Addis Ababa University
School of Graduate Studies
Environmental Science Program

WATER INTERACTION AND WATER PRODUCTIVITY OF DAIRY CATTLE IN WUCHALE WEREDA, NILE RIVER BASIN, ETHIOPIA

Graduate Fellow: TIBEBU SALEHU KEBEDE






A thesis

submitted to the School of Graduate Studies of Addis Ababa University in partial fulfillment of the requirements for the Degree of Master of Science in Environmental Science

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By

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A Thesis Presented to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Environmental Science

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List of acronyms

AAU *(Addis Ababa University)*

CP *(Crude Protein)*

DCWP *(Dairy Cattle Water Productivity)*

dd *(degree decimal)*

DM *(Dry Matter)*

E *(East)*

Ele. *(Elevation)*

FAO *(Food and Agricultural Organization of the United Nations)*

Fig *(Figure)*

GIS *(Geographic Information System)*

Ha *(Hectare)*

HH *(Household)*

ILRI *(International Livestock Research Institute)*

kms *(kilometers)*

Lab *(Laboratory)*

m *(meter)*

m^3 *(Cubic Meter)*

masl *(meter above sea level)*

MoA *(Ministry of Agriculture)*

MoWR *(Ministry of Water Resources)*

N *(North)*

PA *(Peasant Association)*

PET *(Potential Evapotranspiration)*

ppm *(parts per million)*

QTY *(Quantity)*

pH *(power of Hydrogen)*

Sr. No. *(Serial Number)*

Tab *(Table)*

TLU *(Tropical Livestock Unit)*

USD *(United States Dollar)*

VWIDC *(Voluntary Water Intake of the Dairy Cattle)*

WIFDC *(Water Intake in Feeds of the Dairy Cattle)*

WRDC *(Water Requirement of the Dairy Cattle)*

µs/cm *(micro siemens per centimeter)*

Abstract

Livestock interact with the environment directly or indirectly in the process of their production. The interaction with the water resources is also direct or indirect and can be positive or negative depending on the system of production. In the study area of this work, the mixed crop-livestock production is the main type of livestock production by smallhoder subsistence farmers where cattle are reared for dairying. The study was done as a case study of two selected PA's of the wereda. One part of this research was to describe the dairy cattle water interaction. The study has showed that water required for the production of cattle feed was reduced by $2.6*10^5$ m^3 per annum because of crop residual feeds. This implies a good water-dairy cattle interaction in the study PA's of Wuchale wereda. Field measurements, questionnaire surveying and sample water laboratory tests with appropriate statistical analysis were done to complete the description of dairy cattle water interaction. The dairy cattle water productivity evaluation of the two selected PA's of study area was the second part of this study. The productivity of the two PA's was 0.41 USD/m^3 and 0.14 USD/m^3 for the peri urban and rural sample locations respectively. Future improvement aspects of the dairy cattle water productivity were suggested by this work, which all ends up in the sustainable management of the dairy cattle- water interaction in the area.

Key words: dairy cattle, cattle-water interaction, voluntary water intake, water productivity and water use efficiency.

1. Introduction

1.1 Background

Livestock products are important food group that have been neglected in water development and management. Evidence suggests that there is a huge knowledge gap and much misinformation about livestock's use of and impact on water resources. About one fourth of the world's total land area is used for grazing livestock. In addition, about one third of the global cereal production is used for livestock feed (FAO, 2006).

Livestock products comprise an important component of agricultural production in the Nile River Basin, but have largely been ignored in water management for food security (ILRI, 2002). Dairying is an important component of the livestock sector and holds a significantly important social and economic role in Ethiopia irrespective of the low production level (Tesfaye Kumsa et al., 2000). On the contrary, these agricultural production systems have been imposing a variety of environmental challenges, the major challenge being the depletion and degradation of the natural resources. Dairy production and the livestock production in general have grown faster than crop production in most developing countries, and this trend is likely to continue with growth rates over the next twenty years estimated at 4.5 % per annum. The growing need for livestock production for their products and services makes the challenge more severe (FAO, 2006).

Small streams, rivers, lakes, ponds, springs, and wells are common sources of drinking water for ruminants (McDowell, 1985). They also take water in their feed of varying type and moisture content. Generally, these livestock-water interactions differ in different agricultural production systems where these systems in the Nile River

Basin include irrigation, mixed crop livestock, pastoral systems and agro pastoral systems. In irrigation systems, animals kept in and around irrigation systems tend to damage canals and reservoirs when they attempt to drink water and feed on riparian vegetation. In mixed crop livestock systems, animals consume crop residues and drink water either directly from natural sources or at drinking troughs. Limited land constrains both food and feed production by mixed farmers. In pastoral and agro pastoral systems, animals depend on grazing. Extensive grazing lands in the Nile Basin support large numbers of animals spread over very large areas (ILRI, 2005).

Management of cattle-water interaction is a crucial step to be taken to maximize the social and economic role of the dairy cattle and overcome the threat on the environment (ILRI, 2005). Water resources are finite and very susceptible to degradation, and therefore production and management systems to cater for the livestock systems need to be based on quantitative data on water resources endowment and their response to livestock productivity (ILRI, 2005). The following describes what the livestock water productivity means.

Water use efficiency is the ratio of an output to an input. For example, irrigation efficiency can be defined as the ratio of irrigated crop production to amount of irrigated water supplied to the irrigated crop (David et al., 2003). Water productivity is defined in physical terms or monetary terms as the ratio of the product (usually in kg) over the amount of beneficial depletion to multiple uses of water, including the non-agricultural sector, including the environment. Irrigated water is not depleted whereas evapotranspiration is depleted form of water (Kijne, 2003).

Livestock water productivity is about accounting for water consumption of livestock as a ratio of output functions; milk, meat, dung, drought and threshing (ILRI, 2005). It is part of overall productivity of water for food production and is the scale dependent efficiency of direct and indirect use of water for provision of livestock products and services. There are two aspects of livestock water productivity: the livestock impact on water resources and the livestock water use for production (ILRI, 2005). Water productivity can be estimated by (Peden et al., 2002):

$$\text{Water productivity of livestock} = \frac{\sum \text{Net beneficial outputs}}{\sum \text{Depleted water for the livestock}}$$

From this, the dairy cattle water productivity can be derived as:

$$\text{Dairy cattle water productivity} = \frac{\sum \text{Net beneficial outputs of dairy cattle}}{\sum \text{Depleted water for the dairy cattle}}$$

Strategies to improve dairy cattle water productivity (Fig. 1) include effectively distributing drinking water, reducing stocking rates, enhancing animal productivity, and encouraging zero grazing.

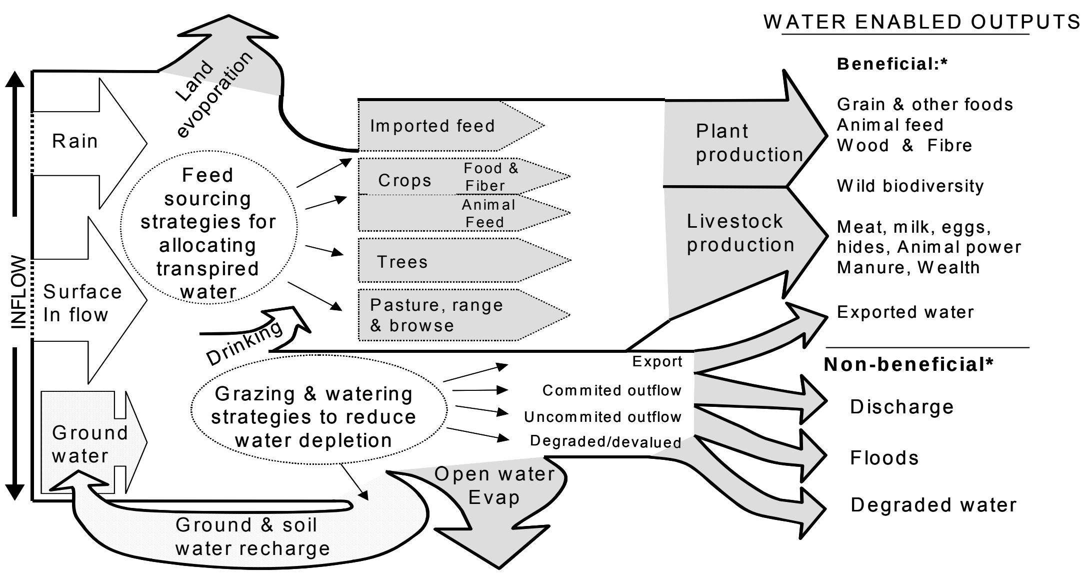

Figure 1: Simplified framework for assessing livestock water productivity (source: Sonder et al., 2005).

The management of livestock-water interaction in the mixed crop livestock systems will contribute to increased water use efficiency for food production. It would, therefore, be a great need to understand the livestock-water interaction and evaluate the existing livestock water productivity in the mixed system of production at farm, landscape and higher levels. At present, there is a challenge to understand how livestock water productivity in the Nile River Basin varies from place to place and under which circumstances does it lead to conflict and environmental degradation (ILRI, 2005).

1.2 The Research Hypothesis

Opportunities exist to increase dairy production and sustain environmental health by increasing livestock-water productivity.

1.3 Statement of the Problem

Nile River Basin supports more than 200 million lives in its riparian countries where most of them are found in poverty. The current available data for the dairy cattle water productivity in the area is almost scant. There has been a limited research information and scientific knowledge base regarding the dairy cattle water interaction which will be helpful in optimizing benefits and improve livelihood. The improvement of the knowledge base on livestock water productivity in the basin will compliment the future pressure on water use for the production of more food.

Wuchale wereda is found in the Nile River Basin and the people in this area lead a very subsistence livelihood. There are two major tributary rivers of the Nile River: the Jema and the Muger rivers. The agricultural productions system in the area is mixed- crop livestock

system where cattle are reared mainly for dairy, drought and threshing purposes.

There is a great need to understand dairy cattle-water interactions for improving dairy cattle water productivity. Mixed crop-livestock systems are important areas for dairy cattle and livestock interactions and Wuchale represents a somewhat representative case study. From this stance, here the main spotlight is to generate research information on dairy cattle production and its water productivity in Wuchale.

1.4 Objectives of the Study

The general objective is describing the dairy cattle water interaction and evaluating the dairy cattle water productivity of Wuchale wereda.

The specific objectives are:

1. to describe the dairy cattle water interactions in Wuchale wereda;
2. to compute the dairy cattle water productivity for selected locations of the study area and;
3. to suggest options for increasing the water productivity of the dairy cattle.

1. 5 Limitations of the research

Major limitations encountered through the progress of this study were:

1. In estimating dairy cattle-water productivity, focus was made on high priority factors based on significance of contribution due to limited time and the impracticability of measuring some of them.

2. The other aspect of dairy cattle water productivity, impacts on water resources by the dairy cattle, was not included in this study.

3. Feed measurement would be more appropriate if it was done at each feed season throughout a year.

4. Only major feeds of the dairy cattle obtained during the study were measured.

2. Literature Review

2.1 Dairy cattle water interaction

2.1.1 Water for feed production

Dairy cattle get their water from three sources: drinking water, water contained in feeds and metabolic water (Kijne, 2005). Water contained in feeds consumed (performed water) is highly variable from feed to feed according to the moisture content, which can range from as low as 5% in dry feeds to as high as 90% or more in succulent feeds (Zinash et al., 2002). Water derived from dry feeds may be insignificant compared with the total water intake, while that obtained from succulent feeds can supply all the water needs. When water content of the feed ingested is low, drinking water is the major source of water intake, and its provision for livestock becomes the main concern. Most of the water that is utilized by the animal's body is ingested either as drinking water or as a component of the feed. Assuming that one m^3 of transpired water would be used to generate 4 kg of dry feed; water for feed production amounts to $450m^3$ /TLU/year, and water for drinking purpose is 9.1 m^3/TLU/year (Sonder et al., 2005). Transpiration is not the only form of depleted water associated with feed production. Water evaporates from plant and soil surfaces six times more than transpiration, particularly in heavily grazed areas with little vegetative cover.

Livestock keeping is one of the most important agricultural livelihood practiced in Africa and particularly so in water scarce arid and semi-arid regions. Globally, livestock make up, on average, 45% of the agricultural contribution to GDP and more than half in some African countries (e.g., Sudan and Somalia). Not included in this indicator are

the economic importance of livestock which are difficult to value roles such as the contribution of livestock to traction and transport that are essential for producing food crops and moving them to markets and consumers. While demand for food must grow by 50% over the next 20 years to sustain human population growth, the demand for livestock products is expected to double during the same period. This depends partly on progress in reducing poverty resulting in an increasing tendency of people to spend more non reusable income on animal products particularly in urban areas. This is a phenomenon now well underway in Asia and expected in Africa. Already, food production uses more than 70% of managed water in developing countries. Achieving a 50% increase in food production with the same amount of water is not possible without increasing water use efficiency. Because of the current importance and the higher rate of growth of livestock production, there is a great need to include livestock production into planning for water resource development. As countries become more industrialized, livestock can use up to half of all agricultural water (Girma Taddesse et al., 2005).

Water requirements for production of animal feed may be as much as 100 times greater than that needed for drinking (Peden et al., 2005). Animals raised on irrigated forages require much more “managed” water than those raised on rainfed grazing land. Even in rainfed mixed farming, production of water demanding feed such as the rhizomatic and deep rooted forages and trees and shrubs may compete with farmers’ ability to grow food crops. The challenge is to develop strategies of how, when and where to produce animal feed in order to minimize demand on irrigated water and to reduce competition with rainfed crop production (Alemayehu Mengistu, 2002). Increasing use

of crop residues for animal feed and shifting feed sourcing to land unsuitable for rainfed crop production may be part of the solution. The trade-off between using irrigated water for forage production and food crops must be considered. Furthermore, strategic investments in watering points for livestock can help spread grazing pressure to areas where feed production does compete with human food production. Balanced and selected investment in water supply for livestock drinking may complement investment in water development for production of human food and animal feed.

2.1.2 Water requirement of the dairy cattle

Water requirement refers to the total water needed for the animals to survive. This can be obtained through feed, voluntary drinking and metabolic generation. The metabolically generated water in the animal's body is very small compared to the other sources. Water intake depends on food intake, nature of the diet, physiological state of the animal and ambient temperature (Matthewan, 1993). The water requirement of domestic animals for example, varies among species, breeds or varieties within species and between individuals within breeds. For example, heavy western breed cows have a higher water intake (60 to 90 liters/day) than zebu cows (25 liters/day with 350 kg live weight (ILRI, 2002). The water demands of sheep, goats and camels are not as high as those of cattle. Water requirement increases with growth, and with increases in productive processes such as lactation and egg laying. Lactating cows consume more water to cope with the water excreted with milk than cows of similar weight fed on maintenance level.

Dairy cows drink 10 times in 24 hours, mostly 7 to 9 a.m. and 6 to 8 p.m. after feeding of hay. Since milk is about 87% water, cows produce more milk and 10.7% more butter fat with a continuous supply of water as opposed to twice a day watering. They drank 18% more water. In stormy weather the amount of water drunk dropped one-third, with 50°C rise in temperature the amount of water drunk rose 75%. With a drop in temperature they drank 75% less. A scale study showed cows used 47L/d and growing cattle 26L/d of which two-thirds is drinking water and one-third other water from the feed (Dan et al., 2006).

Dry Holstein cows drink on the average 40 kilograms per day; milking cows about 85 kilograms per day. Calves drink 4 to 23 kilograms per day providing the opportunity for dairy cattle to consume a relatively large amount of clean, fresh water is essential. Water is consumed several times per day and generally is associated with feeding or milking. Cows may consume 30 to 50 percent of their daily water intake within 1 hour after milking. Reported rates of water intake vary from 1 to 4 gallons per minute (Dan et al., 2006).

2.1.2A Lactating Cows: Drinking water or free water intake satisfies 80 to 90 percent of a dairy cow's total water needs (Dan et al., 2006). The amount of water a cow drinks depends on her size and milk yield, quantity of dry matter consumed, temperature and relative humidity of the environment, temperature of the water, quality and availability of the water, and amount of moisture in her feed. Water is an especially important nutrient during periods of heat stress. The physical properties of water are important in the transfer of heat from the body to the environment. During periods of cold stress, the high heat capacity of body water acts as insulation conserving body heat. Water

intake (lbs/day) for lactating cows can be predicted from the following equation:

Water intake, lbs/day = 35.25 + 1.58 x Dry matter intake (lbs/day) + 0.90 x Milk yield (lbs/day) + 0.11 x Sodium intake (grams/day) + 2.65 x Weekly mean minimum temperature (°F /1.8 – 17.778) (Dan et al., 2006).

2.1.2B Dry Cows: The major factors affecting free water intake of dry cows are concentration of dry matter in the diet, dry matter intake and amount of protein in the diet. Water intake of dry cows can be estimated by the following equation (Dan et al., 2006):

Water intake, lbs/day = -22.80 + 0.5062 x Diet dry matter (%) +2.212 x Dry matter intake (lb/day) +0.0869 x Diet crude protein (%).

2.1.2C Calves and Heifers: During the liquid feeding stage, calves receive most of their water as milk. However, studies show that calves offered water by free choice in addition to a liquid diet gain faster and consume dry feed earlier than calves provided water only in their liquid diet. Therefore, it is recommended to provide water by free choice to calves receiving liquid diets to enhance growth and dry matter intake (Dan et al., 2006).

Dan et al. (2006) reported that the type of feed also plays a decisive role on water intake of the livestock. Inclusion of herbaceous legumes, trees and shrubs into tropical diets was found to cause an increased water requirement. This is because water consumption increases with the level of roughage intake and its nitrogen content and with the intake of other feeds that have laxative properties. Sheep reportedly

require more water on high than on a low protein diet, since the nitrogenous end products require a larger urine volume for excretion. Similarly, higher proportions of salt or other minerals in the diet of sheep can result in more urine excretion and, accordingly, more water requirement. Studies with poultry have shown an increase in water consumption due to increases in the fat, protein, salt or potassium contents in the diet.

A study on water turnover in Boran and Boran × Friesian cows at the ILRI Debre Zeit Research Station showed that the total water intake in early and late lactation was 49.2 and 54.0 kg/cow per day, respectively (ILRI, 2002). The major part of the difference comes from a difference in drinking water intake although the higher feed intake of the late lactating cows was accompanied by a significantly higher extra water intake (+0.1 kg/cow per day). The mean amount of metabolically generated water accounted for 3.1 kg/cow per day. Water turnover, including water intake and metabolically generated water was also lower in early (52.3 kg) than in late lactation (57.1 kg; Standard Error Mean (SEM, 1.53)). The percentages of total water excreted through faeces, urine and milk were 38.0, 17.0 and 13.8%, and 45.0, 19.3 and 8.2% in early and late lactating cows, respectively.

2.1.3 Pasture feeds of the dairy cattle

Pasture is one form of feed in Wuchale wereda and one has to include this feed source in describing the water interaction of grazing animals. Pasture is normally the cheapest source of roughage for dairy cattle. The protein content of legumes is usually high while grass like Kikuyu has low levels of calcium; other pasturages on the other hand have high levels of potassium. Pasture intake is related to the amount of

time spent while grazing, the number of bites per minute, and the size of each bite (National Research Council, 2001). Dairy cattle generally graze six to nine hours per day. Because of a cow's need to ruminate and rest, it seldom grazes over nine hours per day. The number of bites taken per minute does not vary appreciably, ranging from 55 to 65 bites per minute. Thus, dry matter intake from pasture is controlled by the size of the bite of forage. This is directly related to the height and density of the forage stand being grazed. In Scotland, Phillip and Leaver (1989) measured forage intake of cows grazing ryegrass pasture in the Spring when grass was very lush and again in the fall when pasture growth was lower. In the Spring, when forage growth was at its maximum, cows consumed on average 60 bites per minute over an eight-hour grazing period and were able to consume 14.4 kgs of dry matter daily (0.50 grams of dry matter per bite). In the Fall, cows' bites averaged 65 per minute and they grazed for nine hours a day but were able to consume only 8.9 kgs of dry matter daily (0.25 grams of dry matter per bite). These data illustrate the importance of forage density and height when trying to maximize intake of dairy cows grazing pasture. Cows generally prefer to graze during the early and late daylight hours. During the hottest months, cows will not graze during the late morning and afternoon hours and may compensate slightly by increasing the time spent for grazing during the night. Changes in milking times and management may be beneficial in allowing cows to graze during the early morning hours and later in the evening after the sun has gone down.

The availability and quality of pasture forage consumed directly influence milk production. When forage availability decreases, the bite size of pasture forage decreases. Consequently, milk production

decreases. Forage availability in pasture needs to be maintained to allow cows to milk to their genetic potential. Lactating dairy cows will have dry matter intakes of pasture between 1.5 percent and 3.0 percent of body weight depending on the availability of pasture, amount of supplemental concentrates provided, and milk production and stage of lactation of the cows. Holden et al. (1994) reported that mature, mid lactation Holstein cows producing 30.8 kgs of milk on average consumed approximately 14.5 kgs of dry matter per day as pasture in the Spring, or approximately 2.5 percent of their body weight. The authors noted that average daily pasture dry matter intake was the highest in late Spring and Fall and lowest during the Summer.

Grazing pressure on natural pasture in the Ethiopian highlands follows four distinct patterns. During free grazing period (January–May) stocking rate on medium and heavily grazed plots depends much on the preference of grazing animals, and in some cases the stocking rate in controlled or medium grazing pressure exceeds that of the heavily grazed plots. As a result, the stocking rate in medium grazing pressure was higher even than the heavily grazed plots. Except draft animals, most of the livestock species are moved from bottomland of the communal grazing lands to upper slopes. October to December is the period when sown crops get mature and gradual cessation of natural pasture begins, and the stocking rate on the natural pasture rises again. After crop harvest, free grazing on agricultural field is resumed, and burden on natural pasture is reduced. During this time, cattle are needed for threshing the harvested crops, and donkeys are needed for transporting harvested crops from agricultural field to nearby settlement areas, and the available crop stalks can be kept for dry as supplementary feed (Abiy Astatke et al., 2001).

2.1.4 Straw feeds of the dairy cattle

Mixed farming occurs in many forms and it has been around in many countries since the start of agriculture (ILRI, 2005). In the Ethiopian highlands of mixed farming systems farmers use crop stalk as supplement feed for their livestock. The role of crop residue is increasingly becoming very important where grazing land is shrinking (Abiye Astatke et al., 2001). In Wuchale wereda (the study site), crop residues or straws are one major component of animals' feed. Straw comprises the stalks and leaves of crops that remain once the seed had been threshed out. Grain straws are the best-known low-grade roughages. It is low in protein, energy and minerals. Of the most common small grains, oat straw is probably the most valuable, followed by barley and corn straw (Abiye Astatke et al., 2001)). Maize straw and grain sorghum straw are just as good as oat hay or even better. Straws should be ground in order to get good intakes. The low nutritional value of straws limits its inclusion levels. Small grain straws should preferably not be used in rations for dairy cows. With the necessary supplementation straws can be used to a limited extent in the feeding of replacement heifers.

Small grain straws are often upgraded by treating it in an oven or in a stack with ammonia. That way the energy and protein content, as well as the palatability are improved considerably (Abiye Astatke et al., 2001). It is not normally necessary to grind ammoniated straw. In the case of dairy cows it should not make out more than 40% of the ration. When ammoniated straw is used in dairy cow rations, it is important for the levels of phosphorus, magnesium, zinc, cobalt, selenium and copper, as well as vitamin A and E to be supplemented (Abiye Astatke et al., 2001).

The initial evaluation of residue quantity is important to estimate the quantity of feed available to livestock. One method to estimate the quantity of residue present is based on calculations with residue index (Residue index = kg of residue produced/kg of grain produced) (Tab. 1).

Table 1: Multipliers used for converting grain yield to its crop residue equivalent.

Crop	Average grain to straw ratio	Multiplier
Teff	0.45	2.22
Wheat	0.67	1.48
Barley	0.72	1.39
Chickpeas	0.65	1.54
Horse beans	0.87	1.15
Field peas	0.69	1.45

Source: Bekele Shiferaw, 1999.

2.1.5 Water Quality for the dairy cattle

Water quality has not been a major concern with very limited up-to-date information available. Livestock needs in water quality are about the same as humans and they usually tolerate hunger more than thirst (David, 2005). Water quality should always be assessed at the point of use, not at the source. Water which is relatively pure at the source is frequently contaminated when used by dust, nasal and fecal droppings or slime deposits.

Water quality is an important issue in the production and health of dairy cattle. The five properties most often considered in assessing

water quality for both human and livestock use are organoleptic properties (odor and taste), physiochemical properties (pH, total dissolved solids, total dissolved oxygen and hardness), presence of toxic compounds (heavy metals, toxic minerals, organophosphates and hydrocarbons), presence of excess minerals or compounds (nitrates, sodium sulfates and iron), and presence of bacteria. Research on water contaminants and their effects on cattle performance are sparse. Physiochemical properties of water can be a useful way of helping to determine water quality. These include pH, total dissolved solids (TDS), hardness, other substances in excess, sulfate, chloride, nitrate, toxic compounds, and microorganisms.

2.1.5A Total Dissolved Solids: - TDS is a general term defining the sum of all inorganic matter dissolved in water (David, 2005). High amounts of TDS generally are considered an unwanted characteristic. However, TDS *per se* may not provide much information about water quality or the specific individual constituents of concern. For example, the TDS concentration could be quite high, influenced mainly by high concentrations of calcium and magnesium, yet little or no influence on water nutrition or cattle performance would be expected (Tab. 2A).

Table 2A: TDS concentrations and their effects on cattle performance.

TDS (ppm or mg/l)	**Interpretation**
Less than 3000	Usually satisfactory for most livestock
3000-5000	May no cause adverse effects to adults
5000-7000	Should not be used for pregnant or lactating females.
7000-10000	Do not use for pregnant or lactating ruminants

Source: Dan et al, 2006.

2.1.5B Nitrates: - Nitrate toxicity is seldom caused by water alone. It is usually a feed problem. The majority of nitrate poisoning cases in

Ohio involve drought stressed oats, corn and barley (David, 2005). High nitrate content interferes with the oxygen absorbing power of the blood and in infants and gives rise to a "blue baby" condition that may prove fatal. Non-ruminants may convert small amounts of ingested nitrate to nitrite in their intestines, but the amount converted is not harmful. Cud chewing animals at any age can be affected by nitrates in the same way as human infants. They are able, however, to tolerate much higher concentrations of nitrate, as long as the fodder is not unusually high in nitrates. Shortage of breath is one symptom of nitrate toxicity. Blood will look brown instead of red. Frothing at the mouth, convulsions, blue muzzle and bluish tint around eyes can also indicate nitrate poisoning. More moderate levels of nitrate poisoning are thought to cause poor growth, infertility, abortions and vitamin A deficiencies (David, 2005). Some guidelines are indicated in table 2B.

Table 2B: Nitrate Concentrations and their effect on cattle performance.

Nitrates (NO_3) mg/L	Guidelines for ruminants
0-44	Safe for consumption
45-132	Generally safe in balance diets with low nitrate feeds
133-220	Could be harmful if consumed over long periods
221-660	Cattle at risk, upper limits may affect rate of fertility, and possible death
>660	Unsafe, may cause suffocation, incoordination or staggering.

Source: Dan et al., 2006.

2.1.5C pH: - The water pH denotes either alkalinity or acidity. A pH of 7 would be neutral; over 7 indicates alkalinity; below 7 designates acidity. Acid waters (pH below 7) have been found to occur in proximity to coal veins. High alkalinity may cause digestive upsets,

laxative action, poor feed conversion, reduced water and/or feed intake (David, 2005).

Little is known about the specific pH's effect on water intake, animal health and production, or the microbial environment in the rumen. The preferred pH of drinking water for dairy animals is 6.0 to 8.0. Water with a pH outside of the preferred range may cause nonspecific effects related to digestive upset, diarrhea, poor feed conversion and reduced water and feed intake (David, 2005).

Typically, 1 or 2 quarts of water from the source in question should be adequate to complete any needed tests. Samples may be sent to any accredited commercial or state operated laboratory for analyses. Producers should consult with their herd veterinarian or cooperative extension personnel for assistance in selecting a laboratory as well as for assistance in selecting appropriate tests and interpreting test result (Dan et at., 2006).

2.2 Dairy cattle water productivity

One of the ultimate objectives of any livestock industry is the conversion into products of feeds which are either inedible by man or surplus to his immediate requirements (Williamson et al., 1979). The productivity of water in a given use is defined in terms of quantity and quality of water diverted or depleted in that use (David, 2003).

With 35 million tropical livestock units (TLU) (equivalent of close to 80 million herd), Ethiopia has one of the largest livestock populations in Africa. Cattle provide traction power for 95 percent of grain production and also provide milk, meat, manure, cash income and serve as a hedge in times of drought and risks. The livestock sub-sector accounts

for 15 percent of the total GDP and 33 percent of agricultural output (excluding draft power and manure) (Girma Taddesse et al., 2005).

The livestock sector, however, faces very low productivity and livestock water productivity has been challenged frequently in recent years, being described as far lower compared to crop water productivity. Moreover small scale mixed livestock production systems typical in developing countries relying mostly on crop residues for feeds have much higher livestock water productivity. In the arid areas, the livestock water productivity is much related to water availability (adequate yearly rainfall and other water resources). It means also increasing crop yield or non-crop food such as livestock or fish or economic value per unit of water delivered or depleted (David, 2004). Livestock is a form of currency. For many farmers, animals represent savings and sale of livestock manure is quick cash in hard times. Income from Livestock products can allow poor families to improve their nutrition, send their children to school and improve family livelihood. Livestock plough agricultural fields and provide means of transportation and reduces the human load. Considering the importance of livestock in national economy the Ministry of Water Resources (MoWR) already has integrated the livestock water need into its water supply projects for urban areas (MoWR, 2002).

In Ethiopia, the sale of livestock and their products is often the major or only source of income. However, productivity per animal is very low, due to mainly poor nutrition. Grasses contribute a large portion of the feed but the quantities are limited and the nutritive value is low. Where pasture is the sole source of animal feed, its crude protein content should be above the critical level of about 70% DM and if herbage with protein content below the critical level is fed, the low

voluntary intake and protein deficiencies contribute to reduced production and retarded growth of animals (MoWR, 2002).

Livestock keeping contributes up to half of the agricultural GDP (e.g., Sudan and Ethiopia). In addition; livestock provide subsistence farming communities with manure, traction, transport, cultural value and insurance against drought. Managing water resources without due consideration of the contribution of livestock to agricultural production ignores a major component of food security particularly in the Nile River basin. The Nile River basin supports 59 million TLU with 60% in Sudan and Ethiopia, but Uganda, Egypt, Kenya, and Tanzania also have significant herds. Among the production systems totaling 3.3 million km^2, livestock-only rainfed production is most widespread (1.2 million km2 mostly in Sudan and Ethiopia) followed by *mixed* crop/livestock rainfed production (763,292 km^2 around Lake Victoria and in the Ethiopian highlands), mixed crop-livestock irrigated production (150,435 km^2 mostly along the Egyptian and Sudanese Nile), and Urban and peri-urban production (794 km^2) (Girma Taddesse et al., 2003). Each can be subdivided into ecologically and culturally defined sub-systems with varying degrees and forms of livestock-water interactions.

3. Materials and Methods

3.1 Description of the Study area

3.1.1 Location, Physiography and Soil

Wuchale wereda is located from 9.451 dd bottom to 9.765 dd top or North and from 38.737 dd left to 39.081 dd right or East. This wereda is one of the weredas of the North Showa Zone in Oromia region, which is very recently separated from a former wereda of Wuchale and Jida, its zonal head administration being situated in the Selalie Fiche. The main town and the first kebele of Wuchale wereda, Muke Turi is 78 kilometers away from Addis Ababa on the way to Gojam and there are a total of 24 remaining kebeles also preferably called peasant associations located within a maximum of 27 kms away from the main town. The total area coverage of the wereda is 48, 780 ha.

As selected to be a study area of this thesis work, the area is found in the Nile River Basin and there are two major tributaries, Jema and Muger Rivers in the wereda.

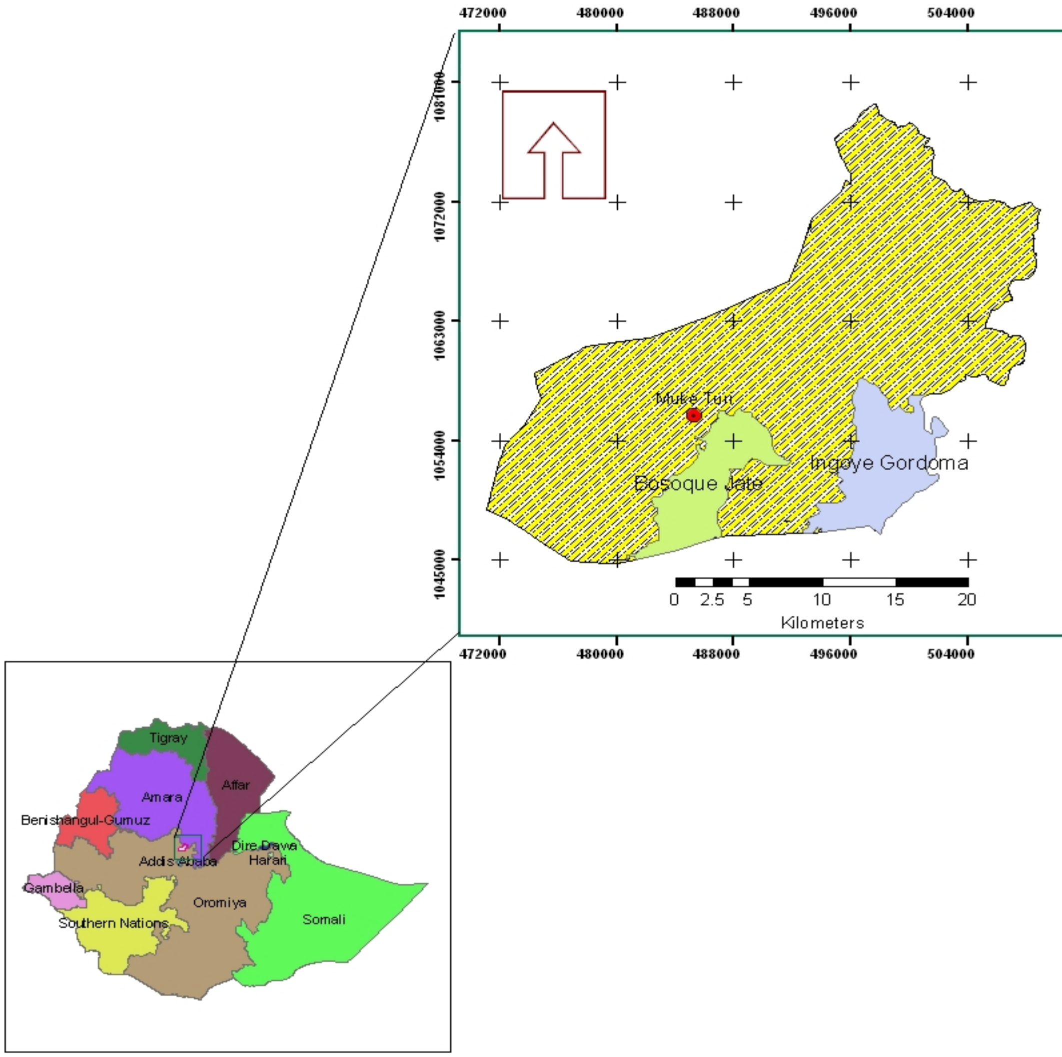

Figure 2: Map of Wuchale wereda and interviewed peasant associations. (Source: Tibebu Salehu, 2006).

According to Wuchale wereda agricultural and rural development office, the wereda has a minimum elevation of 1200, a medium elevation of 2412 and maximum elevation up to 2880 masl. The topography of the wereda consists of 75% flat area, 15% undulated and rugged terrain and 10% mountainous area. The unpublished 2005/2006 report of the office has also suggested that the soil in the wereda has comprised of 35% reddish, 55% black and 15% grey.

Table 3: Altitudinal profile of the selected PA’s of Wuchale wereda.

	Boseque Jate	Ingoye Gordoma
Mean	2,602 m	2,669 m
Range	366 m	118 m
Maximum	2,868 m	2,728 m
Minimum	2,502 m	2,610 m

Source: Wuchale Rural Agriducultural Development Office, 2006. Unpublished document. Note: All altitudes are masl.

3.1.2 Population and Socioeconomic activities

According to Wuchale wereda agricultural and rural development office (2005/06), the current population of the wereda was 96, 579 in 24,570 households with a gender distribution of 48,864 male and 47,715 female. The current population density is around 200 person/km^2. The average family size per household in the area was 6.9.

The majorities of the local people of the wereda were involved in subsistence mixed crop livestock agriculture and collect income from the dairy outputs and crops. The peri urban and rural peasant associations show typical cattle holdings and market accesses for cattle products. Most of the milk is not commercialized at the rural peasant associations, but rather converted into butter and cheese products.

3.1.3 Climate

Wuchale wereda is mainly dega with a 13% woinadega. This Dega agro ecological zone domination is partly manifested by the low yearly average temperature which has a maximum value of 25°C, a medium value of 12°C and down a minimum value up to of 8°C (Wuchale Agricultural and Rural Development Office, Unpublished, 2006..).

Enough rainfall and temperature data was not found to draw the climate maps of Wuchale wereda but from the FAO's New LocClim 1.06, they were estimated from one station as displayed in figures 3 to 6.

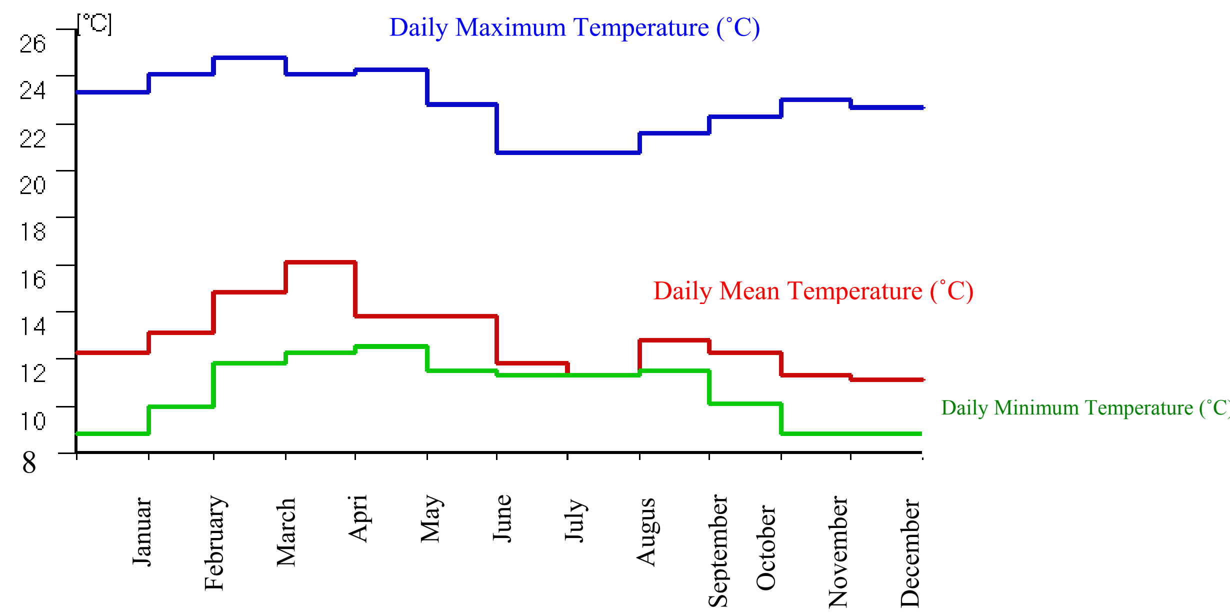

Figure 3: Daily Temperature variations of Wuchale wereda in a year. Source: Jurgen Grieser, 2005; New LocClim 1.06.

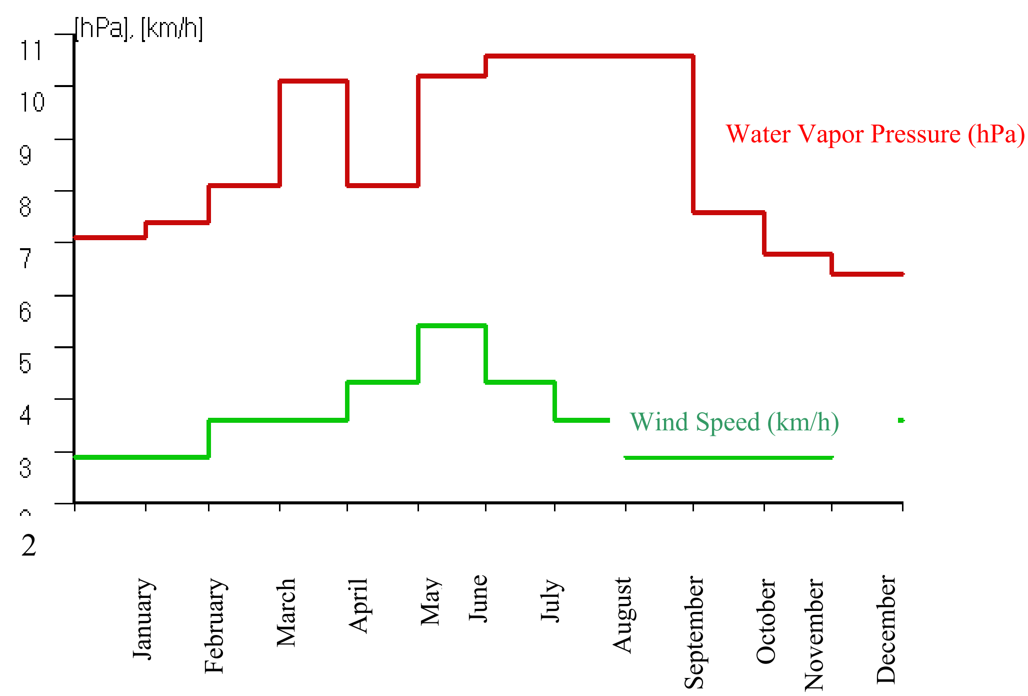

Figure 4: Water vapor pressure and wind speed of Wuchale wereda. Source: Jurgen Grieser, 2005; New LocClim 1.06.

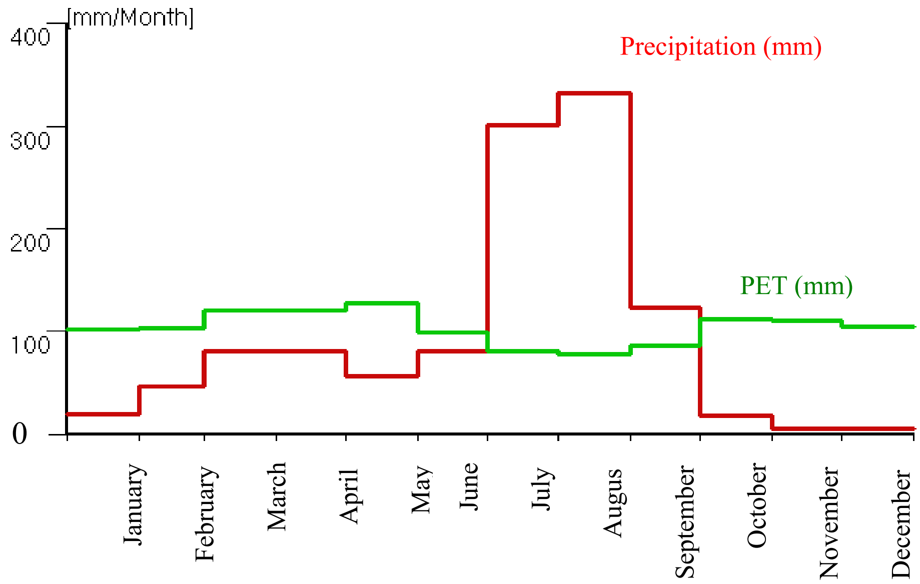

Figure 5: Precipitation and Potential evapotranspiration of Wuchale wereda. Source: Jurgen Grieser, 2005; New LocClim 1.06.

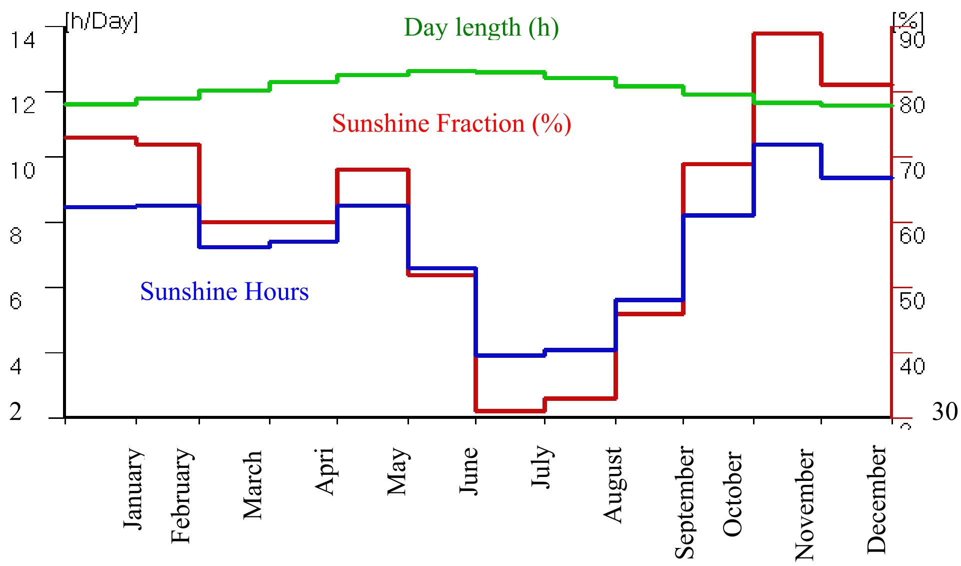

Figure 6: Day length, sunshine fraction and sunshine hours of Wuchale wereda.
Source: Jurgen Grieser, 2005; New LocClim 1.06.

3.1.4 Crop and vegetation

In the wereda, around eight types of crops are dominantly cultivated, which all depend on rain (Tab. 4). Tab. 5 shows the dry matter and crude protein content of these crop residues.

Table 4: Major cultivated crops of the study area.

Type of crop	***Genus***	***Species***
Barley	*Hordum*	*vulgare*
Chickpea	*Cicer*	*arietinum*
Field pea	*Pisum*	*sativum*
Horse bean	*Vicia*	*faba*
Teff	*Eragrostis*	*abyssinica*
Vetch	*Vicia*	*sativa*
Wheat	*Triticum*	*aestivum*
Oats	*Avena*	*sativa*

Source: Wuchale wereda Agricultural and Rural Development Office, 2006.

Table 5: Average dry matter and crude protein content of the dairy cattle feed in Wuchale wereda.

Feed type	**Dry matter % (DM)**	**Crude Protein % (CP)**
Teff Straw (Stem)	92.05	5.05
Barley Straw (Stem)	91.52	2.75
Wheat Straw (Stem)	92.22	1.68
Wheat Stubble	93.00	3.56
Horsebeans Straw Stem	92.70	7.20
Fieldpeas Straw (Stem)	91.56	11.19
Oats Straw (Stem)	92.59	3.38
Natural Pasture (leaf)	89.39	18.85

Source: www.vslp.org/ssafeed/Data.asp and Bekele Shiferaw, 1999.

The wereda's land is covered by both types of indigenous and exotic trees and shrubs (Tab. 6).

Table 6: Major shrubs and trees of the study area.

Local Name	***Genus***	***Species***
Casuarinas	*Casuarina*	*equisetifolia*
Deccurence	*Accacia*	*deccurence*
Kega	*Rosa*	*abyssinica*
Key Bahrzaf	*Eucalyptus*	*grandis*
Koshim	*Dovialis*	*abyssinica*
Koso	*Hygenia*	*abyssinica*
Kundoberbere	*Schinus*	*molle*
Lucerne/Alfafa	*Medicago*	*sativa*
Nech Bahrzaf	*Eulalyptus*	*globulus*
Omedla	*Accacia*	*meleonaxylon*
Saligna	*Accacia*	*saligna*
Sesbania	*Sesbania*	*sesban*
Weyra	*Olea*	*africana*
Yabesha Girar	*Accacia*	*abbysinica*
Yabesha Tsid	*Juniperus*	*procera*
Yefereng Tsid	*Cupressus*	*lusitanica*

Source: Wuchale wereda Agricultural and Rural Development Office, 2006.

The current total livestock number is 437,197 heads; out of this 28.1% of the total livestock heads were dairy cattle. The cross breeds of the cattle were Holstein Friesian with rare Jersey at some households (Wuchale Agricultural and Rural Development Office, 2005) (Tab. 7). The TLU conversion factor of cross and local breed livestock is indicated in Table 8.

Table 7: Estimated livestock number of Wuchale wereda in 2005/06 year excluding two new peasant associations.

Type of Livestock	Number of heads
Oxen	50,166
Cows	35,794
Heifers	15,268
Bulls	5,024
Calves	16,558
Total Cattle	122,810
Sheep	129,570
Goats	2,192
Donkeys	14,690
Horses	18,059
Mules	2,101
Poultry	147,775
Total Livestock	**437, 197**

Source: Wuchale wereda Agricultural and Rural Development Office, 2006.

Table 8: TLU conversion factors used in the survey in the Wuchale wereda.

Class / Species	Average weight		TLU conversion factor	
	Local	Cross	Local	Cross
Oxen	275	475	1.1	1.9
Cows	250	450	1.0	1.8
Young bulls	150	200	0.6	0.8
Heifers	125	175	0.5	0.7
Calves	50	100	0.2	0.4
Sheep	25	-	0.1	-
Donkey	125	-	0.5	-
Horses	200	-	0.8	-
Mules	175	-	0.7	-
Poultry	2.5	-	0.01	-

Note: One TLU equals 250 kg live animal weight. Source: Bekele Shiferaw, 1999. Conversion factors for the cross breed cattle were estimated from this study by the author.

Animals here are raised for direct products and services: milk, meat, hides, dung, drought power and transport and also as a hedge against hard times, a form of capital readily converted to cash.

3.1.5 Water resources

The major water sources in Wuchale wereda functioning as drinking sites for the cattle in the area are some wells, stagnant water bodies and rivers. Cattle access water sources at specified points (Fig. 7).

Figure 7: A stream found in Wuchale wereda and its access point for cattle drinking. Photo Courtesy Tibebu Salehu, 2006.

3.2 Data collection and sampling

Generally, all data of this work were collected using field measurements, surveying via pre-tested questionnaire (Appendix A), laboratory tests, physical observations, target group discussions and electronic and other data from different institutions. The field measurement was carried on by means of random sampling basis and

was based mainly on the weight of different feeds and dairy cattle manure using spring balance. One hundred and twenty household questionnaire interviews were administered by four animal science graduates where they were given meticulous training on the questionnaire so that the execution of the work was prearranged.

In the sampling procedure, stratified random sampling was used in the data collection. The wereda was stratified as Peri urban and rural peasant associations to examine typical dairy cattle productions including the dairy cattle water productivities in the two spatial categories. The randomly selected peri urban peasant association was Boseque Jate and the rural peasant association was Ingoye Gordoma which is located more than 15 kms from Muke Turi, main town of the wereda. The farthest peasant association from the main town was Ilu Etaya which was 27 km away.

For the questionnaire survey, the number of sample households was determined using Cochran, 1977 equations as:

$$n_o = \frac{Z^2pq}{d^2}, \text{ and}$$

$$n = \frac{n_o}{1 + \frac{n_o - 1}{N}}$$

Where,

n_o = the desired size when the population is greater than 10, 000

n= number of sample size when population is less than 10, 000.

Z= 95% confidence limit, i.e. 1.96

P= 0.1 (proportion of the population to be included in the sample, i.e. 10%)

q= 1-p, i.e. 0.9.

N= Total number of population

d= degree of accuracy desired (0.05)

The reconnaissance of the area shows that the area is uniform in the aspect of this research interest except between the peri-urban and

rural categories. The sample households selected were 60 households from one peri-urban peasant association and 60 households form one rural category. The two peasant associations are selected based on convenience to accomplish tasks. The households were randomly selected from list of the two peasant associations of the wereda (Fig. 8).

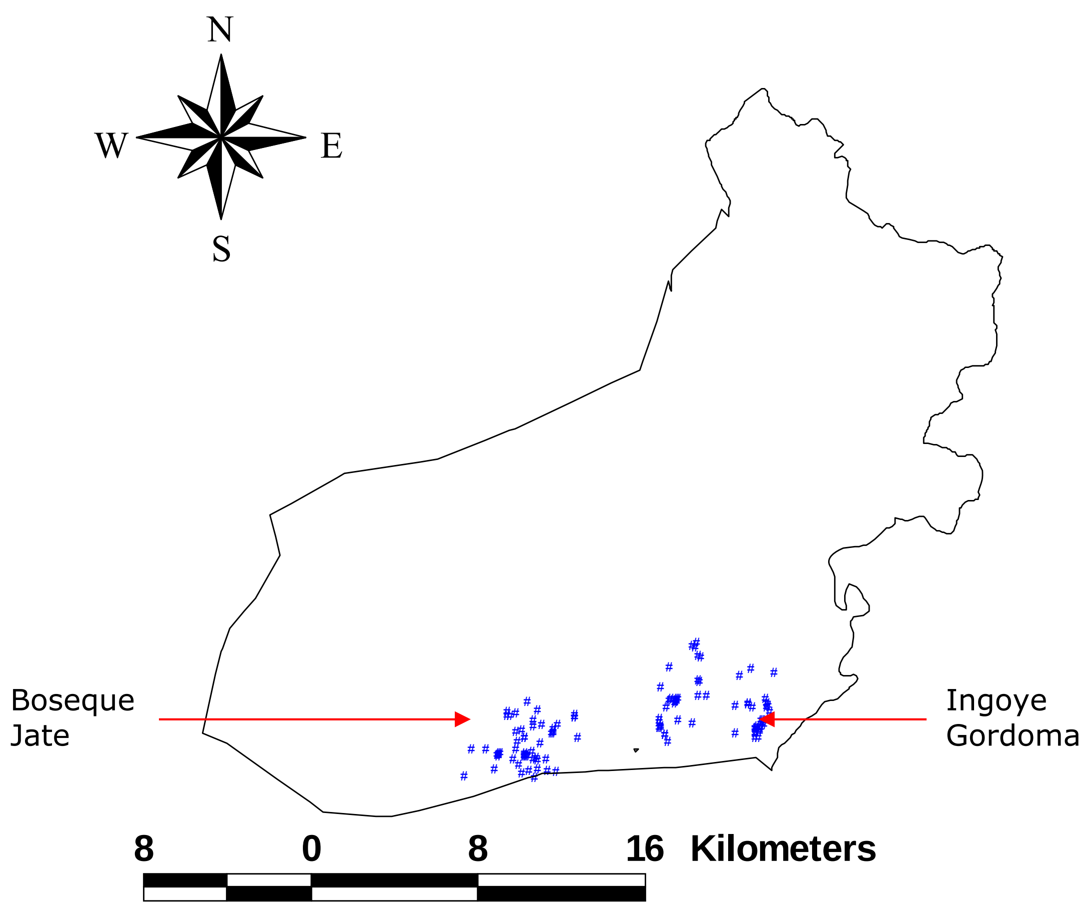

Figure 8: Interviewed household locations. (Source: Tibebu Salehu, 2006).

The water samples used for analyzing quality of water for cattle drinking were collected from four major water sources; i.e. three rivers and one stagnant and artificial big pond that serve for drinking of large number of cattle in the area. Water samples were collected with plastic

and light proof bottles and were brought to the lab after their two hours of collection.

3.3 Description of dairy cattle water interaction

The mixed crop livestock agricultural production systems, also true in Wuchale wereda show an important livestock water interaction. The main factor here is feed from crop residue. This shows that the type of feed can characterize the cattle water interaction.

Water requirement varies among animal species (ILRI, 2002). Again according to Dan et al. (2006), cattle at different physiolocal conditions would have different water requirement. This also shows that the type of cattle species can alter the interaction with water.

In order to describe the dairy cattle water-interaction in the study area, four factors were determined. These were distribution of the dairy cattle by species type, major feeds of the dairy cattle, ratio of water intake in feed to voluntary water intake and quality of water for the dairy cattle.

The quality of water use for the dairy cattle drinking, was analyzed in the laboratory in standard methods. To identify the major feed type supplied the dairy cattle throughout the year, the year was divided in to three feed seasons: dry, wet and harvest seasons. This is because at each of these seasons the dominant feeds available for the dairy cattle were different. The dry season ranges from February to June, the wet season ranges from July to September and the harvest season being from October to January.

The quantities of the major daily feeds provided for the dairy cattle at the current season were determined from sample field measurements.

For this purpose, four random sites in the wereda were selected. The interviewed farmers have provided the feed so that the feed would be arranged for weighing.

3.4 Evaluating the dairy cattle water productivity

The water productivity of the dairy cattle at household level of the two selected peasant associations was quantified using (Peden et al., 2002) as:

$$\text{Water productivity of dairy cattle} = \frac{\sum \text{Dairy cattle Outputs and Services}}{\sum \text{Depleted water for dairy cattle}}$$

Where: the significant dairy cattle outputs and services were identified as milk, butter, cheese, hides, manure, traction and threshing powers. The water actually depleted while producing these dairy cattle products and services is the water used for the production of hay and pasture. The water used for the other crop residue feeds would not be included as it is part of the crop water productivities (ILRI, 2005). The drinking water would not also be included since it would not be depleted from domain of interest area.

3.5 GIS and statistical analysis

Arc GIS was used to display the study area and the locations where interviewed households & field measurements were conducted and sample water collection were collected. The major Data used were Survey, feed measurement and laboratory test and these were entered in spreadsheet and followed statistical analysis using SPSS 12.0. Descriptive statistics was used to calculate mean, average, range and

standard deviations. Correlation and T-tests were used to analyze relationships of a pair of factors.

4. Results

4.1 Description of the dairy cattle- water interaction

4.1.1 Distribution of the dairy cattle by type in the two PA's of Wuchale wereda

From the survey data of the two selected PA's, sixty households from each, the distribution of the cattle species was indicated as in Fig. 9 and Fig. 10.

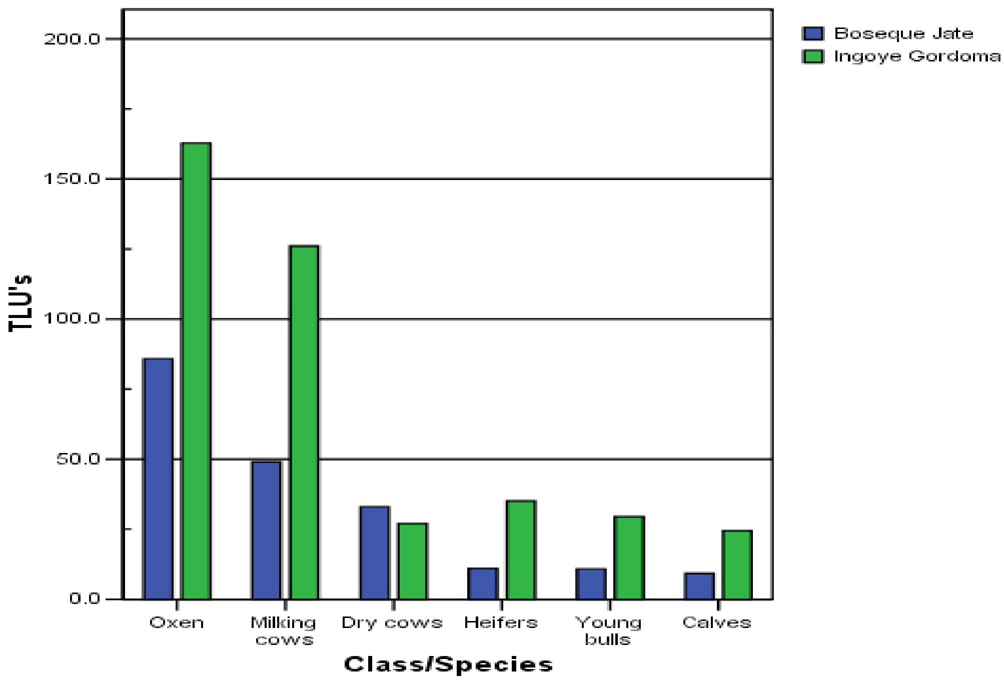

Figure 9: Local breed dairy cattle in the two PA's.

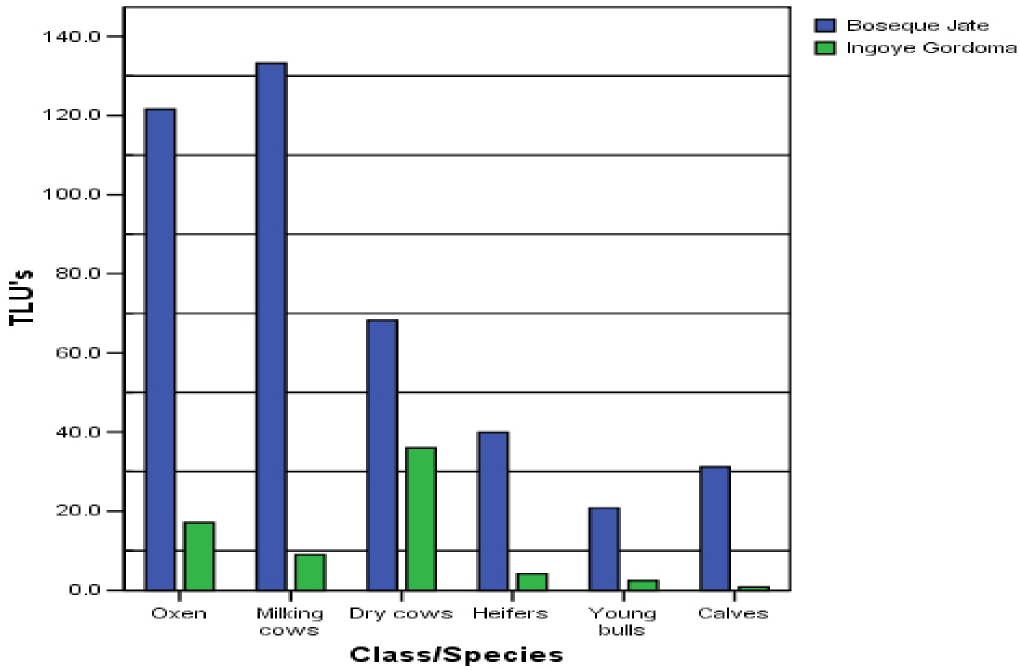

Figure 10: Cross breed diary cattle species in the two PA’s.

4.1.2 Determination of the major dairy cattle feed

The feed available for dairy cattle in the area include cereal straws of wheat, teff, barley, beans & oats, stubble, pasture, green grass & hay (Fig. 11A, 11B & 11C).

Figure 11A: grass cutting.

Figure 11B: Partially converted hay. Figure 11C: Mixed crop residue.

Figure 11: Major feed types of the dairy cattle in Wuchale wereda.

The frequencies of responses to the major feed type for dairy cattle were summarized from the survey. The results to the total of 120 interviewed households were as follows (Fig. 10, 11 & 12).

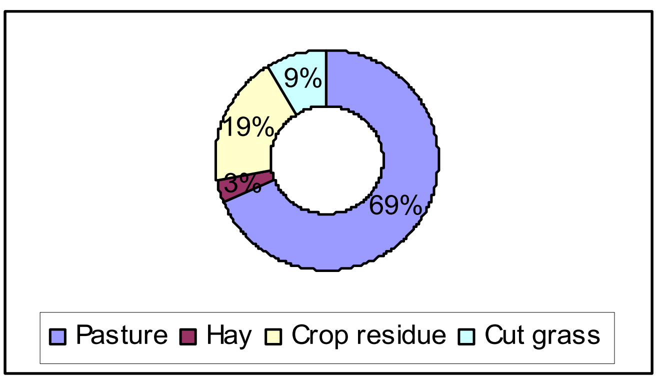

Figure 12: Percentage of responses to wet season feed type of the dairy cattle in the two PA's.

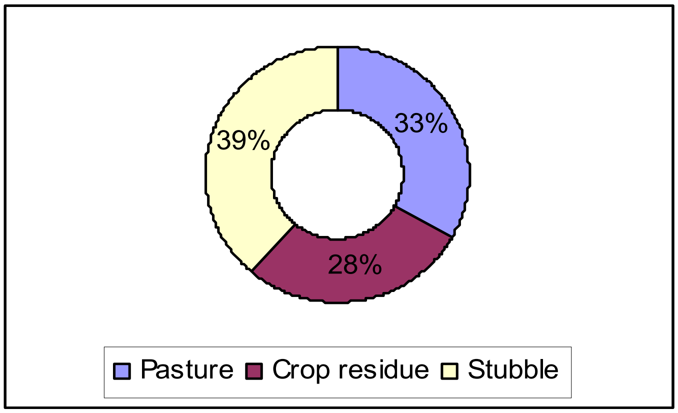

Figure 13: Percentage of responses to harvest season feed type of the dairy cattle in the two PA's.

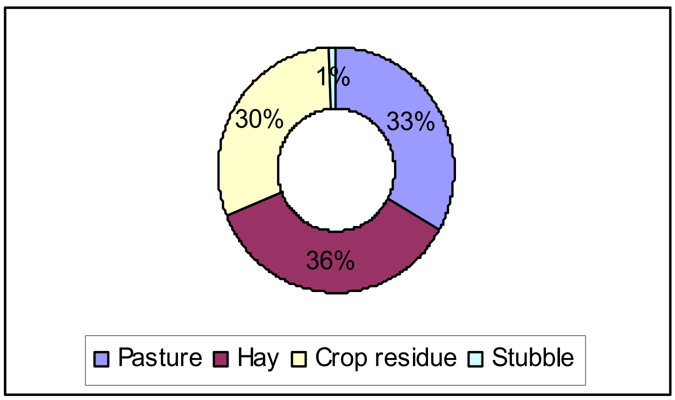

Figure 14: Percentage of responses to dry season feed type of the dairy cattle in the two PA's.

4.1.3 Determination of daily feed quantities of the dairy cattle

Many studies have demonstrated the amount of DM in the feed intake markedly affects water consumption of animals (McDowell, 1985). So, quantifying the feed in DM can be used to estimate the water consumption of dairy cattle. Here, the weight of major daily feeds of

the dairy cattle was measured to determine their daily feed quantities in the two PA's (Fig. 15).

Figure 15: Weighing of the daily Crop residue supplied to a milking cow. Photo Courtesy Mesfin Eshetu, 2006.

The measurement was carried in October when the dry season of the study area was about to begin. The feeds supplied to the different dairy cattle species were provided by the interviewed farmers and arranged for weighing (Appendices B1, B2, B3, B4 and B5).

The average measured weight of each feed was converted to the respective dry matter (DM) content based on the Sub-Saharan Africa Feed Information System at www.vslp.org/ssafeed/Data.asp, checked in November, 2006 and Bekele Shiferaw, 1999 and the results were in tables: Tab. 9, 10, 11, 12 & 13.

Table 9: Major cows feed quantity supplied in a day in DM kg per Tropical Livestock Unit (TLU).

Location of Sampling site	Crop residue		Hay		Green Grass		Oats		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross	Local	Cross
Ele:2607masl 09°28.43N 38°52.40E	2.3	2.3	5.5	6.1	7.2	4.9	0.9	1.1	15.9	14.4
Ele:2624masl 09°28.55N 38°52.23E	1.7	2.6	5.2	7.2	6.5	5.4	0.7	0.8	14.1	15.9
Ele:2655masl 09°29.01N 38°58.03E	1.8	2.1	6	6.7	7.2	4.9	0.9	1.3	15.9	14.9
Ele:2660masl 09°30.08N 38°58.03E	2.1	2.3	5.5	6.1	7.4	5.2	0.9	1.1	15.9	14.5
Total	7.9	9.3	22.2	26.1	28.3	20.4	3.4	4.3	61.8	59.7
Average	2	2.3	5.6	6.5	7.1	5.1	0.9	1.1	15.5	14.9

Table 10: Major oxen feed quantity supplied in a day in DM kg per Tropical Livestock Unit (TLU).

Location of Sampling site	Crop residue		Hay		Green Grass		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross
Ele:2607masl 09°28.43N 38°52.40E	2.4	2.2	5.5	6.1	7.2	4.9	15.1	13.2
Ele:2624masl 09°28.55N 38°52.23E	1.7	2.6	5.2	7.2	7.7	5.4	14.6	15.2
Ele:2655masl 09°29.01N 38°58.03E	1.8	2.1	6	6.7	7.2	4.9	15	13.7
Ele:2660masl 09°30.08N 38°58.03E	2.1	2.3	5.5	6.1	7.4	5.2	15	13.6
Total	8	9.2	22.2	26.1	29.5	20.4	59.7	55.7
Average	2	2.3	5.6	6.5	7.4	5.1	14.9	13.9

Table 11: Major heifers feed quantity supplied in a day in DM kg per Tropical Livestock Unit (TLU).

Location of Sampling site	Crop residue		Hay		Green Grass		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross
Ele:2607masl 09°28.43N 38°52.40E	2.4	2.3	5.6	6.1	6.8	5	14.8	13.4
Ele:2624masl 09°28.55N 38°52.23E	1.6	2.6	5.2	7.1	6.4	5.4	13.2	15.1
Ele:2655masl 09°29.01N 38°58.03E	2	2.1	6	6.4	7.2	4.6	15.2	13.1
Ele:2660masl 09°30.08N 38°58.03E	2.2	2.3	5.4	6.3	7.4	5.1	15	13.7
Total	8.2	9.3	22.2	25.9	27.8	20.1	58.2	55.3
Average	2.1	2.3	5.6	6.5	7	5	14.6	13.8

Table 12: Major Young bulls feed quantity supplied in a day in DM kg per Tropical Livestock Unit (TLU).

Location of Sampling site	Crop residue		Hay		Green Grass		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross
Ele:2607masl 09°28.43N 38°52.40E	2.2	2.3	5.7	6.1	7	4.9	14.9	13.3
Ele:2624masl 09°28.55N 38°52.23E	1.7	2.8	5.2	7.3	6.3	6.1	13.2	16.2
Ele:2655masl 09°29.01N 38°58.03E	2	2.3	6.3	6.8	7.2	5	15.5	14.1
Ele:2660masl 09°30.08N 38°58.03E	2	2.3	5.7	6.1	7.3	5.1	15	13.5
Total	7.9	9.7	22.9	26.3	27.8	21.1	58.6	57.1
Average	2	2.4	5.7	6.6	7	5.3	14.7	14.3

Table 13: Major calves feed quantity supplied in a day in DM kg per Tropical Livestock Unit (TLU).

Location of Sampling site	Crop residue		Hay		Green Grass		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross
Ele:2607masl 09°28.43N 38°52.40E	2.5	2.3	2.0	6.0	7.5	5.0	12.0	13.3
Ele:2624masl 09°28.55N 38°52.23E	1.5	2.8	5.5	7.3	6.5	5.0	13.5	15.1
Ele:2655masl 09°29.01N 38°58.03E	1.5	2.0	7.0	6.8	7.0	5.0	15.5	13.8
Ele:2660masl 09°30.08N 38°58.03E	2.0	2.0	5.0	5.0	7.5	7.5	14.5	14.5
Total	7.5	9.1	19.5	25.1	28.5	22.5	55.5	56.7
Daily Average	1.9	2.3	4.9	6.3	7.1	5.6	13.9	14.2

4.1.4 Water intake in feed and voluntary water intake

Based on Pallas's (1986) water requirement estimation (air temperature: 15-21°C and for the cattle in general), the dry matter intake of 14.5 kg /day/TLU which is determined in 4.1.3, 59.5 liter/day/TLU of water would be required for the dairy cattle production in the two PA's. The voluntary water intake of the dairy cattle, VWIDC in general, in the season of the study time (15-21°C and dry season) was 27.1 liter/day/TLU.

The total water requirement of the dairy cattle (WRDC) is the sum of the water taken in feeds (WIFDC) and the voluntary water intake of the animals (VWIDC). The water intake in feeds of the dairy cattle (WIFDC) is then the difference of the daily water requirement of the dairy cattle and the daily voluntary water intake of the dairy cattle, i.e.

WIFDC = WRDC- VWIDC

=59.5 liter/day/TLU - 27.1 liter/day/TLU

=32.4 liter/day/TLU

4.1.5 Quality of water for the dairy cattle

The main sources of drinking water for the dairy cattle in Wuchale wereda are a number of rivers and streams, some wells and stagnant water bodies that are artificially created. All the surface water bodies are tributaries of the major rivers: Muger and Jema. The dairy cattle in this area directly access these water sources for drinking purpose (Fig. 16A & Fig. 16B).

Figure 16A: River water.

Figure 16B: Stagnant water.

Figure 16: Dairy cattle while drinking accessing the natural water sources directly. Photo Courtesy Tibebu Salehu, 2006.

There were a number of instances that people and the dairy cattle use the same water sources. In the survey, it was found that out of 120 households only 9 households from the peri urban and 17 households from the rural peasant associations had experienced use of a water

source similar to their cattle. Regarding health problems, 10% of the peri urban and 20% of the rural households faced problems related to water. Each household, 10% from the peri urban and 15% from the rural had also their cattle sick because of water quality problem.

Selected quality parameters were tested for water samples collected from the four major dairy cattle water drinking places in the two PA's (Fig. 17).

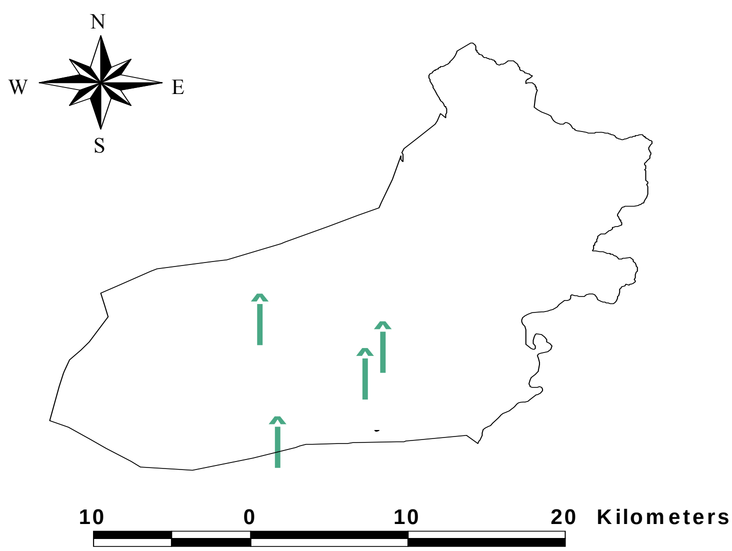

Figure 17: Water sampling sites.

Samples were collected using plastic bottles which were also light proof (Fig. 18).

Figure 18: Water sample collection and GPS reading of the site. Photo Curtesy Tibebu Salehu, 2006.

Summary of the laboratory results were as follows (Tab. 14).

Table 14: Analysis upshot for selected water quality parameters.

Parameters	Sample site 1 N: 09˚33.851 E: 38˚52.059 Ele:2631 masl	Sample site 2 N: 09˚32.400 E: 38˚56.640 Ele:2667 masl	Sample site 3 N: 09˚30.946 E: 38˚57.318 Ele:2662 masl	Sample site 4 N: 09˚28.198 E: 38˚52.725 Ele:22540 masl
TDS	144	120	213	176
EC	239	171	304	256
p^H^	8.09	7.63	7.78	8.02
Nitrate	0.66	1.56	8.94	0.9

NB: The units of parameters being: TDS (105°c, mg/l), EC (µs/cm) and Nitrate (mg/l NO_3)

4.2 Dairy cattle water productivity

The dairy cattle water productivity (DCWP) for the two peri urban and rural peasant associations of the wereda was calculated using:

$$DCWP = \frac{\sum \text{Dairy cattle Outputs and Services}}{\sum \text{Depleted water for dairy cattle}}$$

The nominator in the equation incorporates the monetary values in USD of major dairy cattle products and services and the denominator is the volume of water depleted because of the production of the dairy cattle that bestow these products and services. The dairy cattle products considered in the productivity appraisal were milk, butter, cheese, hide and manure, whereas the dairy cattle services assumed take in threshing and drought power.

There was a disparity in the production and utilization patterns of milk in the two peasant associations given that there was higher production of milk in the peri urban than in the rural area and most of the produced milk in the peri urban area was sold as fresh milk whereas it would be converted into butter and cheese in the rural area before selling because of dearth of market in the former. In monetary benefits, selling of milk as fresh would have a higher income than the milk products.

Dung though produced in the two peasant associations without much difference in quantity, the price of dry dung cakes in the peri urban was 1.4 birr/kg whereas it was 0.8 birr/kg in the rural locations on average.

Drought power was computed based on the fact that cattle provide traction power for 95% of grain production (Abiye Astatke et al.,

2001). The value of a single drought ox was the same in both areas, i.e. 1.15 USD or 10 birr on average as found from the survey.

In the case of threshing service of the dairy cattle, the survey indicated that on average 10 heads of cattle were able to thresh 12 quintals of crop in a day (Fig. 19).

Figure 19: Cattle at threshing service. Photo Courtesy Tibebu Salehu, 2006.

The value of this service for each cattle for a day was the same as of drought power, i.e. 1.15 USD or 10 birr on average as also found from the survey.

Summary of the monetary values of the dairy cattle products and services involved in the productivity calculation are as follows (Tab. 15).

Table 15: Monetary values of the dairy cattle products and services of the peri urban and rural households in the two PA's in last 2004/05 as obtained from the survey.

Dairy cattle products and services	**Peri urban** Boseque Jate USD	Birr	**Rural** Ingoye Gordoma USD	Birr
Milk consumed and sold	19,269	167,720	18.38	160.0
Butter consumed and sold	4,843	42,151	4,452	38,747
Cheese consumed and sold	944	8,216	1,011.00	8,800
Hides pieces	222	1,930	-	-
Manure	2,775	24,150	1,682	14,640
Threshing power	1,113	9,683	1045	9,093.3
Draught power	1,438	12,518	1758	15,300
Total	**30,602**	**266,369**	**9,965**	**86,740**

The depleted water for the dairy production was assumed to be the water used for the dairy cattle feed production. The water voluntarily drunk would not be depleted rather recycled in the system of the area of the study.

The water depleted from the dairy cattle feeds to produce the crop residues was not included in the calculation. This is because it was already included in the crop water productivity. Therefore, only the water depleted by Hay and Natural pasture production was assumed as the useful water for the dairy cattle productivity estimation for the two PA's. The total pasture area for the hay production was 35.35 ha ad 35.8 ha in the peri urban and rural PA's respectively. The hay yields were 94,215 kg in the peri urban and 73,040 kg in the rural PA. These weights were obtained from the donkey load equivalents, where one

donkey load 55 kg on average as determined in the survey. This is summarized in Tab. 16.

Table 16: Feed production in dry matter, kg of the two PA's in 2005/06.

Feed type	**Peri urban** Boseque Jate Dry matter	**Rural** Ingoye Gordoma Dry matter
Natural pasture	164,008	161,946
Hay	86,678	67, 197
Total	250,686	229,143

It was estimated that 300l of water is required to produce one kg of dry matter of feed (David et al., 2003). Tab. 17 was produced based on this estimation.

Table 17: Water depleted for the dairy cattle production in 2005/06.

Peasant Associations	**Water depleted**
Peri urban	
Boseque Jate	75,206 m^3
Rural	
Ingoye Gordoma	68,743 m^3

Then, the productivity using Peden et al. (2002) would be (Tab. 18):

Table 18: DCWP in USD/m3 water of the two peri-urban and rural peasant associations.

Peasant Association	**Peri urban** Boseque Jate	**Rural** Ingoye Gordoma
Monetary value ($USD)	30,602	9,965
Water depleted (m3)	75,206	68,743
DCWP ($USD / m^3)	**0.41**	**0.14**

5. Discussions

5.1 Dairy cattle water interaction

Most of the livestock composition was dairy cattle in the two PA's which imply the presence of higher water demand. In the composition of breeds, more cross breed dairy cattle were found in the peri-urban PA (Boseque Jate). This has a positive feedback to water demand in the peri-urban area.

There were a total of 1,087.8 TLU dairy cattle in the two PA's. From the water requirement of the dairy cattle determined in 4.1.1, 64.7 m^3/day of water would be required for the dairy cattle production in the two PA's (conversion based on Pallas, 1986). The annual requirement would be 23,624 m^3/day.

The higher number of cross breed dairy cattle in the peri-urban PA may have a positive impact to milk production in the area. Correlation analysis was used between percentage of cross bred milking cows and milk production per cow per year in the sampled households in order to objectively evaluate the relationship between milk production and number of cross bred cows in a household (Tab. 19).

Table 19: Percentage of cross bred milking cows and annual milk production of sample households.

HH Sr. No.	Percentage of cross bred milking cows	HH milk production Liter/cow/year
8	33.33	300
12	40	828
19	66.7	1440
39	100	1800
42	50	1000
108	0	62.5

Pearson's coefficient of correlation was determined to find the correlation between the percentage of cross bred milking cows and the

milk production per cow in a household. The analysis of variance for linear regression indicated that there was a linear relationship between the two variables (Tab. 20).

Table 20: Analysis of Variance for linear regression.

	DF	Sum of Squares	Mean of Square
Regression	1	2017223.3	2017223.3
Residuals	4	160811.9	40203.0
F_{cal}=50.17598	F_{α}=0.0021		

The hypotheses to be tested were:

H_0: percentage of cross bred milking cows and household milk production were not linearly related.

H_A: percentage of cross bred milking cows and household milk production were linearly related.

As F_{cal} was greater than F_{α}, H_0 where $\alpha=0.05$, was rejected and H_A was then accepted indicating that the percentage of cross bred milking cows and household milk production were linearly related (Fig. 20).

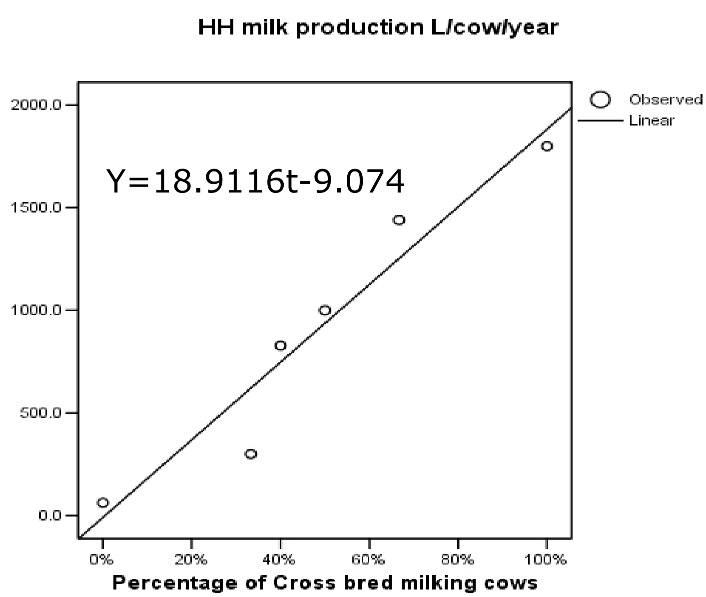

Figure 20: Plot diagram of percentage of cross bred milking cows in the household versus household milk production.

The standard deviation of the percentage of cross bred cows and household milk production were 33.59% and 660.005 respectively and the mean of the household milk production was 905.08 l/cow/year.

The Pearson correlation coefficient measures the linear association between the two variables (Tab.21).

Table 21: Correlations between percentage of cross cows and household milk production.

		Percentage of cross cows	Household milk production
Percentage cross cows	Pearson Correlation	1	.962(**)
	Sig. (2-tailed)	.	.002
	N	120	120
Household milk production	Pearson Correlation	.962(**)	1
	Sig. (2-tailed)	.002	.
	N	120	120

** Correlation is significant at the 0.01 level (2-tailed).

The Pearson's coefficient of correlation (2-tailed) between the two linearly related variables is positive and significantly different from 0. The p value 0.02 is greater than 0.01and the correlation is significant at the 0.01 level. This suggests that focus on cross breeding cows should be encouraged as it would have a significant effect on the amount of milk produced.

From 4.1.2, the major feed of the dairy cattle in the wet season is natural pasture, in the harvest season the crop residue in general will supply the feed of the dairy cattle. Though the cattle are allowed to graze in the dry season, there will not be enough grass to graze and practically the animal's feed is from the previously collected cut and dried grass (hay) with different crop residues. The water depleted for

the dairy cattle would be water used for the production of these feed types.

Hay since available for longest period of time (in the dry season) of the year, is the major feed type in the two PA's for the dairy cattle. In the wet season of the PA's, grazing is dominantly the feed source for the dairy cattle. It will go on to be a major feed source even in the harvest season but next to the crop residue which is available in the form of crop stubble (Fig. 21A & Fig. 21B).

Figure 21A: Barley stubble.

Figure 21B: Wheat stubble grazing.

Figure 21: Crop stubble allowed for dairy cattle to graze in the area. Photo Courtesy Tibebu Salehu, 2006.

From 4.1.4, the daily intake of crop residue feed was 2.2 kg /day/TLU DM. For the total TLU of the PA's, 873 ton/year DM would be supplied from the crop residue. This represents a good dairy cattle water interaction by saving $2.6*10^5$ m^3 of water annually for feed production in the two PA's.

5.2 Dairy cattle water productivity

The higher DCWP of the peri-urban peasant association was attributed mainly to better milk production using cross bred cows & better price

to dung cakes due to better demand in the peri-urban market. This study has also showed that, the better milk production in Boseque Jate was because of better holding of those cross bred milking cows by the farmers. Out of the 79 cross milking cows in the two peasant associations, 93.7% of them were in Boseque-Jate while only 6.3% of them were in the rural, Ingoye Gordoma PA.

6. Conclusions and Recommendations

6.1 Conclusions

This study was all about describing the water interaction as one part and evaluating the productivity of water of the dairy cattle as a second part. Both parts were in the scope of the selected PA’s of Wuchale wereda. In describing the dairy cattle water interaction, the following conclusions can be drawn:

1. The two PA’s were composed of highly water demanding stock of animals, dairy cattle. This has even enhanced as 54.8% of the dairy cattle were cross breeds.

2. The major feed for the cattle were pasture, hay and residues. As crop residue is one component of the major feed, water required for the production of feed was reduced by $2.6*10^5$ m^3 of water per annum. This implies an interesting aspect of water interaction of the animals.

3. The water taken in feed was comparable to the voluntary water intake of the cattle. This is attributed to multiple factors. One of the reasons is because of feed of lower moisture content which increases the drinking habit of the animals to balance the water intake quantity in feed.

5. The quality of water used for cattle drinking was acceptable. This is not true in the occasional instances when the animals made a huge crowd for drinking during dry periods. In the dry periods, animals concentrate to limited watering sites and the water would be dirty by the animals’ hooves and wastes.

In the evaluation of dairy cattle water productivity in the stratified study area, the peri urban PA had 0.41 USD per m^3 of water and the rural PA had 0.14 USD per m^3 of water. This was mainly because of higher prices of dairy cattle products and better milk production from cross bred milking cows in the peri urban area. In the rural locations, the market accesses for milk and milk products and dung cakes were also relatively very poor. As a result, the smallholder farmers do have a lower income out of their dairy cattle products. The productivity of water use for the dairy cattle of the two locations seems to have a great potential to be increased.

6.2 Recommendations

The cattle feed from the crop residue has to be enhanced in quantity and type.

Options for increasing the water productivity of the dairy cattle at the two peri urban and rural locations of Wuchale wereda should include:

1. Establishment of artificial watering sites or trough like structures in both locations. The distance while the cattle travel to drinking water sources was so higher that it could decrease their performance. Drinking troughs reduce these regular travel distances to watering sites, particularly in the peri urban areas where animals travel higher distances from rural animals. The quality of water, drinking interest of the cattle and seasonal shortage of water would also be improved there by increasing productivity.

2. Enhancement of market access. Non commercialized fresh milk, particularly in the rural area and lower prices of dung cakes would get better.

3. Cross breeding (milk production, better water adaptation). The local cows particularly in the rural areas should be crossed with higher yield cows like the Holstein Friesian of the peri urban areas.

4. Encouragement of alternative feed like vetch, oats, concentrates, etc. This would improve the seasonal variation of milk production that was observed in most of the interviewed households.

Suggestions for future work

The following research issues warrant future action:

1. *Impacts of the livestock, particularly the dairy cattle on the water resources: studies on impacts on riparian areas and water quality would have a significant contribution in the sustainable management of the livestock- water interaction.*

2. *Feed resource assessment of the livestock: feed shortages are limiting factors for the cattle production and needs to be alleviated by seeking for alternative feed.*

3. *Options to improve the livestock water productivity*

4. *Market improvement options for the livestock outputs: Market access is a problem for smallholder farmers to sell the out puts from their livestock.*

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Appendix

Appendix A

Household Survey Questioner

Serial Number___________ Date of interview __________

General Information

Name of Respondent_____________	GPS of Residence:
PA name _______________	North ________
Family Size _______________	South ________
	Altitude________

Current Livestock Inventory

Type of Livestock	Current stock		
	Number		Value
	Local Breed	Cross Breed	
Oxen			
Milking cows			
Dry Cows			
Heifers			
Young bull			
Calf			
Total Cattle			
Sheep			
Goat			
Donkey			
Horse			
Mule			
Poultry			

What are your main purposes of owning/keeping cattle?

- Draft power
- Milk
- Meat
- Others (specify)

What is the major limiting factor in your cattle production?

I. Dairy Cattle-Water Interaction

1. Water Resource

What are your main water sources for your dairy cattle use?

☐River ☐Stream ☐Water wells	☐Others (specify)

Water quality and health problems:

Types of Water	Problems Occurred?	
1. Quality of water for human purpose	☐Yes What types of problems? ☐ Water color ☐ Water odor ☐Water taste ☐Other(Specify)	☐No
2. Quality of water for cattle use	☐Yes	☐No
3. Do people get sick because of bad water? 4. Do cattle get sick because of bad water?	☐Yes ☐Yes	☐No ☐No

How much distance they travel for the source?

Wet Season: Distance: ________________________ Travel Time___________ Dry Season: Distance: ________________________ Travel Time___________

How often do you water your cattle in Wet and Dry Seasons?

Wet Season= ___________________________________ Dry Season= ___________________________________

How many cattle on average use the same water source at a time?

Do you water your cattle from the same source that use for human purpose?

☐Yes ☐ No

Do you face water shortage for your cattle use?

☐Yes ☐ No

If yes, in which months?

Do you use fertilizers to your farming?

☐Yes ☐ No

If so, do you think that it will reach the water sources?

2. Dairy Cattle feeding

Major Dairy Cattle feed types and their sources used in the 2005/06

Season 1=Dry 2=Wet 3=Harvest	Feed Type	Sources

Do you face any feed shortage in the year for your cattle?

☐Yes ☐No

If yes, when do you face?

Do you observe any variation in milk production because of season variations?

☐Yes ☐No

If yes, in which season you get better milk production?

3. Dairy cattle Manure

What is your main domestic energy source?

Do you depend on the livestock manure for your energy source?

☐Yes ☐No

Do you think that most of the livestock manure collected for your purpose?

☐Yes ☐No

How much manure do you collect in the last year?

Has the use of manure as fuel been increased time to time?

☐Yes ☐No

If so, what do you think the cause to be?

Do you observe that the animal manure contact the water sources?

☐Yes ☐No

II. Dairy cattle /Water Productivity
1. Dairy cattle Products

Home Consumed and Sold Cattle and Cattle products in 2005/06

Cattle/products	Production/owned (per year)		Consumed/Slaughtered (per year)		Sold (per year)	
	Qnty	Value (Birr)	Qnty	Value (Birr)	Qnty	Value (Birr)
Milk (lit.)						
Butter (kg)						
Cheese (kg)						
Eggs (No)						
Hides (No)						
Cattle (No)						
Manure						

How long do you milk once a cow gives her calf?

Local Cows ____________________
Cross bred Cows ________________

2. Dairy Cattle Services

What are the main services you get from your cattle?

Services	Rank (1st, 2nd...)	Value (birr/day, ...)
1. Traction 2. Transport 3. Hiring/Income 4. ploughing Other (Specify)		- - - - -

How much do you depend on these services of cattle for your living?

ͥMust	ͥWhen conditions are convenient	ͥ Rarely

3. Crop production and feed

Crop and hay productions in the year 2005/06

Crop Types	Land area	Grain Yield (Qt)	Type of Residue or Straw Used				
			Straw Used for cattle		Straw used for other purposes (Qt)	Straw Sold	
			Green (Qt)	Dry (Qt)		Quantity (Qty)	Value (Birr)
Teff							
Barley							
Wheat							
Rough pea							
Chick pea							
Maize							
Sorghum							
Horse bean							
Field peas							
Hay							

Feed availability calendar by months of the year 2005/06

Feed type	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Maize residues												
Cereal residue												
Legume residue												

Private grazing												
Communal grazing												
Stubble grazing												
Others												

Do you think that your grazing lands in your community are over grazed?

Yes No

If yes, do you think that it will create a problem?

Yes No

If yes, what do you think the consequence/problem would be? (Rank)

1st=________________________________

2nd=________________________________

3rd=________________________________

If is yes, what do you think the solutions are? (Rank)

1=________________________________

2=________________________________

3=________________________________

Is there any change in the area of grazing land in your community in the past 10 years?

Yes No

If yes, the grazing area has increased or decreased?

increased decreased

Give reasons why it increased or decreased (list by importance)

1=________________________________

2=________________________________

3=________________________________

How much hour do you usually allow your Cattle to graze?

At what times do you usually make your cattle to graze in Dry and Wet Seasons?

1. Dry Season

ÎMorning ÎAfternoon

ÎEvening ÎNight

ÎOther

2. Wet Season

ÎMorning ÎAfternoon

ÎEvening ÎNight

Î Other

Appendix B1: Major cows feed quantity supplied in a day in dry matter (DM) kg per cow

Location of Sampling site	Crop residue		Hay		Green Grass		Oats		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross	Local	Cross
2607m 09°28.43N 38°52.40E	2.3	4.1	5.5	11.0	7.2	8.9	0.9	1.9	15.9	25.9
2624m 09°28.55N 38°52.23E	1.7	4.6	5.2	12.9	6.5	9.8	0.7	1.4	14.1	28.7
2655m 09°29.01N 38°58.03E	1.8	3.7	6.0	12	7.2	8.9	0.9	2.3	15.9	26.9
2660m 09°30.08N 38°58.03E	2.1	4.1	5.5	11	7.4	9.4	0.9	1.9	15.9	26.1
Total	7.9	16.5	22.2	46.9	28.3	37.0	3.4	7.5	61.8	107.6
Average	2.0	4.1	5.6	11.7	7.1	9.3	0.9	1.9	15.5	26.9

Appendix B2: Major Oxen feed quantity supplied in a day in dry matter (DM) kg per oxen

Location of Sampling site	Crop residue		Hay		Green Grass		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross
2607m 09°28.43N 38°52.40E	2.6	4.0	6.1	11.0	7.9	8.8	16.6	23.8
2624m 09°28.55N 38°52.23E	1.9	4.7	5.7	13.0	7.8	9.7	15.4	27.4
2655m 09°29.01N 38°58.03E	2.0	3.8	6.6	12.1	7.9	8.8	16.5	24.7
2660m 09°30.08N 38°58.03E	2.3	4.1	6.1	10.9	8.1	9.4	16.5	24.4
Total	8.8	16.6	24.5	47.0	31.7	36.7	65.0	100.3

Average	2.2	4.2	6.1	11.8	7.9	9.2	16.3	33.4

Appendix B3: Major Heifers feed quantity supplied in a day in Dry matter (DM) kg per heifer.

Location of Sampling site	Crop residue		Hay		Green Grass		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross
2607m 09°28.43N 38°52.40E	1.2	1.6	2.8	4.3	3.4	3.5	7.4	9.4
2624m 09°28.55N 38°52.23E	0.8	1.8	2.6	5.0	3.2	3.8	6.6	10.6
2655m 09°29.01N 38°58.03E	1.0	1.5	3.0	4.5	3.6	3.2	7.6	9.2
2660m 09°30.08N 38°58.03E	1.1	1.6	2.7	4.4	3.7	3.6	7.5	9.6
Total	4.1	6.5	11.1	18.2	13.9	14.1	29.1	38.8
Average	1.0	1.6	2.8	4.6	3.5	3.5	7.3	9.7

Appendix B4: Major Young bulls feed quantity supplied in a day in Dry matter (DM) kg per bull.

Location of Sampling site	Crop residue		Hay		Green Grass		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross
2607m 09°28.43N 38°52.40E	1.3	1.8	3.4	4.9	4.2	3.9	8.9	10.6
2624m 09°28.55N 38°52.23E	1.0	2.2	3.1	5.8	3.8	4.3	7.9	12.3
2655m 09°29.01N 38°58.03E	1.2	1.8	3.8	5.4	4.3	4.0	9.3	11.2
2660m 09°30.08N 38°58.03E	1.2	1.8	3.4	4.9	4.4	4.1	9.0	10.8

Total	4.7	7.6	13.7	21.0	16.7	16.3	35.1	44.9
Average	1.2	1.9	3.4	5.3	4.2	4.1	8.8	11.2

Appendix B5: Major Calves feed quantity supplied in a day in Dry matter (DM) kg per calf.

Location of Sampling site	Crop residue		Hay		Green Grass		Total	
	Local	Cross	Local	Cross	Local	Cross	Local	Cross
2607m 09°28.43N 38°52.40E	0.5	0.9	1.0	2.4	1.5	2.0	3.0	5.3
2624m 09°28.55N 38°52.23E	0.3	1.1	1.1	2.9	1.3	2.0	2.7	6.0
2655m 09°29.01N 38°58.03E	0.3	0.8	1.4	2.7	1.4	2.0	3.1	5.5
2660m 09°30.08N 38°58.03E	0.4	0.8	1.0	2.0	1.5	3.0	2.9	5.8
Total	1.5	3.6	4.5	10.0	5.7	9.0	11.7	22.6
Average	0.4	0.9	1.1	2.5	1.4	2.3	2.9	5.7