10.1±1.1
	Teff-Wheat	29	5.8±0.3	24	10.9±1.1	1	9.0±9.0	9	9.7±1.7	25	10.3+0.8
	Sorghum	30	6.5±0.4	11	8.4±0.7	4	10±2.1	11	7.8±1.1	8	9.9±1.5
Diga	Teff-Millet	35	6.8±0.3	24	7.6±0.7	13	9.4±0.9	7	8.9±1.9	-	-
	Sorghum	30	8.1±0.4	14	11.8±1.7	2	5.3±1.8	9	11.8±1.4	-	-
Overall		**212**	**6.3±0.1**	**106**	**10.7±0.6**	**43**	**14.0±1.3**	**65**	**10.3±0.6**	**52**	**10.1±0.6**

Appendix Table 10: Least squares means + standard errors of number of day equines was used for different activities

Districts	Farming system	Donkey								Horses					
		For marketing		Crop transport		Fetching water		Milling		For Threshing		Transport Merchandise		Transport human	
		N	LSM + SE	N	LSM + SE	N	LSM + SE	N	LSM + SE	N	LSM + SE	N	LSM + SE	N	LSM + SE
Fogera	Rice-Pulse	12	33.3+3.6	11	6.5+1.2	1	122.0+00	12	13.9+1.5	-	-	-	-	1	50.0+0.0
	Teff-Millet	16	25.8+3.5	15	8.3+2.4	3	122.0+00	20	20.3+2.4	-	-	-	-	-	-
Subtotal		***28***	***29.0+2.6[a]***	***26***	***7.5+1.4[a]***	***4***	***122.0+00[a]***	***32***	***17.9+1.7[b]***	-	-	-	-	***1***	***50.0+00***
Jeldu	Barley-Potato	5	21.0+8.9	4	6.8+1.8	5	107.2+14.8	5	21.6+2.4	22	5.4+0.5	19	67.7+10.7	23	61.2+10.7
	Teff-Wheat	11	25.9+4.8	9	5.9+2.4	9	122.0+00	11	18.7+1.9	26	4.2+0.5	20	62.0+12.2	24	39.3+7.4
	Sorghum	11	35.7+8.4	6	11.0+7.4	6	122.0+0.00	13	29.1+3.7	9	3.1+0.5	10	41.5+7.9	12	33.5+5.6
Subtotal		***27***	***29.0+4.3[a]***	***19***	***7.7+2.5[a]***	***20***	***118.3+3.7[a]***	***29***	***23.9+2.0[a]***	***57***	***4.5+0.3***	***49***	***60.0+6.7***	***59***	***46.6+5.4***
Diga	Teff-Millet	17	19.3+3.6	17	6.9+1.7	5	102.4+19.6	16	31.5+3.6	-	-	-	-	-	-
	Sorghum	10	25.8+5.4	12	6.5+1.1	11	113.5+7.0	14	25.1+2.9	-	-	-	-	-	-
Subtotal		***27***	***21.7+3.0[a]***	***29***	***6.7+1.1[a]***	***16***	***110.0+7.5[a]***	***30***	***28.5+2.4[a]***	-	-	-	-	-	-
Overall		**82**	**26.6+1.9**	**74**	**7.2+0.9**	**40**	**115.4+3.5**	**91**	**23.3+1.3**	**57**	**4.5+0.3**	**49**	**60.0+6.7**	**60**	**46.7+5.3**

Comparison was made across column only for the different districts, supper scripts with different letters indicate significance at ($p<0.05$)

Appendix Table 11: Leas squares means ± standard errors of livestock beneficial outputs in (Liter and kg/HH/year).

Farming systems	Wealth Category	Output per year and units of measure					
			Milk output (Lit)	Manure (Kg)	Manure N (Kg)	Manure P (Kg)	Manure K (Kg)
		N	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE
Rice-pulse/ Fogera	Poor	10	327.0±171.5[b]	2183.9±388.3[c]	33.9±7.1[c]	9.8±1.7[c]	46.5±8.3[c]
	Medium	10	590.3±171.8[ab]	6723.5±690.4[b]	123.0±12.6[b]	30.3±3.1[b]	143.2±14.7[b]
	Better-off	10	849.0±158.0[a]	12767.46±456.5[a]	233.6±8.4[a]	57.5±2.1[a]	271.9±9.7[a]
Subtotal		***30***	***588.8±97.2***	***7224.9±857.1***	***132.2±15.7***	***32.5±3.9***	***153.9±18.3***
Teff-Millet /Fogera	Poor	11	249.7±104.9[b]	4146.4±469.1[c]	75.9±8.6[c]	18.7±2.1[c]	88.3±9.9[c]
	Medium	10	346.5±136.2[b]	7253.9±266.6[b]	132.7±4.9[b]	32.6±1.2[b]	154.5±5.7[b]
	Better-off	11	1050.0±260.1[a]	14534.6±1059.3[a]	265.9±19.4[a]	65.4±4.8[a]	309.6±22.6[a]
Subtotal		***32***	***555.0±120.8***	***8688.4±885.3***	***158.9±16.2***	***39.1±3.9***	***185.1±18.9***
Barley-Potato /Jeldu	Poor	12	43.8±32.6[c]	2797.4±476.2[c]	51.2±8.7[c]	12.6±2.1[c]	59.6±10.1[c]
	Medium	9	315.9±93.2[b]	7644.8±576.6[b]	139.9±10.6[b]	34.4±2.6[b]	162.8±12.3[b]
	Better-off	10	918.0±172.0[a]	14355.5±1800.6[a]	262.7±32.9[a]	64.6±8.1[a]	305.8±38.4[a]
Subtotal		***31***	***404.8±90.9***	***7933.2±1075.3***	***145+2±19.7***	***35.7±4.8***	***168.9±22.9***
Teff-Wheat /Jeldu	Poor	10	360.0±110.1[b]	5504.2±1007.6[c]	100.7±18.4[c]	24.8±4.5[c]	117.2±21.5[c]
	Medium	9	606.7+136.3[ab]	10929.0±635.9[b]	200.0±11.6[b]	49.2±2.9[b]	232.8±13.5[b]

Farming systems	Wealth Category	Output per year and units of measure					
			Milk output (Lit)	Manure (Kg)	Manure N (Kg)	Manure P (Kg)	Manure K (Kg)
		N	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE	LSM ± SE
	Better-off	11	1118.2±311.8 [a]	16898±1079.5[a]	309.2±19.8[a]	76.0±4.9[a]	359.9±22.9[a]
Subtotal		***30***	***712.0±136.8***	***11309.7±1034.3***	***206.9±18.9***	***50.9±4.7***	***240.9±22.0***
Sorghum /Jeldu	Poor	10	102.0±6.4 [c]	3624.6±364.7[c]	66.3±6.7[c]	16.3±1.6[c]	77.2±7.8[c]
	Medium	10	526.5±235.4[b]	7443.2±583.1[b]	136.2±10.7[b]	33.5±2.6[b]	158.5±12.54[b]
	Better-off	10	654.8±224.6[b]	12480.4±716.2[a]	228.4+13.1[a]	56.2±3.2[a]	265.8±15.3[a]
Subtotal		***30***	***427.8±114.9***	***7849.4±745.4***	***143.6±13.6***	***35.3±3.4***	***167.2±15.9***
Teff-Millet /Diga	Poor	12	115.0±32.8 [c]	3373.3±468.4[c]	61.7±8.6[c]	15.2±2.1[c]	71.9±9.9[c]
	Medium	11	359.7±53.1[b]	7323.8±649.1[b]	134.0±11.9[b]	32.9±2.9[b]	155.9±13.8[b]
	Better-off	12	559.0±93.5[a]	12445.1±885.6[a]	227.7±16.2[c]	56.0±3.9[a]	265.1±18.9[a]
Subtotal		***35***	***344.1±48.5***	***7725.2±753.3***	***141.4±13.8***	***34.8±3.4***	***164.5±16.0***
Sorghum /Diga	Poor	11	57.3±38.9[c]	2327.5±420.1[c]	42.6±7.7[c]	10.5±1.9[c]	49.6±8.9[c]
	Medium	9	280.0±104.4[b]	6816.2±621.9[b]	124.7±11.4[b]	30.7±2.8[b]	145.2±13.2[b]
	Better-off	12	686.5±125.2[b]	13488.9±1154.6[a]	246.8±21.1[a]	60.7±5.2[a]	287.3±24.6[a]
Subtotal		***32***	***355.9±73.5***	***7775.5±978.5***	***142.3±17.9***	***34.9±4.4***	***165.6±20.8***
Total	**Poor**	**76**	**173.31±32.64[c]**	**3399.9±230.2[c]**	**62.2±4.2[c]**	**15.3±1.0[c]**	**72.4±4.9[c]**
	Medium	**68**	**432.53±54.34[b]**	**7695.3±265.8[b]**	**140.8±4.9[b]**	**34.6±1.2[b]**	**163.9±5.7[b]**
	Better-off	**76**	**829.13±76.97[a]**	**13855.4±429.9[a]**	**253.6±7.9[a]**	**62.3±1.9[a]**	**295.1±9.2[a]**

Comparisons were made within column, for the wealth categories within farming systems separately at ($p<0.05$).

Appendix Table 12: Least squares means ± substandard errors of amount of water depleted (m^3) per HH for feed production

Districts	Farming system	Water depleted/ HH (m^3)/ year	
		N	LSM ± SE
Fogera	Rice-Pulse	30	4679.92±433.29^{bc}
	Teff-Millet	32	5281.01±442.10^{b}
Jeldu	Barley-Potato	31	5374.94±511.35^{ab}
	Teff-Wheat	30	6590.67±478.21^{a}
	Sorghum	30	4933.38±423.47^{bc}
Diga	Teff-Millet	35	3873.37±282.59^{c}
	Sorghum	32	4768.43±472.63^{bc}
Overall		**220**	**5044.97±170.68**

Comparisons were made within column, for the farming systems (p<0.05).

Own survey: 2011

Appendix Table 13 Major reasons of Livestock death by farming system (Index)

Constraints	Fogera						Jeldu				Diga				For all farming systems	
	Rice-Pulse		Teff-Millet		Barley-Potato		Teff-Wheat		Sorghum		Teff-Millet		Sorghum			
	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Disease	0.36	1st	0.33	1st	0.28	2nd	0.31	2nd	0.33	2nd	0.33	1st	0.39	1st	0.34	1st
Bloat	0.25	2nd	0.29	2nd	0.37	1st	0.37	1st	0.40	1st	0.22	2nd	0.14	3rd	0.29	2nd
Feed shortages/hunger	0.19	3rd	0.16	3rd	0.16	3rd	0.08	4th	0.09	4th	0.09	5th	0.12	4th	0.13	3rd
Accident	0.10	4th	0.10	4th	0.15	4th	0.13	3rd	0.12	3rd	0.15	4th	0.15	2nd	0.12	4th
Predation	0.00	6th	0.01	6th	0.01	6th	0.01	6th	0.03	5th	0.06	3rd	0.09	6th	0.05	6th
Un-known reason	0.10	4th	0.11	5th	0.03	5th	0.10	5th	0.03	5th	0.04	6th	0.12	4th	0.08	5th

Appendix Table 14: Major reasons for veterinary interventions problems in the farming systems understudy (Index)

Constraints	Fogera						Jeldu				Diga				For all farming systems	
	Rice-Pulse		Teff-Millet		Barley-Potato		Teff-Wheat		Sorghum		Teff-Millet		Sorghum			
	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank	Index	Rank
Distance to reach the service place	0.34	1st	0.36	1st	0.33	1st	0.42	1st	0.45	1st	0.42	1st	0.24	1st	0.30	1st
Luck of drug	0.20	3rd	0.24	2nd	0.18	3rd	0.17	3rd	0.19	3rd	0.20	3rd	0.24	3rd	0.23	3rd
Un-affordability of the service	0.21	2nd	0.11	5th	0.28	2nd	0.21	2nd	0.21	2nd	0.24	2nd	0.26	2nd	0.24	2nd
Lack of skilled technician	0.18	4th	0.16	3rd	0.11	4th	0.10	4th	0.07	5th	0.06	5th	0.11	4th	0.13	4th
Lack of awareness	0.08	5th	0.12	4th	0.11	4th	0.10	4th	0.09	4th	0.07	4th	0.04	5th	0.09	5th

Index= sum of (5 X number of HHs ranked first + 4 X number of HHs ranked second + 3 X number of HHs ranked third 2 X number of HHs ranked fourth + 1 X number of HHs ranked fifth) for particular constraint divided by sum of (5 X number of HHs ranked first + 4 X number of HHs ranked second + 3 X number of HHs ranked third + 2 X number of HHs ranked fourth + 1 X number of HHs ranked fifth) for constraints..

Appendix Table 15a: Reported prevalence of diseases of cattle in the Jeldu District (%)

Diseases	Vernacular name (*Affaan Oroomo*)	Barley-Potato (N= 31)	Teff-Wheat (N=30)	Sorghum (N=30)
		%	%	%
Blackleg		16.13	10.00	16.67
Trypanosomiasis	Gendi	-		10.00
Internal parasites	Ramo kesa	6.45		7.39
Anthrax	Chifa	22.58	16.67	26.67
Ticks	Silmi	9.68	6.67	10.00
Bloat	Bokoka	38.71	30.0	10.00
Pneumonia	Qufa	3.23		
Skin disease	Chito		13.33	3.33
Leech		3.23	10.00	3.69
Foot & mouth disease			13.33	6.53

N = number of respondents.

Appendix Table 15b: Reported prevalence of diseases of cattle in the Fogera District (%)

Diseases	Vernacular name (Amharic)	Rice-Pulse (N= 30)	Teff-Millet (N=30)
		%	%
Blackleg	Aba gorba	13.79	
Trypanosomiasis	Gerefita	31.03	31.25
Internal parasites	Tilatil	10.34	6.25
Anthrax	Kurba	10.34	15.63
Ticks	Mezger	10.34	25.00
Bloat	Nifat	6.90	15.63
Pneumonia	Sal		
Skin disease	Ykoda Beshta	3.45	3.13
Leech	Alekt		
Foot & mouth disease	Maze	13.79	25.00

N = number of respondents.

Appendix Table 15c: Reported prevalence of diseases of cattle in the Diga District (%)

Diseases	Vernacular name (*Afaan Oroomo*)	Sorghum (N= 30)	Teff-Millet (N=30)
		%	%
Blackleg	Bushoftu		5.71
Trypanosomiasis	Gendi/Kokisa	78.13	65.71
Internal parasites	Ramo Gera Kesa		5.71
Anthrax	Chifa	3.13	8.57
Ticks	Silmi	6.25	2.86
Bloat	Boloksisa		5.71
Skin disease	Chito	6.25	5.71
Foot & mouth disease		6.25	-

N = number of respondents.

Appendix Table 16: Status of extension service and input delivery to the farm households (%)

Districts	Farming system	Extension advisory		Access to improved seed		Credit for LS improvement		Did you practice	
		N	%	N	%	N	%	N	%
Fogera	Rice-Pulse	17	56.67	9	30.00	3	10.00	10	33.33
	Teff-Millet	28	80.00	4	12.50	2	6.25	3	9.38
Jeldu	Barley-Potato	17	54.84	14	45.16	6	19.35	8	25.81
	Teff-Wheat	18	60.00	5	16.67	5	16.67	5	16.67
	Sorghum	15	50.00	3	10.00	3	10.00	0	0.00
Diga	Teff-Millet	28	80.00	8	22.86	2	5.71	8	22.86
	Sorghum	10	31.25	5	15.63	0	0.00	1	3.13
Overall		**119**	**54.09**	**48**	**21.82**	**21**	**9.55**	**35**	**15.91**

Appendix Table 17: Relative Wealth Ranking of HHs depending on the Cattle and land holding.

Farming systems	**Wealth category**	**Cattle Holding in Number**	**Land Holding in hectare**
Rice-pulse/ Fogera	Poor	0-4	<0.75
	Medium	4-7	1.00-1.75
	Better-off	>7	1.75-3.00
Teff-Millet /Fogera	Poor	1-4	<0.75
	Medium	4-7	0.75-1.75
	Better-off	8-15	1.75-3.25
Barley-Potato /Jeldu	Poor	0-3	<1.50
	Medium	5-7	1.50-2.25
	Better-off	7-14	2.25-3.50
Teff-Wheat /Jeldu	Poor	0-7	<1.75
	Medium	8-9	1.75-2.75
	Better-off	8-19	2.75-5.00
Sorghum /Jeldu	Poor	0-3	<1.75
	Medium	4-8	1.75-2.75
	Better-off	8-13	2.75-4.00
Teff-Millet /Diga	Poor	0-4	<2.00
	Medium	4-8	2.00-2.75
	Better-off	8-18	2.75-4.50
Sorghum /Diga	Poor	0-4	<1.25
	Medium	4-8	1.25-2.50
	Better-off	8-17	2.50-6.00

Source: Key informants and MoA experts (2011)

Appendix Table 18: ANOVA test resulting for effect of farming system on livestock holdings

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	276.93	6	46.16	2.8	0.012
Within groups	3510.79	213	16.48		
Total	3787.72	219			

Appendix Table 19: ANOVA test resulting for effect of farming system on HH labor force availability

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	46.29	6	7.71	3.07	0.0067
Within groups	535.08	213	2.51		
Total	581.37	219			

Appendix Table 20: ANOVA test resulting for effect of farming system on Kraal shifting in wet season

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	29.59	4	7.397	4.93	0.0025
Within groups	61.56	41	1.50		
Total	91.15	45			

Appendix Table 21: ANOVA test resulting for effect of farming system on Kraal shifting in dry season

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	540.22	6	90.04	8.62	0.0001
Within groups	616.27	59	10.45		
Total	1156.48	65			

Appendix Table 22: ANOVA test resulting for effect of farming system on cows lactation length in months.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	138.65	6	23.11	3.33	0.0037
Within groups	1421.90	505	6.94		
Total	1560.55	211			

Appendix Table 23: ANOVA test resulting for effect of farming system on Age at first mating for female cattle in months.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	1869.33	6	311.55	5.08	0.0001
Within groups	12581.59	505	61.37		
Total	14450.92	211			

Appendix Table 24: ANOVA test resulting for effect of farming system on Age at first parturition for cattle in months.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	2857.73	6	476.29	7.89	0.0001
Within groups	12368.87	505	60.34		
Total	15226.61	211			

Appendix Table 25: ANOVA test resulting for effect of farming system on parturition interval for cattle in months.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	936.38	6	156.06	6.19	0.0001
Within groups	5172.62	213	25.23		
Total	6108.995	219			

Appendix Table 26: ANOVA test resulting for effect of farming system on Livestock beneficial output and services in USD/ HH/Year.

Beneficial output value	Source	Sum of Squares	Df	Mean Square	F	Sig
Total milk values	Between groups	2256414.25	6	42735.70	1.76	0.1079
	Within groups	5160768.33	213	24228.96		
	Total	5417182.56	219			
Total off-take values	Between groups	193430.92	6	32238.449	1.5	0.1794
	Within groups	4577356.25	213	21489.94		
	Total	4770787.17	219			
Total value of services	Between groups	928904.17	6	154817.36	1.28	0.2677
	Within groups	25762771.56	213	120951.98		
	Total	26691675.74	219			
Total manure values	Between groups	87496.93	6	14582.82	2.19	0.0450
	Within groups	1417275.25	213	6653.87		
	Total	1504772.18	219			
Total beneficial output values	Between groups	3624760.99	6	604126.83	1.67	0.1302
	Within groups	77148427.36	213	362199.19		
	Total	80773188.35	219			

Appendix Table 27: ANOVA test resulting for effect of wealth category on Livestock beneficial output and services in USD/ HH/Year. (Poor, Medium and better-off farm clusters).

Beneficial output value	Source	Sum of Squares	Df	Mean Square	F	Sig
Total milk values	Between groups	1324037.11	2	662018.55	35.10	0.0001
	Within groups	4093145.45	217	18862.42		
	Total	5417182.56	219			
Total off-take values	Between groups	672670.54	2	336335.27	17.81	0.0001
	Within groups	4098116.63	217	18885.33		
	Total	4770787.17	219			
Total value of services	Between groups	15641226.05	2	7820613.02	153.58	0.0001
	Within groups	11050449.69	217	50923.73		
	Total	26691675.74	219			
Total manure values	Between groups	1076203.82	2	538101.91	272.46	0.0001
	Within groups	428568.36	217	1974.97		
	Total	1504772.18	219			
Total beneficial output values	Between groups	48356535.90	2	24178267.95	161.85	0.0001
	Within groups	32416652.45	217	149385.50		
	Total	80773188.35	219			

Appendix Table 28: ANOVA test resulting for effect of farming system on number of ploughing days in a year.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	4492.93	6	748.77	0.92	0.4829
Within groups	165582.99	203	815.68		
Total	170075.62	209			

Appendix Table 29: ANOVA test resulting for effect of farming system on number of threshing days in a year.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	2337.27	6	389.545642	24.32	0.0001
Within groups	2882.59	180	16.014373		
Total	5219.86	186			

Appendix Table 30: ANOVA test resulting for effect of wealth category on number of ploughing days in a year.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	66428.1968	2	33214.0984	66.33	0.0001
Within groups	103647.4270	207	500.7122		
Total	170075.6238	209			

Appendix Table 31: ANOVA test resulting for effect of wealth category on number of threshing days in a year.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	386.099590	2	193.049795	7.35	0.0001
Within groups	4833.761373	184	26.270442		
Total	5219.860963	186			

Appendix Table 32: ANOVA test resulting for effect of farming system on Annual Reproductive Rate for goats in the study areas.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	36167.7209	6	6027.9535	1.18	0.3348
Within groups	198520.0844	39	5090.2586		
Total	234687.8053	45			

Appendix Table 33: ANOVA test resulting for effect of farming system on Annual Reproductive Rate for sheep in the study areas.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	34163.9186	6	5693.9864	1.10	0.3683
Within groups	518066.9499	100	5180.6695		
Total	552230.8685	106			

Appendix Table 34: ANOVA test resulting for effect of farming system on Annual Calving Rate for cattle in the study areas.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	11625.14936	6	1937.52489	7.24	0.0001
Within groups	54865.23811	205	267.63531		
Total	66490.38747	211			

Appendix Table 35: ANOVA test resulting for effect of farming system on LWP values per HH/year.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	0.04091146	6	0.00681858	0.79	0.5821
Within groups	1.84886324	213	0.00868011		
Total	1.88977470	219			

Appendix Table 36: ANOVA test resulting for effect of wealth category on LWP values per HH/year.

Source	Sum of Squares	Df	Mean Square	F	Sig
Between groups	0.34672703	2	0.17336352	24.38	0.0001
Within groups	1.54304767	217	0.00711082		
Total	1.88977470	219			

Appendix Table 37: Conversion factor of man equivalent and adult equivalent.

	Man Equivalent		Adult Equivalent	
Age group (years)	Male	Female	Male	Female
<10	0	0	0.6	0.6
10-13	0.2	0.2	0.9	0.8
14-16	0.5	0.4	1.0	0.75
17-50	1.00	0.8	1.0	0.75
>50	0.7	0.5	1.0	0.75

Source: Storck, et al. (1991 as cited in Arega and Rashid, 2005).

Appendix Table 38: Tropical Livestock Unit (TLU) equivalent conversion factors

Livestock Type	Conversion factors
Cattle	0.7
Sheep	0.1
Goats	0.1
Donkeys	0.5
Camels	1.0
Horse	0.8
Chicken	0.01

Source: Janke (1982)

Appendix Table 39: Average manure produdcution and nutrients compsion

Livestock types	Manure yield DM TLU^{-1} (kg day^{-1})	Nutrient composition (%DM)		Sources
		N	P	
Cattle	3.30	1.83	0.45	Haileselassie *et al.* (2006); Lupwayi *et al.* (2000)
Goat	2.48	1.56	0.55	Workneh *et al.* (2003); FAO (2004)
Sheep	2.48	1.56	0.55	FAO (2004)
Equines	2.40	1.83	0.45	Lupwayi *et al.* (2000), Haileselassie *et al.* (2006)

Appendix Table 40: Average market prices in the study area (ETB)

Description of the Item	Unit of measure	Price in ETB	Remarks
Milk	L	4.50	Sorghum & Teff-Millet Diga
	L	4.00	Teff-Millet/Fogera, Sorghum/Jeldu
	L	5.00	Teff-Wheat/ Jeldu
	L	6.00	Barley-Potato/Jeldu farming system
Urea	Kg	5.00	
Dap	Kg	7.00	
Sheep Hide	N	60.00	
Goat Skin	N	20.00	
Ploughing service	Pair of oxen/day	40.00	
Threshing service	Animal/day	20.00	
Transport service	Animal/day	20.00	

Source: Survey result 2011, 1USD= 17ETB

Appendix Table 41: Conversion factors used to estimate crop residues from grain

Crop type	Conversion	Sources
Teff	**1.5**	FAO, 1987; Tessema et al., 2002
Sorghum	**2.5**	Tessema et al., 2002
Chickpea	**1.2**	FAO, 1987; Tessema et al., 2002
Maize	**2.0**	de Leeuw et al., 1990; Tessema *et al*., 200
Vegetables	**0.3**	FAO, 1987

Appendix Figure 1: Livestock management practices (tethering) in Fogera and Diga Districts

Appendix Figure 2: Outdoor corals and closed housing systems in the BNB

Appendix Figure 3: River is the main source of drinking water in the study farming systems of the BNB

Appendix Figure 4: Striving to get feed in the Rice-Pulse farming system of Fogera district

Appendix Figure 5: *Amykila* and *Karaaba* (weeds) invading the grazing land at Fogera and Diga

BIOGRAPHICAL SKETCH

The author was born in October 1975 in Arsi, Oromia Region. He attended his primary and secondary schools in Ras Darge and Assela Comprehensive high schools. He was admitted to Awassa College of Agriculture and graduated with College Diploma in Animal Science and Technology in 1989, He also was pursued his BSc Degree in Animal Production and Range land Management at Debub University. After his graduations the author has worked for Ethiopian Agricultural Research Organization and Amhara Agricultural Research Institute in different capacities from Research Technical Assistance to Assistance Researcher III positions, during his long years of service **Ayele** has worked as Animal Production Research Division Head and as Small Ruminant Research Program Leader at Debre-Birhan Agricultural Research Center. In October 2010 he joined the school of graduate studies at Hawassa University to follow his study for the degree of Master of Science and specialization in Animal Production. **Ayele** is married and has two sons.