

**EFFECT OF UPPER CATCHMENT MANAGEMENT AND WATER COVER PLANTS  
ON QUANTITY AND QUALITY OF WATER IN RESERVOIRS AND THEIR  
IMPLICATIONS ON LIVESTOCK WATER PRODUCTIVITY (LWP)**

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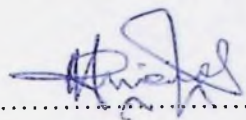
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AWARD OF A MASTERS DEGREE IN ANIMAL SCIENCE MAKERERE  
UNIVERSITY**

**JANUARY, 2009**

## DECLARATION

I declare that this thesis has never been submitted for a degree in any other university. All the work contained herein is original unless stated otherwise.

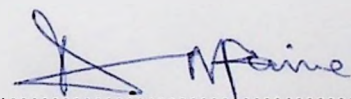


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This Thesis has been submitted with our approval as the University supervisors.

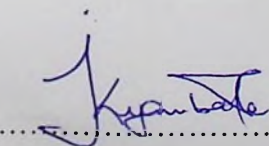


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## **DEDICATION**

I dedicate this thesis to my late brother Musoke Jude Balikuddembe. May his soul rest in eternal peace

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## ABSTRACT

Seasonal water fluctuations both in quality and quantity negatively affect livestock production and subsequently reduce livestock-water productivity (LWP) in rainfed pastoral production systems. The major contributing factors to this phenomenon are poor upper catchment and water resource management which result in contamination, sedimentation/silting, eutrophication due to nutrient enrichment, and excessive discharge of runoff into water reservoirs. This study investigated the effect of upper catchment management (un-vegetated and vegetated catchment, un-vegetated and vegetated gullies); and water cover plants on water quality and quantity in surface water reservoirs, and their impacts on livestock water productivity (LWP) in rainfed pastoral production systems of Uganda. Water quality and quantity in sixteen reservoirs were monitored on a monthly basis in Nakasongola and Kiruhura districts for a period of one year covering two dry and two rain seasons.

Sedimentation studies showed that about 250 m<sup>3</sup> of silt from un-vegetated catchment entered a reservoir, reducing the storage capacity by 18 % in a period of one year. The silt that entered the reservoir was responsible for degradation of about 47 m<sup>3</sup> of water. Un-vegetated upper catchments therefore had detrimental impacts on water reservoirs.

Total coliform (TC), faecal coliform (FC), ammonium-nitrogen (NH<sub>4</sub>-N) and total phosphorus (TP) levels were significantly higher ( $p < 0.001$ ) in reservoirs receiving water from open gullies while reservoirs with un-vegetated catchments had significantly higher concentrations ( $p < 0.001$ ) of nitrite-nitrogen (NO<sub>2</sub>-N), nitrate-nitrogen (NO<sub>3</sub>-N), total nitrogen (TN), total dissolved solids (TDS), total suspended solids (TSS) and turbidity.

TC and FC concentrations were significantly high ( $p < 0.001$  and  $p < 0.05$ , respectively) in the dry season, with highest concentrations recorded in reservoirs receiving water from open gullies.  $\text{NO}_2\text{-N}$  and  $\text{NO}_3\text{-N}$  were significantly high ( $p < 0.001$ ) in the rain season. There were significant interactions between season and treatment effects on the concentration of  $\text{NO}_2\text{-N}$ ,  $\text{NO}_3\text{-N}$ , TSS and turbidity ( $p < 0.001$ ). Reservoirs receiving water from un-vegetated catchments had high  $\text{NO}_2\text{-N}$ , TSS and turbidity in the rain season while those with vegetated gullies had high  $\text{NO}_3\text{-N}$  in the rain season.

Four plant species (*Pistia*, *Azolla*, *Lemna* and *Nymphaea spp.*) were identified as the common plant species covering water reservoirs in the study area. The results showed that reservoirs covered by *Lemna sp* had significantly lower ( $p < 0.001$ ) TC, FC,  $\text{NO}_2\text{-N}$ ,  $\text{NO}_3\text{-N}$ , TN, TSS, and turbidity than reservoirs covered by other cover plants in the study, indicating its potential application in water quality improvement for livestock production systems. *Nymphaea spp* had significantly higher ( $p < 0.001$ ) concentrations of nitrite, total nitrogen, TDS, TSS and turbidity while *Azolla spp* had significantly high ( $p < 0.001$ ) TC concentrations compared to other water cover plants. This indicated that *Nymphaea spp* is an undesirable water cover plants species and hence should be eliminated.

Improvement of upper catchment and water resource management greatly increased livestock water productivity (LWP) by 353%, 518% and 280% in the settled, semi-settled and non-settled pastoral communities. In addition, un-vegetated catchments and gullies were shown to have detrimental impacts on the reservoir water quality. Therefore, a great potential exists for improving livestock water productivity in the pastoral communities of Uganda through use of

vegetated catchments and gullies. Although the amount of rainfall in the pastoral communities of Uganda greatly contributes to the quantity of water available in reservoirs to sustain livestock and human needs through dry seasons, other factors such as evaporation, sedimentation and degradation of water quality may critically reduce the availability of water in pastoral communities. Therefore, increasing water supply through creation of more surface water resources without proper upper catchment and water management practices would only provide a temporal solution to problems of livestock water scarcity in dry seasons within the rangeland pastoral communities of Uganda due to high evaporation and reservoir sedimentation rates experienced in these communities.

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## LIST OF ACRONYMS

|        |                                                                  |
|--------|------------------------------------------------------------------|
| AfDB   | African Development Bank                                         |
| ANZECC | Australian and New Zealand Environment and Conservation Council. |
| DWD    | Directorate of Water Development                                 |
| FAO    | Food and Agriculture Organization                                |
| LWP    | Livestock Water Productivity                                     |
| MAAIF  | Ministry of Agriculture Animal Industry and Fisheries - Uganda   |
| MAF    | Ministry of Agriculture and Forestry - New Zealand               |
| MWLE   | Ministry of Water Lands and Environment - Uganda                 |
| NEMA   | National Environmental Management Authority - Uganda             |
| PFRA   | Prairie Farm Rehabilitation Administration - Canada              |
| TLU    | Tropical Livestock Unit                                          |
| SAS    | Scientific Analysis Systems                                      |

## CHAPTER ONE

### INTRODUCTION

#### 1.1 Background

Scarcity of water for livestock consumption is a major factor affecting livestock production and productivity in Uganda (AfDB, 2002; MWLE and DWD, 2003). Although the amount of water needed to produce animal feed resources can be 100 – 200 times higher than that consumed by animals, drinking water is often a major factor limiting production and has to be available in sufficient quantity and quality (Peden *et al.*, 2005). Low water intake reduces animal performance quicker and more dramatically than any other nutrient deficiency (Boyles, 2003). Livestock management and watering practices carried out in the rangelands of Uganda have led to excessive depletion of water through contamination, runoff and enhanced discharge and evaporation leading to a decrease in livestock water productivity.

Water for livestock constitutes a significant form of water use especially in the semi-arid and pastoral areas where surface water sources are scarce and long dry periods are common (NEMA, 2000). Water is a critical nutrient for livestock (Waldner and Looper, 2002; Pfost *et al.*, 2003) and as with feed ingredients, livestock water should meet the nutritional needs of the animal. Supply of inadequate and poor quality water to livestock adversely affects health, growth, reproduction and productivity of livestock (Patterson *et al.*, 2003; Pfost, *et al.*, 2003; Beede, 2005). This leads to a reduction in products obtained from animals and thus lowering livestock water productivity.

In Uganda, livestock rearing (cattle and small ruminants) is spread all over the country although it tends to be concentrated in areas inhabited by traditional pastoral tribes, mainly the Karamajong, the Iteso and the Banyankole/Bahima who occupy the dry lands (MWLE and DWD, 2003). The main features characterizing the dry lands in Uganda include low and unreliable rainfall, frequent drought and precarious water supply, charcoal burning, seasonal fires, dominance by communal land ownership, livelihoods dominated by rearing livestock, marginal productivity for arable farming and squalor and endemic abject poverty (MAAIF, 2006). Surface water reservoirs are the major means of storing water for range cattle; however, the variability in the quality of surface water is of concern due to the possible impacts on animal health and productivity (Willms *et al.*, 2002; MAF, 2004). Surface water Reservoirs are expected to have natural microbiological contamination as well as other impurities, which could affect animal health and weight gain (Willms *et al.*, 2002). Through exposure to surface runoff, all reservoirs become sinks for nutrients which lead to proliferation of microorganisms and algal population that produce toxins (Scott, 2002).

## 1.2 The concept of Livestock Water Productivity (LWP)

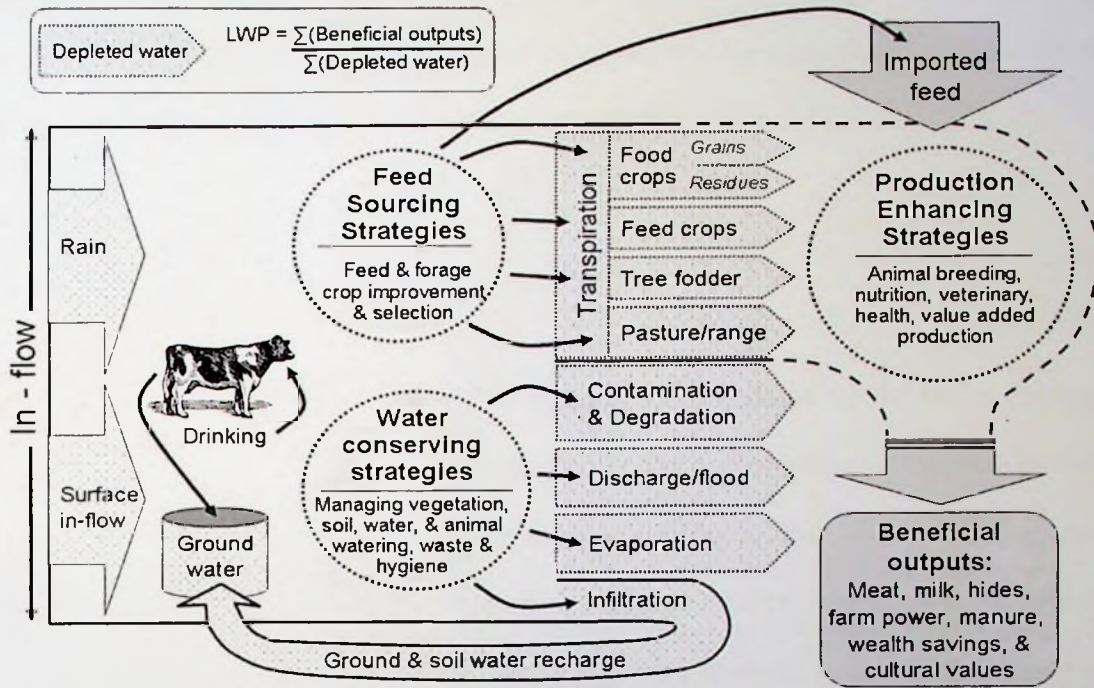
Livestock water productivity (LWP) is defined as the ratio of beneficial value of animal products and services to the amount of water depleted and degraded in producing them (Peden *et al.*, 2007). The unit of expression can be  $\text{kgm}^{-3}$  (e.g. for meat, milk and manure) or  $\text{Joule m}^{-3}$  (e.g. for meat, milk, traction services). Similar to financial crop water productivity the most frequently used LWP unit is  $\text{USDm}^{-3}$ .

$$LWP = \frac{\sum \text{Beneficial output per unit of}}{\sum (\text{depleted water} + \text{degraded water})}.$$

- Beneficiaries out put =  $\Sigma$ sales of live animals + Energy + sales of livestock products + transportation – (cost of Artificial insemination + veterinary + other service costs).
- Depleted water =  $\Sigma$ water used for feed + washing + drinks + barn management
- Degraded water =  $\Sigma$ contaminated water i.e. water is not in use, mix with feces and other adulteries.

LWP is part of the overall productivity of water for food production and is dependent on the efficiency of direct and indirect use of water for production of livestock products and services (Molden *et al.*, 2003). The LWP framework (Figure 1) takes into account the impact of livestock keeping on water quality, availability and value to subsequent users (Peden *et al.*, 2005). Water available for agricultural production including livestock either enters the system in the form of rain, surface in-flow or available in ground and soil water and is primarily lost from the system through transpiration, evaporation or discharge (Sonder *et al.*, 2005). Water is important for livestock production through drinking, feed production, maintenance of hygienic animal housing, and processing of meat, hides and skins. The amounts of water used directly by livestock for drinking and other purposes are relatively small with much larger amounts being used to produce the feed resources (Peden *et al.*, 2007). In view of the definition of LWP given above, evapotranspiration (ET) is an important variable in estimating water depleted to produce livestock feed (i.e the LWP denominator) (Molden *et al.*, 2003).

**Figure 1: Livestock Water productivity (LWP) frame work**



Source: Peden *et al.*, 2005

Livestock management and watering practices negatively impact on water productivity through contamination of surface and ground water with manure and urine, soil compaction and ground cover loss causing increased runoff and down stream hydrological changes and sedimentation (Peden *et al.*, 2005; Zhang and Schilling, 2006; Sugita *et al.*, 2006). Contaminated water is viewed as lost or depleted particularly if it is no longer useful to users within the system. However, water that percolates into soil and that discharged from surface reservoirs at full capacity are not considered as lost water because it is still available in the system either as ground water recharge to surface reservoirs or used in downstream production systems respectively (Figure 1, above). The definition of LWP (Peden *et al.*, 2005; 2007), indicates that

increase in the values of products and services, through improving livestock productivity and adding values to the products, can increase the values of the LWP. Similarly reducing the amount of water depleted and or degraded by livestock, for example, reduced evaporation and enhancing the transpiration components can increase the values of LWP.

### **1.3 Problem Statement**

Surface water resources, in form of valley tanks and valley dams are the major sources of water for both livestock and humans in the pastoral rangeland communities of Uganda. However, these water reservoirs are faced with major problems of siltation and seasonal fluctuations both in quality and quantity which greatly affect livestock productivity. Although Uganda is considered to have abundant freshwater resources, there are greater disparities in availability and use within the country because the water resources are so unevenly distributed (NEMA, 2000). The creation of dams, ponds, valley tanks and other surface water sources both as drinking water sources and as sources for irrigation schemes can considerably enhance livestock production and productivity if properly managed (Sonder *et al.*, 2005). In the rangelands, poor livestock management and watering practices expose surface water sources to surface runoff, manure deposition, and pollution (Taddese and Peden, 2005). This results into a decrease in both the quality and quantity of water in the reservoirs (Mutua *et al.*, 2006). Consequently a reduction in livestock production and productivity occurs since water intake directly affects feed intake, digestion and other metabolic and physiological processes (Landfeld and Bettinger, 2002; Waldner and Looper, 2002).

Direct access of animals to reservoirs and ponds during watering causes a reduction in water quality (Willms *et al.*, 2002). Poor water quality can be a concern both in terms of down stream water users, as well as animal health, safety and productivity. Animals defecate in and around water sources if they are allowed direct access thereby adding nutrients and reducing the palatability of water (Willms *et al.*, 2002). They also pulverize the soil around dams and aggravate the rate of soil erosion resulting into siltation of reservoirs thus reducing their volume and the quantity of water they can hold (Mutua *et al.*, 2006; Sugita *et al.*, 2006). Animals have been often noted to take little water or sometimes reject water from valley tanks covered by some aquatic plants due to the foul smell imparted in water. Animal excreta contributes to excessive algae and plant growth and also introduces disease causing organisms such as bacteria, viruses and parasites to water resulting into water born diseases which can be transmitted to other livestock and humans (Scott, 2002).

The health of people within the water stressed areas is therefore at a risk as they access the same water sources with animals for domestic use. For example, in Nakasongola, Wanzogi community development plan (2004 – 2007), it was estimated that about 15% of deaths in Kalungi sub-county, is caused by diarrhea and is attributed to the poor quality of water in the area. Presently, limited studies exist about the quality and quantity of water in reservoirs that would maximize livestock productivity in rainfed pastoral communities. This study therefore investigated the effects of different livestock and catchment management practices on water quality and quantity and established their implications on LWP.

#### 1.4 Justification

Variability in the quality of water for livestock production raises questions about the possible impacts on animal health and productivity. Livestock farming is one of the major causes of deterioration of water quality through their grazing, drinking and trampling activities (Bagshaw, 2002). Sugita *et al.* (2006) noted that cattle potentially impact on water quality by (a) increasing suspended solids concentration due to the physical stirring up of the bottom sediments when they are in the water, and due to the increased runoff from grazed foreshores areas, (b) increasing nutrients in water either through direct deposit into the water or entrained in runoff entering the water body, thereby causing effects such as increased biological oxygen demand and (c) increasing fatal bacteria and potential pathogenic microorganisms, again through direct defecation into the water, or in runoff from nearby areas.

Cattle are sensitive to taste and odor in water supplies and this limits their intake of less palatable water, possibly leading to reduced weight gain (Willms *et al.*, 2002). The poor taste and odor in water is mostly imparted by fecal contamination (Willms *et al.*, 2002), excess minerals in water like nitrates and sulphates (Jordan and Tomaszewski, 2003), and decay of algae and plant material in water (Lynch, 2006). It is therefore probable that particulate organic and inorganic matter makes water unsafe for animal consumption and also imparts undesirable taste and odor.

Water is generally brought into rangelands as precipitation. The presence or lack of water is one of the key variables determining the fate of rangeland ecosystems and productivity, and thus the understanding of the hydrologic processes is critically important (Sugita *et al.*, 2006). The presence of bare patches of soil in the upper catchment increases the rate of soil erosion and

runoff speed (Zhang and Schilling, 2006; Bhattarai and Dutta, 2007). This leads to the creation of gullies that carry runoff and manure into the reservoirs. The silt carried in runoff reduces reservoir capacity and manure introduces bacteria and nutrient elements which reduces water quality (Franeos, 2000; Alexandrov *et al.*, 2003). In Uganda, reduction in reservoir volumes has aggravated the problem of water scarcity and farmers move their animals a distance of between 15–30 kms in dry seasons looking for water (Sabiiti, 2001). Water access and quality affects livestock performance (Landefeld and Bettinger, 2002).

Therefore, quantifying the available water resources and understanding the effects of human and livestock activities on water resources is vital in maintaining the integrity of rangelands (Mazvimavi *et al.*, 2008), and is a necessary condition for integrated management of water resources. This study will therefore assess the seasonal variation of water and effect of upper catchment and water resource management practices on the quality of water in surface reservoirs with in the rainfed pastoral communities. This will provide a basis for identifying the factors affecting water availability and quality in surface reservoirs, their impact on livestock production and subsequent effects on Livestock Water Productivity.

## **1.5 Objectives of the Study**

### **1.5.1 General objective**

The main aim of this study was to establish the effects of upper catchment management and water cover plants on the quality and quantity of water in surface water reservoirs, and establish their impacts on livestock water productivity (LWP) in rainfed pastoral production systems of Uganda.

### **1.5.2 Specific objectives**

The specific objectives were to:

1. Evaluate the effects of upper catchment management on the quality and quantity of water in surface water reservoirs in pastoral areas.
2. Identify the common water cover plants and investigate their effects on the quality of water in surface water reservoirs in pastoral areas.
3. Establish the contribution of improved upper catchment and water resource management to Livestock Water Productivity (LWP) in rain fed pastoral production systems of the Nile basin.

### **1.5.3 Hypothesis**

1. Un-vegetated catchments and gullies degrade water quality and increase the amount of silt deposited in reservoirs
2. Water cover plants can improve the quality of water in surface water reservoirs
3. Improved upper catchment and water resource management improves Livestock Water Productivity (LWP).

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 Importance of water to livestock

Water is an essential nutrient, only second to oxygen in importance to sustain life and optimize growth, lactation and reproduction in livestock (Beede and Meyers, 2000). Water contributes about 60 to 70% of the body of livestock (Waldner and Looper, 2002) and limitation of water intake reduces animal performance quicker and more dramatically than any other nutrient deficiency (Waldner and Looper, 2002; Boyles, 2003). Water is required for digestion and metabolism of energy and nutrients, transport and circulation of nutrients and metabolites to and from tissues, excretion of waste products, maintenance of proper ion, fluid and heat balance, and as a fluid and cushioning environment for the developing fetus (Murphy *et al.*, 1983; Adams and Sharpe, 1995). Domestic animals can live about sixty days without food but only seven days without water (Landfeld and Bettinger, 2002).

Rangeland productivity and ecosystem sustainability is mostly determined by water availability (Sugita *et al.*, 2006). Water availability affects the quality and quantity of herbage produced thus influencing dry matter intake and livestock production. Peden *et al.* (2007) noted that evapotranspiration is the most beneficial way of water depletion in livestock production systems, since animal production depends on the use of feed produced through evapotranspiration. Practices that promote useful evapotranspiration of available water therefore result into more feed production and thus increase Livestock Water Productivity. Conserving available water for pasture production in the pastoral communities, minimizing losses to evaporation and run-off,

will therefore lead to restoration of the lost vegetation cover (Beckes and Cowling, 2003; Haukun *et al.*, 2005). Once vegetation is restored, runoff and surface evaporation will reduce while water infiltration and evapotranspiration will increase (Mugerwa *et al.*, 2008; Zziwa *et al.*, 2008). This will in turn increase pasture and livestock production and thus improve Livestock Water Productivity.

There are three sources of water for livestock: Drinking water, Water contained in feeds and metabolic water (Zinash *et al.*, 2002). Metabolic water comprises only 5% to 10% of the water intake for most domestic animals but may account for up to 15% the total water intake in sheep (Aganga *et al.*, 1989; Abdelatif and Ahmed, 1992). Water contained in feeds consumed is highly variable from feed to feed depending on the moisture contents, which can range from as low as 5% in dry feeds to as high as 90% or more in succulent feeds (Sirohi *et al.*, 1997). When water content of the feed ingested is low, drinking water requirements increase and its provision to livestock becomes the main concern (Degan, 1997; Sirohi *et al.*, 1997). Most of the water that is utilized by the animal body is ingested either as drinking water or as a component of the feed (Woodford *et al.*, 1984).

## **2.2 Livestock water requirements**

A successful livestock enterprise requires a good water supply, both in terms of quality and quantity (Olson and Foxprofessor, 2003). Generally, water requirements for drinking by one Tropical Livestock Unit (TLU) of indigenous cattle (i.e an animal weighing 250 kgs of body mass) is estimated to be 25 liters per day (Kiwuwa, 2006). The drinking water requirements of livestock depend on their abilities to withstand dehydration and on their demand for free water.

The demand for water of individual animals is variable depending on season and type of food digested. As the air temperature increases, water requirements increase and similarly, as the moisture contents in feed decrease, water requirements increase (Grooms, 2003). When the overall nutritional need is high, such as during lactation or during the finishing period, water intake also increases (Ross, 2004). Availability of sufficient water quantities increases dry matter intake, subsequently increasing production (Grooms, 2003). The quantity of water consumed per unit weight gain increase as the dry season progresses presumably because the forage became senescent and moisture content and quality of the forage decline (Willms *et al.*, 2002).

### **2.3 Factors affecting quantity and availability of water in reservoirs**

Surface water reservoirs (Ponds, Valley tanks and Dams) are the major sources of water for livestock in the rangelands and therefore, access must be controlled to maintain the integrity of the structure and water quality. The quantity of water stored in a reservoir is determined by the volume (Depth, length and width). However, the availability of this water throughout the year is affected by various factors, which include; soil and vegetation type, weather conditions, water cover plants, sediment deposition and livestock and domestic water use.

#### **2.3.1 Soil and vegetation type**

Soils that have high water seepage hold water for fewer months compared to soils with a lower infiltration rate (Gwaltney, 2003). This therefore implies that soils with high seepage rates recharge surface reservoirs for only short time in the dry season. Changes in land cover and land use have significant effects on hydrological processes such as evapotranspiration, soil moisture

and groundwater recharge (Rodriguez-Iturbe, 2000). The more the vegetation cover in the upper catchment, the more efficient water use through increased infiltration and reduced run-off. This therefore reduces the amount of silt that is delivered into down stream water reservoirs and thus maintains the capacity of reservoirs to hold enough water throughout the dry season. Substantial increases in milk output have been reported in high producing dairy cows with readily accessible water. Using a watering source where livestock do not have direct access not only protects the water source but may also increase nutrient distribution throughout the field (Landefeld and Bettinger, 2002). Management aspects such as provision of grassed watersheds around banks of the reservoir have been found to stabilize the slopes and prevent slumping thus increasing the useful life of the reservoir (Lardner, 1999; Zhang and Schilling, 2006).

### **2.3.2 Weather conditions**

Water and air temperature, wind speed and humidity are major climatic factors that affect the amount of water in reservoirs (Sanchez-Carrillo *et al.*, 2004). The chaotic behavior of the climate complexes hydrological management in rangelands (Molles *et al.*, 1992), and is often controversial because of the increasing imbalance between water supply and demands. Evapotranspiration is a major component of the water balance in semi-arid areas (Winter, 1992), but few studies have addressed its dynamics in regions with this kind of climate.

Evapotranspiration is large consumer of energy, influences water temperature, water level and salinity (Prihan and Ondok, 1985). Evaporation and transpiration depend on vertical (water level fluctuations) and horizontal (inundation) hydrological changes. As the water surface area increases, evaporation increases. Therefore, reservoirs with a large surface area loose more water

through evaporation than reservoirs with similar capacity but having a great depth and smaller surface area. Increases in vegetation cover increases the transpiration to evaporation ratio and increased open water area results in to increased evaporation (Sanchez-Carrillo *et al.*, 2004; Gokbulakl and Ozhan, 2006).

### **2.3.3 Water cover plants**

Hoyer and Canfield (1997), classified aquatic macrophytic plants in four groups; Emergent, Floating-leaved, Submersed, and Freely floating, and these have varying effects on the physical, chemical and biological properties of water (Ramsey, 2001). Aquatic plants often affect water courses depending on the density of their coverage (Adams *et al.* 1974). As plant densities increase, evapotranspiration increase. Aquatic plants enhance the deposition of fine sediment that would otherwise be eroded thus increasing the accumulation of sediments and a subsequent reduction in reservoir volume (Krake, 1999).

### **2.3.4 Sediment deposition**

Soil erosion is a natural geomorphic process that can be accelerated under improper land use and management practices (Bhattarai and Dutta, 2007). Problems caused by soil erosion and sediment yield include loss of soil productivity, water quality degradation, and less capacity to prevent natural disasters such as floods (Lewis *et al.*, 2001; Renwick *et al.*, 2005). Apart from reducing the water storage capacity, sediment delivered into water bodies may also be a source of contamination, adversely impacting the aquatic biota (Mutua *et al.*, 2006). Soil erosion and associated sediment deposition are thus becoming a serious threat for the sustainable

intensification of the agricultural production as well a major problem for watershed management and conservation of the natural resource base (Lal, 2000; Walling, 2001). Suspended sediments in water bodies affect water quality and cause pollution because of various agrochemicals adsorbed on the sediments (Queralt *et al.*, 2000). The sediments also cause loss of reservoir storage capacity and eutrophication of the water bodies (Clark, 1985).

#### **2.3.5 Livestock and domestic water intake**

The numbers of animals accessing a water reservoir and the amount of water drawn for domestic use have an effect on the time taken for the reservoir to dry off. Livestock drink about 25 l/day/TLU (Peden, 2003). Therefore water in reservoirs accessed by very many animals takes a short time to dry out compared to reservoirs accessed by few animals. Similarly the number of households withdrawing water from reservoirs affects water availability. The high the household water consumption, the shorter time it takes for a reservoir to dry out and this will impact on livestock production. Water withdrawn from reservoirs for domestic use depend on season, other water resources and potential water harvesting techniques available in the area (Owoyesigire *et al.*, 2008). In areas with limited alternative water supply resources and where the established bore holes dry out faster than surface reservoirs, people share the same water resource with animals as in Migyera and Wanzogi sub-counties, Nakasongola district (Owoyesigire *et al.*, 2008).

## **2.4 Water quality and livestock production**

Water quality is defined as the combined physical attributes and chemical constituents of water that contribute to its usefulness for a particular purpose (Jenny, 1998). Factors contributing to good quality water include taste, smell, turbidity, electrical conductivity and presence or absence of certain substances (Socha *et al.*, 2003). Kavana *et al.* (2003) defined good quality water for livestock as that which contains some salt and with moderate color. Clear and tasteless water is considered as not ideal for livestock because it doesn't provide mineral required by animals for better performance in rangelands. Most ground and surface water are adequate for cattle consumption. However, contaminated water can result in poor performance or even death in cattle confined to it (Grooms, 2003).

Most elements in water do not cause problems because they do not occur at high enough levels. Cobalt, copper, iodine, iron, manganese and zinc may be toxic in excessive concentrations but rarely are seen at levels high enough to cause problems (Landefeld and Bettinger, 2002). Therefore, when evaluating water quality for livestock, consideration should be made to investigate whether water could serve as a carrier to spread diseases, and if the acceptability or safety of animal products for human consumption will be affected.

## **2.5 Water quality parameters and livestock productivity**

Water quality, as well as quantity affects feed consumption and animal health since poor water quality normally result in reduced water and feed consumption thus reducing animal growth and production. Parameters typically considered in water quality evaluation include odor and taste

(Organoleptic properties), physical and chemical properties, presence of toxic compounds, concentration of macro and micro mineral elements and microbial contaminations (Mills, 2002; Ross, 2004). Excessively high levels of some of these parameters may have direct effects on the acceptability (palatability) of drinking water (Willms *et al.*, 2002) or may affect the animal's digestive and physiological functions once consumed (Patience, 1994). Cattle detect Organoleptic properties such as odor and taste, and if the water source is unpalatable, they may avoid the water or not drink sufficient to meet production needs (Willms *et al.*, 2002).

### **2.5.1 Organoleptic Properties**

Odor, colour and turbidity are used to assess the organoleptic property of water. If the water has an offensive smell, cows may not drink enough to meet production needs or it may be completely refused (Willms *et al.*, 2002). Off-odors are a result of physicochemical properties, substances present in excess and presence of bacteria and their metabolic by products (Beede, 2005).

### **2.5.2 Physicochemical Properties**

These are very useful in determining water quality. They include pH, Hardness, Total Dissolved Solids (TDS), other substances in excess, Sulfur, Chloride, Nitrate, Phosphorus, toxic compounds and microorganisms (Beede and Myers, 2000; Pfoest *et al.*, 2003).

### 2.5.2.1 Total Dissolved Solids (TDS)

TDS is a general term defining the sum of all inorganic matter dissolved in water (Patterson *et al.*, 2004a). It also indicates the salinity of water (Beede, 2005). High concentrations of TDS are generally considered un-wanted characteristic and an indicator of poor quality water. Patterson *et al.* (2003) indicated that growing steers given water with 1019 mg/L TDS increased water intake, daily gain and feed efficiency compared to steers that were given water with 4,835 mg/L of TDS. Steers that consumed water with less TDS also showed a decrease in morbidity, mortality and polioencephalomyelitis.

Water intake decreases linearly with increase in TDS and above 4,720 mg/L, reduced performance and health of growing steers is noted (Patterson, 2004 a). However, TDS *per se* may not provide much information about water quality or the specific individual constituent of concern. The concentration of TDS could be high, influenced mainly by high concentration of calcium and magnesium, yet little or no influence on water nutrition or cattle performance could be expected (Beede, 2005). More extensive assessment must be done when water analyses indicate high TDS with excessively high concentration of sodium chloride, sulphate, iron and manganese. A number of observations have been made relative to saline livestock waters, some of them verified by experimental findings. (Jaster *et al.*, 1978), found that milk production decreased when cows consumed water containing 2500 mg/L NaCl added to tap water that already contained 196 mg/L TDS. The effect of high levels of TDS on the livestock production is aggravated by water under which livestock access such water directly. Challis *et al.* (1987), found a trend towards decreased milk yield when cows were given water with 4300 mg/L TDS during hot weather. At high concentration that is somewhat less than toxic, increasing salinity

actually cause an increased water consumption, even when the animal refuses to drink for a short period of time at first (Olson and Fox, 2003).

Weeth and Heverland (1961), found that growing heifers tolerated 1.75% NaCl in drinking water during the winter, but tolerated only 1.2% NaCl in the summer before toxicity signs presented. This is basically attributed to a low nutritive value of pastures in summer as compared to winter. This therefore indicates that animals in pastoral communities can tolerate water with high TDS in wet seasons better than in dry seasons. All in all, older animals are more resistant to harm from salinity than the young animals (Olson and Fox, 2003).

## 2.2 Sulfur and Sulfates

Sulfur is always present as hydrogen sulfide and imparts the rotten egg smell, and is believed to affect water intake (Beede, 2005). High concentration of sulfate in drinking water reduces water consumption, decreases dry matter intake and milk production (Jordan and Tomaszewski, 2003). Sulfates also cause diarrhea in young calves and tie up dietary copper, zinc and manganese leading to their deficiency in animals (Grooms, 2003). The tolerance threshold of sulfate is about 50 mg/L for growing heifers but levels of 1500 ppm were also found not to reduce consumption of water (Weeth and Capps, 1972). Iron Sulfate is the most potent depressor of water intake compared with other forms of sulfates. Water and feed with high sulfate contents have been linked to the development of polioencephalomalacia (PEM) in beef calves and can induce copper deficiency with or without the assistance of molybdenum (Waldner and Looper, 2002).

### 5.2.3 Nitrates

Nitrates are a potential problem when present in excess in drinking water and can pollute water (Beede, 2005). Nitrates can be used in the rumen as a source of nitrogen for synthesis of bacterial protein but reduction to nitrite also occurs (Waldner and Looper, 2002). When absorbed into the body, nitrites reduce the oxygen carrying capacity of blood, which can lead to asphyxiation in several cases (Waldner and Looper, 2002). Symptoms of nitrate or nitrite poisoning are labored breathing, rapid pulse rate, and increased urination, restlessness, frothing at the mouth, vomiting, convulsion, blue muzzle and bluish tint around the eyes, chocolate- brown blood and death. More moderate levels of nitrate poisoning have been incriminated in poor growth, infertility problems, abortions, vitamin A deficiencies, reduced milk production and general unhealthiness (MAF, 2004).

Ruminants exhibit adaptation to high nitrate diets developing a rumen flora with a higher capacity for reduction of nitrate/ nitrite (MAF, 2004). Despite this, non-ruminants such as pigs and chickens are less susceptible as they rapidly eliminate nitrate in the urine (ANZECC, 2000). The nitrate content of feed and water are additive, therefore interaction of dietary constituents and water is important. The nitrate concentration of water should not exceed 20 mg/L, for proper livestock performance (Waldner and Looper, 2002).

### 5.2.4 Iron

High iron concentration in drinking water may reduce the palatability (acceptability) and consumption of water (Beede, 2005). Iron deficiency is rare in adult cattle because of abundant iron ( $\text{Fe}^{3+}$ ) in feedstuffs. The predominant chemical form of iron in drinking water is the ferrous

( $\text{Fe}^{2+}$ ) form, which is highly soluble and can interfere with the absorption of copper and zinc. Excess livestock iron intake can be a problem especially when drinking water contains high iron concentration. Iron concentrations in drinking water greater than 0.3 mg/L are considered a risk for human health, and problematic for dairy cattle health and performance (ANZECC, 2000). Consequences of iron toxicity include; compromised immune function, increased mastitis and metritis, greater incidence of retained fetal membranes as well as diarrhea, sub-normal feed intake, decreased growth and impaired milk yield.

#### **2.5.2.5 Toxic compounds**

Toxic compounds are defined to be deleterious to man and livestock (Patience, 1994). They are normally found in water sources but do not cause problems to livestock in trace amounts. Lead, arsenic, cyanide and mercury are all examples of toxic compounds found in water.

#### **2.5.2.6 Water Hardness**

Hardness is generally expressed as the sum of calcium and magnesium (the major factors) reported in equivalent amounts of calcium carbonate (MAF, 2004). Other cations in water such as zinc, iron, strontium, aluminum and manganese also contribute to water hardness (Waldner and Looper, 2002). Water hardness has no effect on animal performance, milk production, weight gain or water consumption even up to 300 mg/L (Graf and Holdaway, 1952; Blosser and Soni, 1957; Allen *et al.*, 1958). The actual cations involved, the composition of the diet and the physiological state of animal may affect the specific response to the hardness of the water. This is particularly so with cations such as calcium and magnesium in the late pregnancy and early

itation in dairy cows, being two minerals that are associated with metabolic upsets during these periods (hypocalcaemia and hypomagnesemia) (MAF, 2004).

### 5.2.7 Acidity or pH

Water with a pH of less than 5.5 may cause problems related to mild acidosis such as reduced milk yield, depressed milk fat percentage, low daily gain, more infectious and metabolic diseases, and reduced fertility (Grant, 1996). Grant also stated that alkaline water with pH greater than 8.5 may result in problems related to mild alkalosis such as acid and vitamin B deficiencies. The preferred pH of drinking water for dairy animals is 6.0 to 8.0 (Waldner and Looper, 2002). Water with a pH outside this range may cause non-specific effects related to digestive upsets, diarrhea, poor feed conversion and reduced water and feed intake.

### 5.2.8 Temperature

Temperature affects the physical and chemical properties of water and greatly influences aquatic organisms. It also affects how much oxygen water can hold and how quickly nutrients will be cycled through aquatic systems. Runoff from heated impervious surfaces increases water temperatures. Most aquatic organisms can tolerate gradual change in temperature but drastic changes can cause thermal stress. Temperatures above 32°C may be lethal to many aquatic organisms (Hoyer and Canfield, 1997). The temperature of non-vegetated sites is always higher because of more runoff and less shade due to the lack of riparian vegetation (Peterson, 2006).

**2.5.2.9 Dissolved oxygen**

Oxygen enters water through diffusion from the atmosphere and when aquatic plants and algae release oxygen during photosynthesis (Hoyer and Canfield, 1997). A dissolved oxygen value of at least 5.0 ppm is desirable for most aquatic organisms. Dissolved oxygen's percent saturation is the amount of oxygen water can hold. When dissolved oxygen concentrations exceed 100 percent of the amount that can be dissolved by physical mixing alone, water become super saturated. An acceptable range for dissolved oxygen percent saturation is between 12% and 60% (Andrea, 2006). Dense aquatic plant covers use more oxygen than is produced in photosynthesis on cloudy days (Hoyer and Canfield, 1997). If the situation persists, oxygen depletions occur drastically affecting all organisms in water. The death and decay of aquatic plants leads to oxygen depletion as bacteria use oxygen as they break down these dead plant tissues. However, the amount of oxygen dissolved in water does not affect livestock production directly, but greatly influences biological processes in water which may yield unfavorable conditions resulting into bad smelling water that can reduce livestock consumption and hence limit production (Hoyer and Canfield, 1997).

**2.5.3 Microbiological water quality properties**

Water supplies for livestock in Uganda are not treated for microbial contamination, and hence livestock are exposed to bacterial loadings in the water supply. Livestock can tolerate relatively high bacterial loadings in drinking water (Beede, 2005, and PFRA, 2003). The microbiological limits for livestock water supplies vary considerably depending on age of the animal, feeding and environment (Grant, 1996; ANZECC, 2000). Young calves have been shown to contract scours

when drinking water containing coliform bacteria of more than one count per 100ml. They sometimes suffer from coccidiosis, which leads to bloody diarrhoea, dehydration, weight loss, depression, and sometimes death (PFRA, 2003). On the other hand, adult animals can tolerate bacterial concentrations of up to 100 counts per 100ml without any side effect (Grant, 1996).

The level of fecal (thermo-tolerant) coliforms provides an indication of fecal contamination, but does not directly relate to the number of known harmful bacteria present in the water. Surface water supplies to which livestock has ready access are always potential candidates for contamination (Pfoest *et al.*, 2003). The presence of coliform bacteria in a water source is an indication that surface water is finding its way into the reservoir.

#### **2.5.3.1 Algae**

Algal growth is a common problem in freestanding water, and they are found as single cells or in clumped or filamentous colonies but only become a potential hazard when they are present in large numbers (blooms) (ANZECC, 2000). Stagnant water contaminated with manure or other nutrients may develop blue-green algae, which can poison livestock, causing muscle tremors, liver damage, and death to animals (Pfoest *et al.*, 2003). The presence of algae in water also affects livestock by discouraging consumption due to reduced palatability (taste and odor) (PFRA, 2003). An increasing risk to livestock health occurs when cyanobacteria counts exceed 11,500 cells/ml (ANZECC, 2000).

## **6 Water quality protection and management**

number of management strategies are available to improve water quality or to limit deterioration of water quality. Some strategies such as fencing off water reservoirs to restrict livestock from entering them are already used in the rangelands all over Uganda but others have either been put to limited practice or have not been practiced at all.

### **6.1 Fencing of water reservoirs**

Research has indicated a great potential of reducing contamination of waterways and reservoirs by preventing access of livestock to stream channels, parts of riparian zones and into water reservoirs (Bagshaw 2003; Willms *et al.*, 2002). Lardner (1999) noted that it is good practice to ensure that banks of dams are vegetated as plants with spreading root systems stabilize the slopes preventing slumping and increasing the useful life of the dam. Fencing protects animals from eating and trampling on vegetation surrounding reservoirs which helps to stabilize slopes, prevent slumping and filter runoff (Lardner, 1999).

### **6.2 Riparian vegetation**

Riparian area of any water reservoir functions as sponges, absorbing and filtering out sediment and other debris as well as providing unique habitats for some organisms (Simmons, 2004). Planting of the riparian areas is a component of a long – term strategy to discourage development of cyanobacterial blooms in water bodies. Over time, this approach leads to increased shading and reduced nutrient inputs (from livestock effluent, bank erosion and runoff from agricultural

land), both of which will reduce the suitability of a water body for cyanobacterial growth (MAF, 2004).

### **2.6.3 Vegetation filter strips**

These are areas of vegetation bordering a body of surface water. Seeded with close – growing plants, such as grasses or legumes, filter strips protect surface water from eroded soil, nutrients, chemicals and organic materials. Plants in the filter strip slow water runoff, which reduces the water's ability to carry pollutants (Kenneth, 1997). Potential pollutants, especially those associated with sediment, are deposited before they reach surface water.

### **2.6.4 Grassed waterways**

Grassed waterways are natural or constructed channels established for transport of concentrated flow at safe velocities using adequate vegetation (Green and Haney, 2004). They are generally broad and shallow by design to move surface water across farmland without causing soil erosion. Grassed waterways are used as outlets to prevent rill and gully formation and provide filters that keep silt and some attached heavy metals and pesticides from contaminating water resources (Adams, 1992; Whitwell *et al.*, 1997). The vegetative cover slows the water flow, minimizing channel surface erosion. This management practice can reduce sedimentation of nearby water bodies and pollutants in runoff (Streamlines, 1998). The vegetation improves the soil aeration and water quality due to its nutrient removal (Nitrogen, Phosphorus, herbicides and pesticides) through plant uptake and sorption by soil (Green and Haney, 2004).

### **2.6.5 Trough cleaning**

Frequent cleaning of troughs offers a cleaner source of water for livestock (MAF, 2004). Although LeJeune *et al.* (2001) found that recently cleaned troughs had higher coliform counts and that cleaning interval had no significant effect on the *E. coli* counts, both *E. coli* and *Salmonella spp.* tended to be isolated more frequently in the less recently cleaned troughs. Recently cleaned troughs are less likely to harbor these particular strains of bacteria until they are recontaminated by an outside source. It is therefore more likely that the type of trough, method of cleaning and the ability for livestock to re-contaminate influences the prevalence of bacteria in livestock drinking troughs

### **2.6.6 Aeration of dams and troughs**

Aeration is also used to enhance the quality of water in dams and troughs and thus improve livestock water intake and performance (Willms *et al.*, 2002). Dissolved oxygen (DO) is essential to aquatic organisms in a dam. In waters with low oxygen levels, the production of “swamp gases” such as hydrogen sulphide and methane is likely to occur, and phosphorus is more rapidly released from decomposing sediments (MAF, 2004) which favor rapid growth of algae. In most dams, the decomposition of dead plants and animals uses up oxygen more rapidly than it can be absorbed from the atmosphere creating a layer of poorly oxygenated water at the bottom leading to production of noxious gases (Peterson, 2006).

### **2.6.7 Livestock water treatment**

Various methods of water treatments (disinfection, reduction of dissolved salts, and others) to produce higher quality water are available, but most of them have their limitations especially for

delivery to animals at pasture. The methods include filtration, coagulation (to precipitate suspended solids), reverse osmosis, chlorination, and oxidation (Solsona, 1996). Before considering treatment, it must first be established whether it is the microbiological or the chemical quality of the water that is of concern or whether other factors, such as palatability due to faecal contamination are of greater significance (MAF, 2004). In addition, the costs to benefit ratios of such processes are questionable and have no practical application to farmers as management interventions.

## 2.7 The importance of aquatic Plants on livestock water

Aquatic and wetland plants (macrophytes) are classified into four groups: Emergent, Floating-leaved, Submersed, and Freely floating (Hoyer and Canfield, 1997). Emergent macrophytes are plants that are rooted in substrate with the tops of the plant extending into the air. They are typically rooted in the bottom, have their base portions submersed in water, and have their tops elevated into the air. Common emergent macrophytes include plants such as reeds (*Phragmites* spp.), bulrushes (*Scirpus* spp.), cattails (*Typha* spp.), and spikerushes (*Eleocharis* spp.) (Hoyer and Canfield, 1997).

Floating-leaved macrophytes are plants that are rooted to the lake bottom with leaves that float on the surface of the water. They generally occur in areas of a lake that do not occasionally dry out. Common representatives include waterlilies (*Nymphaea* spp.), spatterdock (*Nuphar* spp.), and watershield (*Brasenia* spp.). Floating leaves are attached to roots or rhizomes with a flexible, tough stem

Submersed macrophytes are plants that grow completely submersed under the water. They are a diverse group that includes quillworts (*Isoetes* spp.), mosses (*Fontinalis* spp.), muskgrasses (*Chara* spp.) and curly-leaf pondweed. Submersed species face special problems obtaining light for photosynthesis and they must obtain carbon dioxide from the water where it is much less available than it is in air.

Free floating macrophytes are plants that typically float on or just under the water surface with their roots in the water and not in sediment. Small free floating plants include duckweeds (*Lemna* spp.), mosquito fern (*Azolla caroliniana*) and water fern (*Salvinia* spp.). Larger surface floating plants include water lettuce (*Pistia stratiotes*) water hyacinth (*Eichhornia crassipes*), frog's bit (*Limnobium spongia*). Free floating species are entirely dependent on the water for their nutrient supply, and most of them have been used in wastewater treatment to remove excess nutrients.

### 2.7.1 Effects of aquatic macrophytes on their environment

Dense stands of aquatic plants form a heavy shading canopy that significantly alters the photosynthetically available light under macrophyte stands (Adams *et al.*, 1974). Reduction in water flow through macrophyte beds enhances deposition of fine sediment that would otherwise be eroded and also act as a sieve, retaining coarse particulate organic detritus (Hoyer and Canfield, 1997). Both of these mechanisms increase the accumulation of sediments in water reservoirs which is usually undesirable (Krake, 1999). During daylight hours, while photosynthesis occurs, water can become supersaturated with oxygen. Respiration at night can deplete dissolved oxygen in dense beds with little water circulation. Dense growths of floating or matted submersed species decreases oxygenation by inhibiting oxygen exchange with the

atmosphere (Louie, 2002). Macrophytes influence nutrient cycles (Kyambadde, 2005). Phosphorus for example, is removed from the sediment via plant roots and incorporated into plant biomass (Sabine *et al.*, 2003). When plant tissue dies, phosphorus is circulated, at least briefly, back into the water column. Macrophyte death and decay also adds organic matter to the sediments (Lynch, 2006). In general, macrophyte stands are sinks for particulate matter and sources of dissolved phosphorus and inorganic carbon (Carpenter and Lodge, 1986). This therefore lowers the quality of water for livestock consumption and in some cases impart an awful smell in water making animals to reject such water.

### **2.7.2 Evaporation and evapotranspiration from aquatic systems**

Rainfall amounts and aquifer levels are not the only reasons why reservoir volumes cycle between seasons and years (Ramsey *et al.*, 2004). Water may seep into the ground, flow away, evaporate from the open surface, or it may be transpired through aquatic and wetland plants.

Evaporation is the process by which water vaporizes and escapes from the water surface, into the atmosphere. In many open water lakes and wetlands, evaporation is the major outflow component of the hydrologic cycle (Gökbülak and Özhan, 2006). Evaporation rates are affected by latitude of the water body (solar energy input), air and water temperatures, air pressure, wind velocity over the water surface and turbulence in the water (Ramsey *et al.*, 2004). In low rain years, evaporation loss may exceed the amount of gain from rainfall. Evaporation rates are also affected by the plant coverage on a lake's surface. In general, evaporation decreases as submersed and floating plant coverage increases (Ramsey *et al.*, 2004). Floating-leaved plants

that reduce evaporative water loss include *Salvinia*, *Azolla*, *Nymphaea*, *Nelumbo*, *Lemna*, *Wolffia*, and *Spirodela*.

Evapotranspiration is the process by which water is taken up by plants, used and transpired (emitted as water vapor) to the atmosphere. In most situations, aquatic macrophyte evapotranspiration greatly increases water loss from a water body (Ramsey *et al.*, 2004). Evapotranspiration rates of plants depend on those plant characteristics that expose more photosynthesizing cells to the air, such as height (especially for cattail), and leaf area index (for water hyacinth and water lettuce). Environmental factors also greatly affect evapotranspiration rates on a water body. Primary environmental factors are latitude (solar energy input), air and water temperatures, wind speed, relative humidity, plant growth phase, and nutrient availability.

## CHAPTER THREE

### METHODOLOGY

#### 3.1 Description of study area

The study was undertaken in *Kiruhura and Nakasongola districts* which are found in the dry lands of Uganda, referred to as the cattle corridor (Figure 2). The “cattle corridor”, occupies an area of 84,000 km<sup>2</sup> (~43% of the land area) of Uganda and contains a population of about 6.6 millions (~30% of the total population of Uganda). The system stretches from the North-east, through the central to South east of the country (Figure 2) and covers, (fully or partially) several districts of Uganda: Kotido, Moroto, and Katakwi in the North east through Nakasongola and parts of Luwero in the central to Rakai, Mbarara and Ntugamo in the South west. Nakasongola is located in central region of Uganda on Bombo – Gulu road 114 Km North of capital Kampala, while Kiruhura is located in South western Uganda on Masaka - Mbarara highway about 210 Km South west of Kampala.

#### 3.2 Biophysical settings of the study sites

##### 3.2.1 Climate

Climate data from metrological stations located within about 30 Km radius indicates a bi-modal rainfall regime for Kiruhura (Figure 3). The first rainy season occurs in the months of March–May while the second is September–November. The potential evapotranspiration remains high through the year (~100mm /month) and shows less variability unlike the rainfall. Nakasongola shows a similar pattern of rain fall and potential evapotranspiration (PET), but with stronger magnitude for both variables (PET and precipitation) compared with the Kiruhura areas.

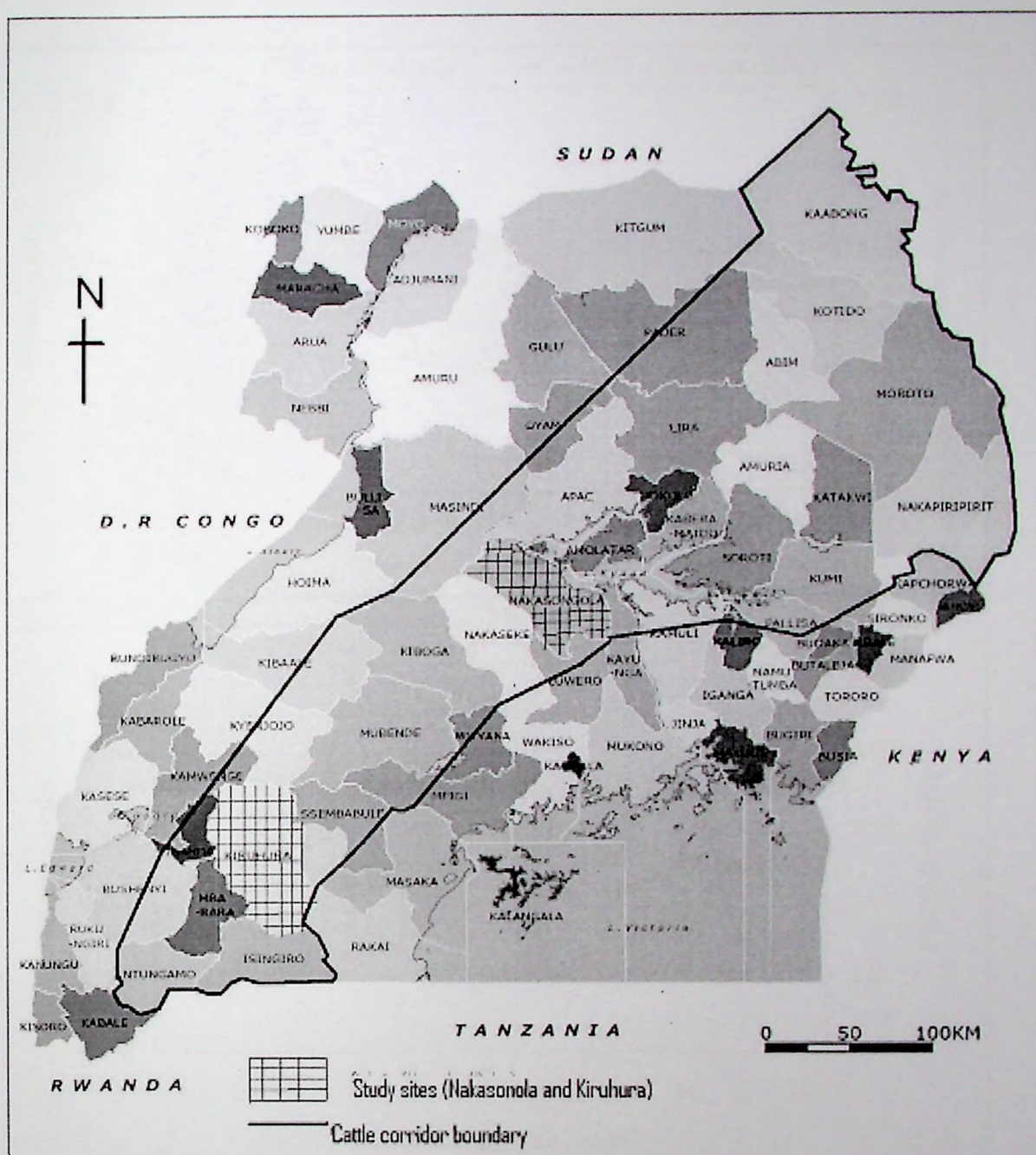


Figure 2: Approximate location of the study sites in the cattle corridor.

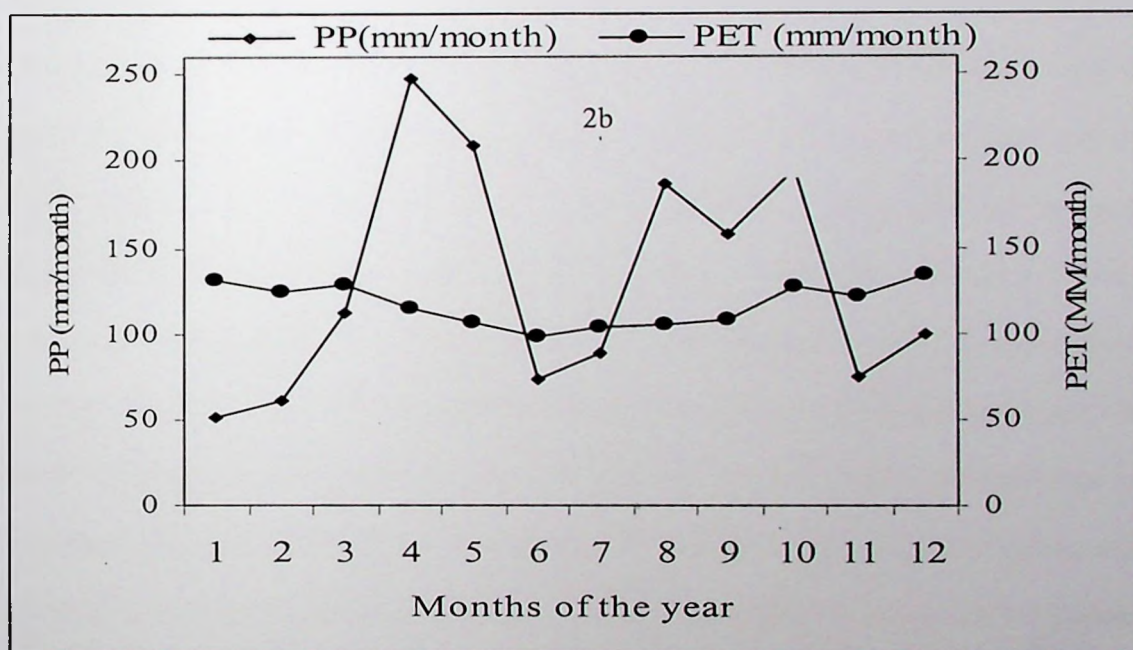
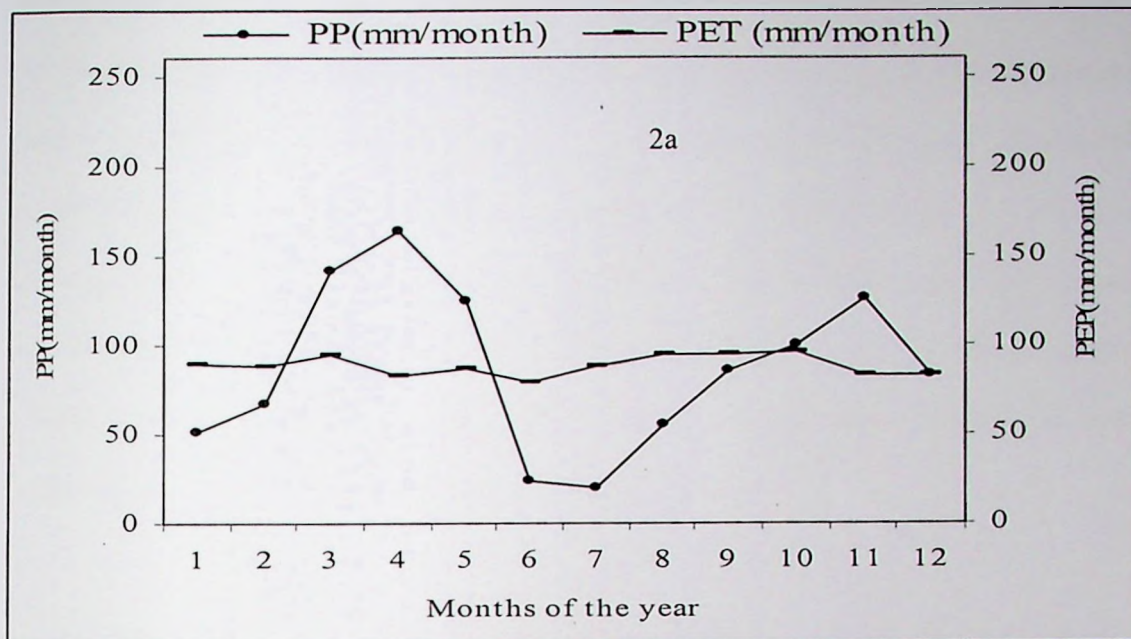


Figure 3: Precipitation and potential evapotranspiration in the two study sites 2a (*Kiruhura*) and 2b (*Nakasongola*). PET is for Potential Evapotranspiration and PP is for precipitation. Source: Hailelassie *et al.*, 2008

### 3.2.2 Vegetation

The natural vegetation in *Nakasongola* is dominantly open savannah woodland with tall grasses. Major woody species in *Nakasongola* include: *Combretum terminalis*, *Acacia brevispica*, *Canthium lactescens*, *Grevia mollis*, *Teclea nobilis* and *Vernonia brachycalyx* and the dominant grass species is *Hyparrhenia rufa*. (NEMA, 1996). In *Kiruhura* area, grass land dominates: the woody vegetations are mainly composed of different acacia species and grass species include *Themeda triandra*, guinea grass (*Panicum maximum*), Signal grass (*Brachiaria spp*), Rhodes grass (*Chloris gayana*) Dog's tail (*Setaria anceps*).

### 3.2.3 Soils

The soils in *Nakasongola* are relatively homogeneous and dominated by strongly weathered soils with high sesquioxide content (*Haplic Ferralsols*) (FAO, 1988). Those soil units are located on slope ranging between 5-8% of the plain landscape units. These soils are not suitable for permanent cultivation unless combined with the traditional fallowing techniques to restore basic cations and reduce acidity. Another major soil unit in *Nakasongola* study site is the *Fluvisols* and *Dystic Fluvisols* formed from undifferentiated and unconsolidated sediments on 0-2% slope around Lake Kyoga and Kwania. Unlike the *Nakasongola* sites soil at *Kiruhura* are relatively heterogeneous and composed of young and also highly weathered old *Plinthic* and *Haplic Ferral soils* and *Eutric* and *Lithic Leptosols*. Around Lake Mburo, *Histosols* has important area coverage (slope 0-2%, swampy vegetation). Similar to the *Nakasongola*, the *Plinthic* and *Haplic Ferral soils* in the *Kiruhura* area are not suitable for permanent cultivation, but the presence of younger soil units like the *Leptosols* and patchily distributed *Nitosols* have created opportunity for settled farming practices in this area.

### 3.2.4 Production systems and livelihood strategies in Nakasongola and Kiruhura

The *Nakasongola* study sites is grouped to the Banana-Millet-Cotton system of central Uganda, while the *Kiruhura* site belongs to the pastoral and annual crops systems of the North eastern and Mabarara areas (Mwebaze, 2008). Community in the *Kiruhura* produce crops such as Banana (*Musa acuminata*), cassava (*Manihot esculenta*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), sweet potatoes (*Ipomea batatas*), ground nuts, (*Pennisetum glaucum*). Similar cropping patterns were observed for the *Nakasongola* study sites except the production of cotton (*Gossypium hirsutum*) and productivity differences between the two sites. Crop production is less important and farmers are more focused on livestock intensification in *Kiruhura*. Farmers in both study areas manage different livestock groups: cattle (e.g. *Bos indicus* and *Bos Taurus*), sheep (*Ovis aries*), goat (*Capra hircus*), and swine (*Sus scrofa*) poultry (*Gallus domesticus*).

### 3.3 Selection of sites and valley tanks used in the study

Livestock production systems are continually evolving in the rangeland pastoral communities of Uganda. Apparent differences in the degree of intensification of livestock management exist, which appear to come as the result of decreased land sizes and contrastingly increased livestock populations. Study sites were therefore selected basing on three production systems recognized in the pastoral communities of Uganda. Nyakahita parish, Kiruhura district was selected to represent the settled pastoral community in the cattle corridor. Here, farmers have intensified livestock production through fencing of their pasture land, provision of water on own pasture land, introduction of crossbreds cows into their herd and uprooting invasive weed species from pasture lands. On the other hand, Migyera and Wanzogi parishes, Nakasongola district were selected to represent the non-settled and semi-settled pastoral communities respectively. Here, no

communal ownership of some resources especially watering points is still practiced, watering points are sparsely distributed and seasonal movements in search of water is common during dry seasons, although more frequent in non-settled system. In all the three production systems (settled, semi-settled and non-settled), integration of crops into livestock systems is emerging.

The general principle followed in the selection of valley tanks was that big water reservoirs constructed in small catchments often can not get filled up with water to full capacity (Albergel *et al.*, 2004). Only valley tanks constructed in catchments big enough to collect enough water to fill them were selected.

### **3.4 Study one: Effects of upper catchment management on the quality and quantity of water in surface reservoirs**

#### **3.4.1 Treatments**

Eight valley tanks were selected based on how they receive water from the upper catchment; supplied with water from un-vegetated catchment, vegetated catchment, open gullies/channels and vegetated gullies/channels. The valley tanks were monitored for water quality and quantity over a period of one year (November 2006 - October 2007) covering two dry and two wet seasons.

#### **3.4.2 Measurement of reservoir volume**

A concrete block tied on a calibrated rope (sounding lead) was used to establish the depth profile of the valley tanks, using a small wooden boat. Ropes were tied at a distance of 10 meters across the width of valley tanks. The depth of valley tanks was measured at 2 meters intervals following

the ropes tied across. The depth profile was then established (Appendix Figure 2 - 7) and the volume of water calculated (Appendix Table 1).



*Plate 1: Sounding lead*



*Plate 2: Taking depth measurements*

*Source: Photos taken by Don Peden, in 2006 during a volume measuring exercise by the researcher*

### **3.4.3 Measurement of Evaporation and Rainfall**

To account for the water lost from the reservoirs, evaporation, precipitation and water taken by animals were measured during the study. A mini weather station was established in which evaporation pan (Class A) and a rain gauge were installed. These were used to measure evaporation (mm) and precipitation (mm) respectively. The Class A evaporation pan has a cylindrical design, 25.4 cm and 120.7 cm in diameter. The bottom of the pan was supported 5 cm above the ground level on an open-frame wooden platform. The pan was filled to 5 cm below the rim (this was taken as the reference level). The level of water in the pan was measured by means of a fixed – point gauge every day between 8: 00 am – 9:00 am. The pan was refilled whenever the water level, as indicated by the gauge, dropped by more than 2.5 cm from the reference level. A standard rain gauge, measuring 5 inch diameter and 12 inch from ground level was used to measure rainfall.

#### **3.4.4 Measurement of livestock water consumption**

The number of animals drinking from a given valley tank were counted and the volume of water taken by animals was measured by counting the number of 10 liter buckets used to fill water troughs during watering. This was done for a period of seven days in a month for two rain and two dry seasons.

#### **3.4.5 Water quality analysis**

Water samples were collected on a monthly basis, and delivered to the laboratory in an ice box, where they were frozen until analysis was made within 36 hours. Nitrites, nitrates, ammonia, total nitrogen, total phosphorus, total dissolved solids and Turbidity (FAU) were determined using a spectrophotometer (HACH, DR/4000). Total suspended solids (TSS) (mg/L) were determined by filtering water samples on pre washed Whatman GF/F Glass filters, oven drying the collected solids, and weighing them following standard methods of analyzing water and waste water (UNBS, 1998). pH was measured using WTH pH meter LF 90. Total and faecal coliform bacteria levels were determined by the membrane lauryl sulfate broth method (UNBS, 1998) after incubation at 44<sup>0</sup>C for 18 to 24 hours.

### 3.5 Study two: Effects of water cover plants on the quality of water in surface water reservoirs.

#### 3.5.1 Study treatments

Aquatic plants that covered reservoirs by 70% - 100% of the total surface were identified in the study. Eight valley tanks were then selected based on four common aquatic plants covering them; *Azolla sp*, *Lemna sp*, *Pistia sp* and *Nymphaea sp*. All the covered reservoirs selected received water from vegetated catchments and gullies. These reservoirs were monitored for water quality by collecting water samples on a monthly basis, which were analyzed as described in section 3.4.5 above. The quality of water in the covered reservoirs was then compared with that of un-covered tanks, with vegetated catchments and those with un-vegetated catchments.



Plate 3: *Pistia sp*



Plate 4: *Azolla sp*



Plate 5: *Lemna sp*



Plate 6: *Nymphaea sp*

Source: Photos taken by the researcher in 2006

### **3.6 Study three: Effects of upper catchment and water resource management on LWP in rain fed pastoral production systems in the Nile basin**

The beneficial outputs accrued from the management options in the study were fitted into a spreadsheet computation model (Hailelassie *et al.*, 2008) taking into account the Metabolizable Energy (ME) to assess the relative impacts of synchronized land (upper catchment) and water resource management interventions on the magnitude of LWP. LWP was first calculated based on the current status of land and water management practices that were practiced by livestock farmers before research interventions were implemented. This was referred to as the 'base scenario'. In this scenario, consumption of available dry matter (Mugerwa *et al.*, 2008) by livestock was considered with out accounting for the inefficiencies of dry matter uses due to inadequate drinking water supply for livestock.

Dry matter yields of existing crop land (Owoyesigire *et al.*, 2008) and dry matter yield under proper land management (reseeding and manure application) (Mugerwa *et al.*, 2008) were factored into ME balance. Based on the assumptions of Hailelassie *et al.*, (2008), only the ME that is required by livestock to produce different livestock products and services was considered and the land in excess of ME requirement was removed from the system. LWP was then estimated to see the impacts of upper catchment and land management on LWP assuming adequate supply of quality drinking water (Zziwa *et al.*, 2008). Finally a combination of land and water based management interventions were considered to see if integration would affect LWP.

### 3.6.1 Estimation of depleted water

The amount of water used in production of animal feeds greatly exceeds livestock drinking water requirements (Peden, 2007). Therefore, water lost in the process of producing animal feeds (Evapotranspiration) was used to estimate depleted water. The crop coefficient ( $K_c$ ) and the evapotranspiration of the reference crop ( $E_{Po}$ ) approaches were used to estimate evapotranspiration. A pan evapotranspiration correction factor was used to estimate  $E_{Po}$ . Estimation of the Length of Growing Period (LGP) involved the use of New LocClim 1.06 (FAO 2005). Finally, this was factored in to  $E_{Po}$  and ( $K_c$ ) and areas under the different land use to calculate evapotranspiration values for the whole system in our study sites (Appendix, Table 2).

Depleted water ( $m^3$ ) = Water depleted in producing livestock feeds (evapotranspiration).

$$= ET_m \times LGP \times \text{Total area cultivated (m}^2\text{)} \dots \text{Equation 1}$$

Where:  $ET_m$  = Maximum evapotranspiration from crop

$$= \text{Crop factor (} K_c \text{)} \times \text{evapotranspiration of reference crop (mm/day) (} E_{Po} \text{)}$$

LGP = Length of growing period for a particular crop (days)

### 3.6.2 Quantification of Livestock products and services

Only livestock products and services that could be methodologically quantified were used. Manure, milk, meat and traction were considered as the beneficial outputs and services. The household survey data (Owoyesigire *et al.*, 2008), was used to estimate milk yield which was converted to monetary values based on the current market price. Meat production was estimated basing on off take rate, carcass weight and average slaughter age for different livestock species and applied similar procedures to estimate the values of hides and skins. Traction power is a very recently started livestock multiple use strategies in Nakasongola and was fixed on contractual basis of about 1.5 USD  $ha^{-1}$ . The value of manure was estimated by converting the total number

of livestock in the study area to Tropical Livestock Unit (TLU) using a conversion factor of 0.8 for cattle and 0.1 for sheep and goats (FAO, 2002). Dung production was calculated using dry weight daily dung productivity of 3.3 kg day<sup>-1</sup> TLU<sup>-1</sup> for cattle (Haileselassie *et al.*, 2006). In this study only Nitrogen (N), Phosphorus (P) and Potassium (K) and their concentration 1.4% for N, 0.2% for P and 1.8% for K as reported by (Mugerwa *et al.* 2008), were considered. This was finally converted to the fertilizer values using the 2008 market price of NPK (Appendix, Table 3).

$$\text{Beneficial outputs (USD)} = \text{Milk value} + \text{Meat value} + \text{Hides and skins value} + \text{Manure value} + \text{Traction value} \dots\dots\dots \text{Equation 2}$$

$$\text{Milk value (USD)} = \text{Total milk produced (litres)} \times \text{Price/litre of milk}$$

$$\text{Meat Value (USD)} = \text{Meat produced in a year (kgs)} \times \text{price of meat}$$

$$\text{Meat produced per year} = \text{Carcas weight/slaughter age}$$

$$\text{Carcas weight} = (\text{Off take} \times \text{liveweight}) \times 0.58$$

$$\text{Hides and skins value (USD)} = \text{Number of hides and skins} \times \text{price}$$

$$\text{Traction value (USD)} = \text{Number of hectares ploughed by animals} \times \text{cost of digging one hectare}$$

$$\text{Manure value (USD)} = \text{Quantity (kg) of P + N + K in total manure produced} \times \text{price of NPK fertilizer that can give an equivalent amount of N, P, and K nutrients in manure}$$

$$\text{Where total manure produced} = \text{TLU} \times 3.3 \text{ kg manure per day}$$

$$\text{Amount of nutrients in manure are given by} = 1.4\% \text{ N, } 0.2\% \text{ P and } 1.8\% \text{ K}$$

Therefore;

$$\begin{aligned} \text{Livestock water productivity (LWP)} &= \text{Beneficial output/Depleted water} \\ &= \text{Equation 1/Equation 2} \end{aligned}$$

### 3.6.3 The metabolizable energy (ME) concept

ME was estimated using the crude protein (CP) and acid detergent fiber (ADF) of the feed in the study areas (Mugerwa *et al.*, 2008) using the formula:

$$ME (MJ / kg) = 14.3 + 0.017 CP - 0.019 ADF$$

Energy used for maintenance was estimated as the minimal requirements of energy to maintain the animal (Fasting Metabolism -FM)

$$FM (MJ / day) = 5.67 + 0.061 W \quad W \text{ is live weight of animals in kg.}$$

The net energy requirements for gains (Eg) and the energy content of that gain are the products of the live weight of gain (LWG) and its energy value (EVg). For cattle the energy values of gain is related to the live weight in kg (W and energy stored in MJ (Eg) and was estimated as:

$$Eg = \frac{LWG (6.28 + 0.0188 W)}{1 - 0.3 LWG} MJ / day \quad \text{Weight gain of } 0.38 \text{ kg day}^{-1} \text{ was assumed.}$$

To estimate the energy requirement for milk production, the current values of milk production (4 liters for local Ankole and 6 liters for crossbred cows) were used. This was converted to weight bases using 1.03 g/lit of milk density. The total milk produced in the areas was estimated using the survey results (6 months of lactation period for Ankole and 8 months of lactation period for cross breed cows) by Owoyesigire *et al.*, 2008.

$$MI (MJ) = 1.61 EVI$$

MI is energy for production of milk while EVI its energy value which was calculated assuming butterfat content of 36g/kg and solid-not-fat content of 86g/kg.

Maintenance Energy (FM) + Weight gain Energy (Eg) + Milk Energy (ML) = Total Energy requirements.

### 3.7 Data analysis

Data collected on effects of upper catchment management and water cover plants on the quality of water were subjected to analysis of variance using the General Linear Model procedure of SAS (1989) and standard errors of the mean were used to separate means. Season was factored in the model to establish the effects of the treatments in different seasons and establish the interaction between season and treatments.

$$1. Y_{ij} = \text{Season}_i + \text{Upper catchment mgt}_j + \text{Season} \times \text{Upper catchment mgt} + e_{ij}$$

Where:  $Y_{ij}$  = dependent variable

$\text{Season}_i = i^{\text{th}}$  season effect

$\text{Upper catchment mgt}_j = j^{\text{th}}$  upper catchment management treatment

$\text{Season} \times \text{Upper catchment mgt}$  = interaction of season and upper catchment management treatment

$e_{ij}$  = random error

$$2. Y_{ij} = \text{Season}_i + \text{water cover plant}_j + \text{Season} \times \text{water cover plant} + e_{ij}$$

Where:  $Y_{ij}$  = dependent variable

$\text{Season}_i = i^{\text{th}}$  season effect

$\text{Water cover plant}_j = j^{\text{th}}$  water cover plant treatment

$\text{Season} \times \text{water cover plant}$  = interaction of season and water cover plant treatment

$e_{ij}$  = random error

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### 4.1 Study one: Effects of upper catchment management on the quality and quantity of water in surface reservoirs

##### 4.1.1 Effects on water availability (quantity) throughout the year

Figure 4 shows monthly variation of rainfall and evaporation of water from the water surface over the study period. The amount of water in reservoirs varied with rainfall pattern, getting to full capacity in rain seasons and declining in the dry seasons (Table 1). Annual evaporative loss from reservoirs, volume of silt deposited (sedimentation) and annual livestock water consumption from reservoirs are presented in Figure 5. Annual precipitation was higher than annual evaporation. However, evaporation was higher than precipitation in dry seasons. Reservoirs receiving water from un-vegetated upper catchments experienced high rates of sedimentation ( $250 \text{ m}^3$  in a year) and water degradation ( $47 \text{ m}^3$  in dry season) compared to reservoirs receiving water from vegetated catchments and gullies.

Rainfall is the major source of water that fills surface reservoirs in the pastoral communities of Uganda. The amount of water in reservoirs varies with rainfall amounts received, evaporation and livestock water consumption. Although evaporation increases with surface area (Ferhat and Ozhan 2006), high TDS and TSS concentrations in reservoirs with un-vegetated catchments and open gullies (Table 2) also increases evaporation rates due to increased heat conduction. This could possibly explain the fast rate of reduction in water level in the reservoirs with high levels of TDS and TSS (reservoirs with un-vegetated catchments and open gullies).

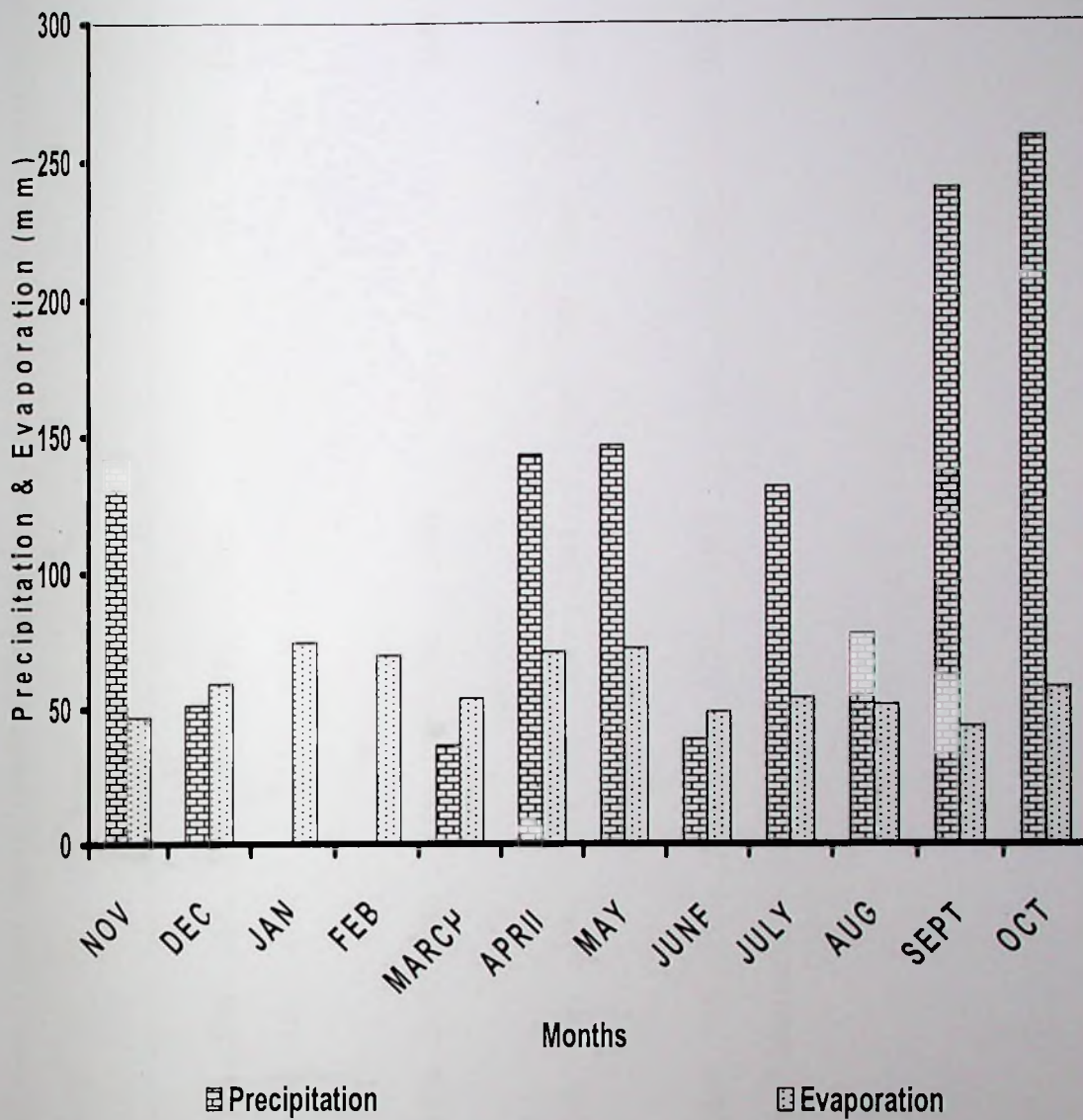


Figure 4: Variation of monthly rainfall and water evaporation

Table 1: Changes in volume of water in reservoirs (m<sup>3</sup>) under different upper catchment management practices for a period of one year (Nov. 2006 – Oct. 2007)

| Months                 | Nov  | Dec  | Jan  | Feb  | Mar  | Apr  | May  | Jun  | Jul  | Aug  | Sep  | Oct  |
|------------------------|------|------|------|------|------|------|------|------|------|------|------|------|
| Un-vegetated Catchment | 1380 | 361  | 47*  | -    | 736  | 1140 | 1140 | 979  | 709  | 756  | 1130 | 1130 |
| Vegetated Catchment    | 2650 | 2040 | 1490 | 1330 | 1890 | 2000 | 2090 | 1620 | 1790 | 1490 | 1970 | 2630 |
| Un-vegetated gully     | 358  | 306  | 156  | 124  | 211  | 294  | 342  | 221  | 301  | 162  | 340  | 340  |
| Vegetated gully        | 1860 | 1530 | 1170 | 591  | 265  | 529  | 1860 | 1610 | 1060 | 589  | 1390 | 1850 |

*Bold text indicates full capacity of valley tanks, \* indicates degraded water*

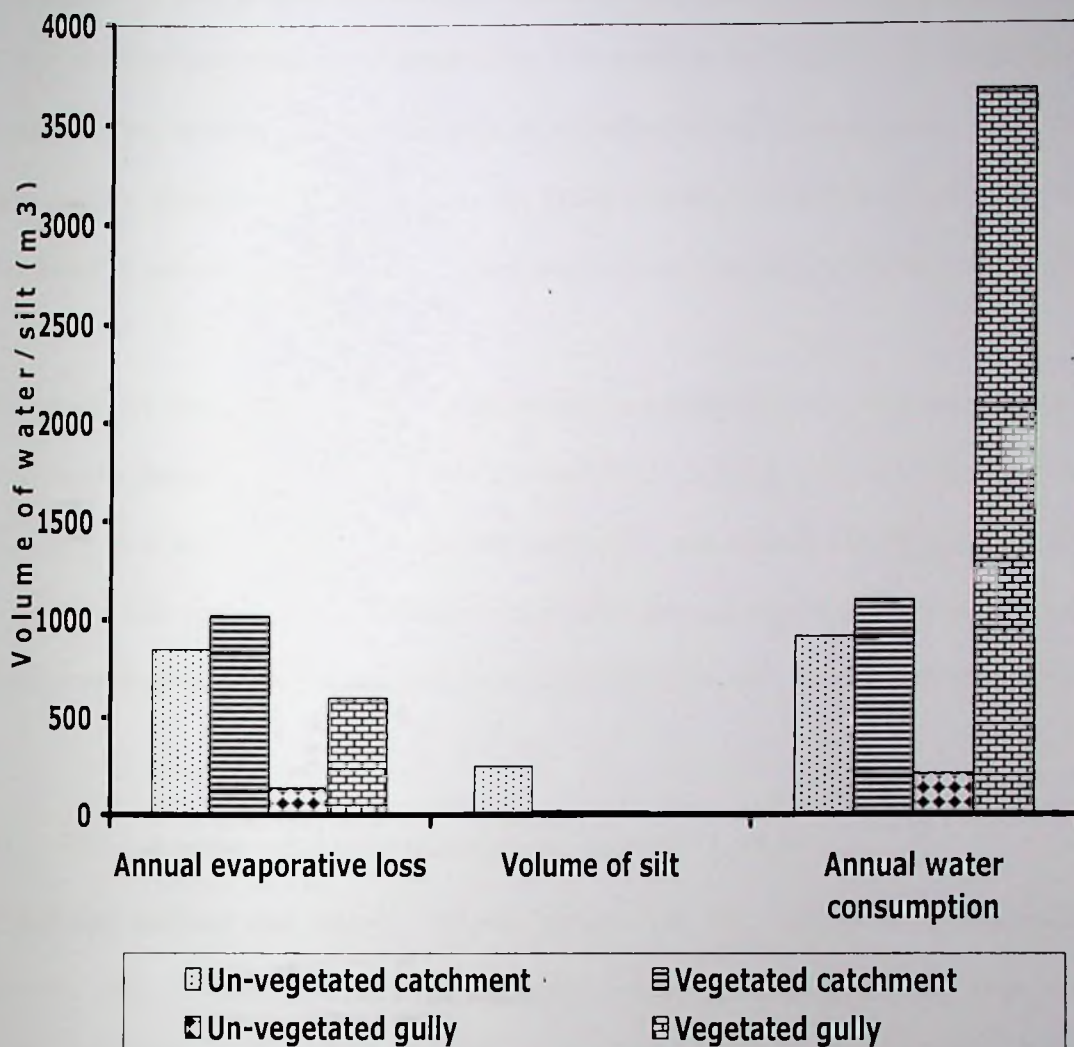


Figure 5: Water depletion in reservoirs under different upper catchment practices

The presence of bare ground in the upper catchment and open gullies increase runoff speed and erosion resulting into reservoir sedimentation. This explains the high rates of sedimentation and reduction in the capacity of reservoirs with un-vegetated catchments and gullies. The runoff also takes manure deposited by animals in the upper catchments into reservoirs which further increases TSS and turbidity of water in reservoirs with un-vegetated catchments and gullies.

The amount of water in reservoirs at full capacity is ideally enough to sustain livestock water requirements throughout the year (Table 1), but this is not usually the case as water shortages may occur within a short period from the end of the rain season. This therefore implies that other water loss processes; particularly evaporation and degradation cause significant water losses from reservoirs, and greatly limit the availability of water to livestock throughout the year.

#### **4.1.2 Effect of upper catchment management on water quality**

Overall data indicate that  $\text{NH}_4\text{-N}$ ,  $\text{NO}_2\text{-N}$ ,  $\text{NO}_3\text{-N}$ , TN, TP, TDS, TSS and turbidity were generally high in reservoirs with un-vegetated catchments and lowest in reservoirs with vegetated catchments. Significant differences were recorded between treatments and seasons. Reservoirs receiving water from open gullies had significantly high levels of Total coliform, Faecal coliform,  $\text{NH}_4\text{-N}$  and Total phosphorus ( $p < 0.001$ ) in both seasons, while reservoirs with un-vegetated catchments had significantly higher concentrations of  $\text{NO}_2\text{-N}$ ,  $\text{NO}_3\text{-N}$ , TN, Total Dissolved Solutes (TDS), Total Suspended Solids (TSS) and turbidity ( $p < 0.001$ ) (Table 2).

Table 2: Effects of upper catchment management on water quality

| Season                    | Treatment              | Parameters |       |                              |                              |                              |       |       |       |       |           |       |
|---------------------------|------------------------|------------|-------|------------------------------|------------------------------|------------------------------|-------|-------|-------|-------|-----------|-------|
|                           |                        | TC         | FC    | NH <sub>4</sub> <sup>+</sup> | NO <sub>2</sub> <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | TN    | TP    | TDS   | TSS   | Turbidity | pH    |
| Dry                       | Open gully             | 5771       | 1229  | 1.933                        | 0.024                        | 0.034                        | 3.598 | 1.07  | 29    | 85    | 74        | 6.95  |
|                           | Un-vegetated Catchment | 3569       | 810   | 1.323                        | 0.057                        | 0.054                        | 4.344 | 0.745 | 68    | 81    | 73        | 6.64  |
|                           | Vegetated Catchment    | 1405       | 618   | 0.658                        | 0.03                         | 0.065                        | 2.142 | 0.254 | 49    | 25    | 22        | 6.61  |
|                           | Vegetated gully        | 353        | 123   | 0.415                        | 0.029                        | 0.098                        | 1.735 | 0.278 | 38    | 34    | 20        | 6.51  |
| Rain                      | Open gully             | 5100       | 600   | 1.398                        | 0.019                        | 0.033                        | 2.528 | 1.537 | 40    | 54    | 40        | 6.71  |
|                           | Un-vegetated Catchment | 1256       | 643   | 2.422                        | 0.151                        | 0.101                        | 4.169 | 0.836 | 67    | 133   | 115       | 6.59  |
|                           | Vegetated Catchment    | 887        | 81    | 0.713                        | 0.08                         | 0.18                         | 2.054 | 0.268 | 50    | 35    | 21        | 6.59  |
|                           | Vegetated gully        | 128        | 24    | 1.148                        | 0.079                        | 0.247                        | 1.892 | 0.668 | 40    | 38    | 21        | 6.54  |
| SE                        |                        | 401        | 236   | 0.294                        | 0.015                        | 0.018                        | 0.429 | 0.263 | 5     | 10    | 9         | 0.135 |
| Significance (p - values) |                        |            |       |                              |                              |                              |       |       |       |       |           |       |
| Season                    |                        | 0.001      | 0.05  | 0.086                        | 0.001                        | 0.001                        | 0.302 | 0.17  | 0.292 | 0.177 | 0.785     | 0.418 |
| Treatment                 |                        | 0.001      | 0.002 | 0.001                        | 0.001                        | 0.001                        | 0.001 | 0.001 | 0.001 | 0.001 | 0.001     | 0.101 |
| Season*Treatment          |                        | 0.034      | 0.540 | 0.023                        | 0.001                        | 0.001                        | 0.446 | 0.743 | 0.5   | 0.001 | 0.001     | 0.716 |

TC and FC (counts/100ml), NH<sub>4</sub><sup>+</sup>, NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, TN, TP, TDS and TSS (mg/L), turbidity (FAU)

Total Coliform and fecal Coliform concentration were significantly high ( $p < 0.001$  and  $p < 0.05$  respectively) in the dry season, with highest concentrations in reservoirs filled with water from open gullies (Table 2).  $\text{NH}_4\text{-N}$ ,  $\text{NO}_2\text{-N}$ , TSS and turbidity were significantly high in the rain season in reservoirs with un-vegetated catchments, while  $\text{NO}_3\text{-N}$  were significantly high in reservoirs with vegetated gullies in the rain season. Nutrient concentrations were below the recommended maximum levels of intake for livestock in all seasons. However, coliform counts were above the recommended maximum intake in all treatments in the dry season but lower in the rain season in reservoirs with vegetated catchments and gullies. This therefore implies that animals (especially calves) drinking water from reservoirs with un-vegetated catchments and gullies have a high risk of contracting scours and coccidiosis which leads to bloody diarrhoea, dehydration, weight loss, depression, and sometimes death (ANZECC, 2000; PFRA, 2003).

Runoff from bare patches of ground and the sediments it carries introduce nutrients and manure into water reservoirs from the un-vegetated upper catchments and open gullies. This greatly increases total coliforms, faecal coliforms,  $\text{NH}_4\text{-N}$ ,  $\text{NO}_2\text{-N}$ ,  $\text{NO}_3\text{-N}$ , TN, TP, TDS, TSS, and turbidity as compared to reservoirs receiving water from vegetated catchments and gullies. The deposited sediments and manure increase also impart an awful smell in water. This explains the farmers' observation that animals reject water in reservoirs with un-vegetated catchments as the dry season progresses due to bad smell of water.

The presence of vegetation in upper catchments stabilizes the soil, increases water infiltration, and reduces storm water velocity, thereby reducing soil erosion, manure and nutrient deposition, and reservoir sedimentation. Therefore, vegetation slow run-off and reduces its ability to carry sediments and pollutants into water reservoirs (Kenneth, 1997). Vegetated gullies catch runoff

and sediments flowing from upper catchments and trap them before they enter water reservoirs. Vegetation also increases water quality through its functioning as sponges absorbing and filtering out sediments and nutrients from runoff. Well vegetated upper catchments and gullies were therefore critical in improving the quality of water in reservoirs. This is consistent with earlier studies which showed that maintaining good plant cover in upper catchments and gullies is one of the most effective ways to reduce the amount of siltation and keeping nutrients out of reservoirs (Streamlines, 1998; Rodriguez-Iturbe, 2000; Simmons, 2004).

#### 4.2 Study two: Effects of water cover plants on the quality of water in surface

##### Reservoirs

Four common water cover plants were identified in the rangeland pastoral communities of Uganda; *Azolla spp*, *Lemna spp*, *Nymphaea spp* and *Pistia spp*. These plants were found covering water reservoirs up to 70% - 100 % of the total surface, and farmers had different experiences with them, particularly *Azolla spp* which was reported to limit livestock water intake or even causing total rejection of water due to a foul smell imparted to water.

Table 3 shows that reservoirs covered by *Nymphaea spp* had significantly higher concentrations of nitrite, total nitrogen, TDS, TSS and turbidity ( $p < 0.001$ ) in the dry season. *Azolla spp* had a significantly high ( $p < 0.001$ ) TC concentrations in the dry season, while *Lemna spp* had a significantly high ( $p < 0.001$ ) nitrate concentrations in the rain season. Nitrite and nitrate concentrations were significantly high in the rain season in valley tanks covered by *Nymphaea spp* and *Lemna spp* respectively.

Table 3: Effect of water cover plants on water quality

| Season                    | Treatment          | Parameters |       |                              |                              |                              |       |       |       |       |           |       |
|---------------------------|--------------------|------------|-------|------------------------------|------------------------------|------------------------------|-------|-------|-------|-------|-----------|-------|
|                           |                    | TC         | FC    | NH <sub>4</sub> <sup>+</sup> | NO <sub>2</sub> <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | TN    | TP    | TDS   | TSS   | Turbidity | pH    |
| Dry                       | <i>Azolla sp</i>   | 4474       | 566   | 1.39                         | 0.049                        | 0.087                        | 2.68  | 0.7   | 13    | 72    | 67        | 6.75  |
|                           | <i>Lemna sp</i>    | 256        | 95    | 0.357                        | 0.026                        | 0.102                        | 1.74  | 0.251 | 38    | 34    | 20        | 6.59  |
|                           | <i>Nymphaea sp</i> | 4161       | 915   | 2.113                        | 0.138                        | 0.17                         | 6.18  | 0.975 | 53    | 96    | 76        | 6.84  |
|                           | <i>Pistia sp</i>   | 2986       | 588   | 1.647                        | 0.027                        | 0.073                        | 2.93  | 1.056 | 17    | 64    | 59        | 6.76  |
| Rain                      | <i>Azolla sp</i>   | 4312       | 252   | 1.119                        | 0.041                        | 0.076                        | 1.83  | 1.272 | 18    | 63    | 80        | 6.61  |
|                           | <i>Lemna sp</i>    | 173        | 29    | 1.146                        | 0.079                        | 0.25                         | 1.89  | 0.67  | 40    | 38    | 21        | 6.50  |
|                           | <i>Nymphaea sp</i> | 4152       | 840   | 1.982                        | 0.269                        | 0.175                        | 4.44  | 1.747 | 45    | 72    | 107       | 6.85  |
|                           | <i>Pistia sp</i>   | 2920       | 644   | 1.159                        | 0.027                        | 0.082                        | 2.17  | 1.981 | 24    | 51    | 44        | 6.63  |
| SE                        |                    | 313        | 163   | 0.45                         | 0.017                        | 0.018                        | 0.63  | 0.443 | 4     | 9     | 11        | 0.169 |
| Significance (p - values) |                    |            |       |                              |                              |                              |       |       |       |       |           |       |
| Season                    |                    | 0.699      | 0.356 | 0.93                         | 0.001                        | 0.003                        | 0.057 | 0.026 | 0.503 | 0.059 | 0.304     | 0.404 |
| Treatment                 |                    | 0.001      | 0.001 | 0.03                         | 0.001                        | 0.001                        | 0.001 | 0.063 | 0.001 | 0.001 | 0.001     | 0.321 |
| Season*Treatment          |                    | 0.995      | 0.67  | 0.44                         | 0.001                        | 0.001                        | 0.454 | 0.931 | 0.170 | 0.353 | 0.196     | 0.958 |

TC and FC (counts/100ml), NH<sub>4</sub><sup>+</sup>, NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, TN, TP, TDS and TSS (mg/L), turbidity (FAU).

Nitrogen enters water in particulate and dissolved organic and inorganic forms. Numerous biological and physical processes transform nitrogen between various forms. Ammonification, nitrification and denitrification are the major nitrogen transformation processes (Kyambadde, 2005). The presence of high levels of ammonium, total nitrogen and total phosphorus in reservoirs covered by *Nymphaea spp.* and *Pistia spp.* would be explained by the fact that *Nymphaea spp.* and *Pistia spp.* are large aquatic macrophytes, with high root and shoot biomass production, which upon death and decomposition releases a lot of  $\text{NH}_4\text{-N}$  and phosphorus (Sabine *et al.*, 2003; Lynch, 2006).

*Azolla spp.* and *Pistia spp.* form a dense mat cover on water surfaces which creates anaerobic conditions. This reduces nitrification, and result into lower levels of nitrites and nitrates in reservoirs covered by these plants compared to reservoirs covered by *Nymphaea spp.* and *Lemna spp.* The anaerobic conditions created *Azolla spp.* and *Pistia spp.* also favors the proliferation of anaerobic microbes, thus the high bacterial concentrations than in reservoirs covered by *Lemna spp.* and *Nymphaea spp.* *Azolla spp.* is also known to live symbiotically with a cyanobacterium *Anabaena azollea* (Mandal *et al.*, 1998; Hove and Lejeune, 2006; Sitnykov, 2006). This therefore explains the high concentrations of coliforms in reservoirs covered by *Azolla spp.*

#### 4.2.1 Comparison between the quality of water in covered and un-covered reservoirs

Table 4 shows that the quality of water in reservoirs with un-vegetated catchments is greatly impaired compared to reservoirs with vegetated catchments (un-covered or covered with different plants). Reservoirs covered by different plants had higher concentrations of nitrites, nitrates and total nitrogen but a lower total dissolved solutes compared to un-covered reservoirs with vegetated catchments.

Table 4: Comparison of water quality in covered and un-covered reservoirs

| Reservoir type | Treatment              | Parameters |     |                              |                              |                              |       |       |      |      |           |       |
|----------------|------------------------|------------|-----|------------------------------|------------------------------|------------------------------|-------|-------|------|------|-----------|-------|
|                |                        | TC         | FC  | NH <sub>4</sub> <sup>+</sup> | NO <sub>2</sub> <sup>-</sup> | NO <sub>3</sub> <sup>-</sup> | TN    | TP    | TDS  | TSS  | Turbidity | pH    |
| Un-covered     | Vegetated catchment    | 5312       | 248 | 1.24                         | 0.02                         | 0.05                         | 0.93  | 1.64  | 42.5 | 35   | 40.5      | 6.88  |
|                | and gully              |            |     |                              |                              |                              |       |       |      |      |           |       |
| Un-covered     | Un-vegetated catchment | 6828       | 656 | 4.41                         | 0.28                         | 1.04                         | 7.75  | 1.84  | 36.5 | 107  | 189       | 6.60  |
|                | and gully              |            |     |                              |                              |                              |       |       |      |      |           |       |
| Covered        | Lemna spp              | 215        | 62  | 0.752                        | 0.053                        | 0.176                        | 1.815 | 0.461 | 39   | 36   | 20.5      | 6.55  |
|                | Azolla spp             | 4393       | 409 | 1.255                        | 0.045                        | 0.082                        | 2.255 | 0.986 | 15.5 | 67.5 | 73.5      | 6.68  |
|                | Pistia spp             | 2953       | 616 | 1.403                        | 0.027                        | 0.078                        | 2.55  | 1.52  | 20.5 | 57.5 | 51.5      | 6.7   |
|                | Nymphaea spp           | 4157       | 878 | 2.048                        | 0.204                        | 0.173                        | 5.31  | 1.361 | 49   | 84   | 91.5      | 6.845 |

TC and FC (counts/100ml), NH<sub>4</sub><sup>+</sup>, NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, TN, TP, TDS and TSS (mg/L), turbidity (FAU)

Only reservoirs covered by *Lemna* had lower concentrations of total suspended solids, turbidity, total coliform and faecal coliform counts than un-covered reservoirs with vegetated catchments. However, with the exception of coliforms, all reservoirs had acceptable nutrient concentrations for livestock water consumption (Grant, 1996; ANZECC, 2000; Waldner and Looper, 2002; Patterson, 2004 a).

*Lemna spp* presents a high surface area over which sediments are adsorbed. This significantly reduces the concentration of total suspended solids and turbidity as compared to other cover plants. The results of this study are supported by earlier studies in which *Lemna sp* was efficient in treatment of waste water (Sabine, 2003; Ran *et al.*, 2004). *Lemna spp* is also known to have high protein content, almost similar to that of soybean (Culley *et al.*, 1981; Becerra *et al.*, 1995; Leng *et al.*, 1995). Therefore, utilization of *Lemna sp* in improving water quality and exploring appropriate harvesting mechanisms for utilization in animal feeding is necessary.

#### **4.3 Study three: Implications of improved upper catchment and water resource management on LWP in rain fed pastoral production systems**

Table 5 represents the LWP variables for different livestock production systems under different upper catchment and water resource management practices in the pastoral rangeland communities of Uganda. Improved upper catchment and water resource management greatly increased LWP in all production systems. Settled communities had high LWP values (0.075, 0.21, 0.122 and 0.34) compared to semi-settled (0.034, 0.19, 0.09 and 0.21) and non-settled communities (0.05, 0.121, 0.08 and 0.19) in the base scenario, under improved catchment management, improved water resource management and under integrated upper catchment and water resource management respectively.

**Table 5: Livestock Water Productivity variables for different production systems in rangeland pastoral communities of Uganda**

$$LWP = \frac{\sum \text{Beneficial output}}{\sum (\text{depleted water} + \text{degraded water})}$$

| Scenario                                       | Production system | Beneficial outputs (USD) | Depleted water (m <sup>3</sup> ) | LWP (USD/m <sup>3</sup> ) |
|------------------------------------------------|-------------------|--------------------------|----------------------------------|---------------------------|
| Base scenario                                  | Settled           | 465,968.2                | 6,248,580                        | 0.075                     |
|                                                | Semi-settled      | 68,897.08                | 2,008,361                        | 0.034                     |
|                                                | Non-settled       | 294,764                  | 5,831,548                        | 0.05                      |
| Improved upper catchment management            | Settled           | 465,968.2                | 2,249,013                        | 0.21                      |
|                                                | Semi-settled      | 460,792.24               | 2,431,012                        | 0.19                      |
|                                                | Non-settled       | 294,763.10               | 2,431,012                        | 0.121                     |
| Improved water management                      | Settled           | 763,786.62               | 6,248,580                        | 0.122                     |
|                                                | Semi-settled      | 578,144                  | 6,248,580                        | 0.09                      |
|                                                | Non-settled       | 476,792.24               | 5,831,548                        | 0.08                      |
| Integrated upper catchment and water resources | Settled           | 763,786.62               | 2,249,013                        | 0.34                      |
|                                                | Semi-settled      | 465,968.2                | 2,249,013                        | 0.21                      |
|                                                | Non-settled       | 460,792.24               | 2,431,012                        | 0.19                      |

Improving upper catchment management increased LWP to 0.21, 0.19 and 0.121 in the settled, semi-settled and non-settled communities respectively where as improving water resource management increased LWP to 0.122, 0.09 and 0.08 in the settled, semi-settled and non-settled communities respectively (Figure 6). Improving upper catchment management therefore increased LWP more than improving water resource management. However, integrated management of water and upper catchment increased LWP greatly (0.34, 0.21 and 0.19 in the settled, semi-settled and non-settled communities respectively) compared to sole management interventions of upper catchment and water resource management (Figure 6).

The results for LWP revealed that settled communities depleted more water in the base scenario than semi-settled and non-settled communities. This is attributed to the extensive pasture production that exists in settled communities. Because of extensive fencing of individual grazing land, farmers in the settled communities keep less livestock numbers so as to avoid pasture scarcity during the dry seasons. This leads to production of excess dry matter, above that consumed by livestock and consequently, this depletes more water compared to systems where almost all the available dry matter is consumed.

As the upper catchment is improved, the amount of water depleted in semi-settled and non-settled communities increase and under integrated upper catchment and water resource management, all systems depleted the same water after factoring out excess land to provide dry matter that is meeting livestock requirements without excess. The beneficial output differs because of differences in livestock numbers, breeds (productivity) and services offered by animals in different production systems. For example, animal draught technology is basically

common in semi-settled systems and thus the higher beneficial outputs in the base scenario compared to other systems where animal power is not utilized.

The settled and semi-settled systems also utilized more of the animal manure in crop production than in the non-settled production systems where little agriculture is practiced. Therefore, a higher monetary value is attached to manure in the settled and semi-settled systems resulting into higher beneficial outputs compared to the non-settled production systems.

The higher LWP values in the settled communities are attributed to the high prevalence of water and pastures in these communities due to fencing of farms and construction of private valley tanks, as opposed to the semi-settled and non-settled communities. Also to note was the fact that settled communities have introduced high producing livestock breeds (Friesian for milk and Boran for beef). This increases livestock products (milk and beef) and thus a high LWP value compared to the semi-settled and non-settled communities where local breeds with very low growth rates, low carcass weight and low milk production predominate.

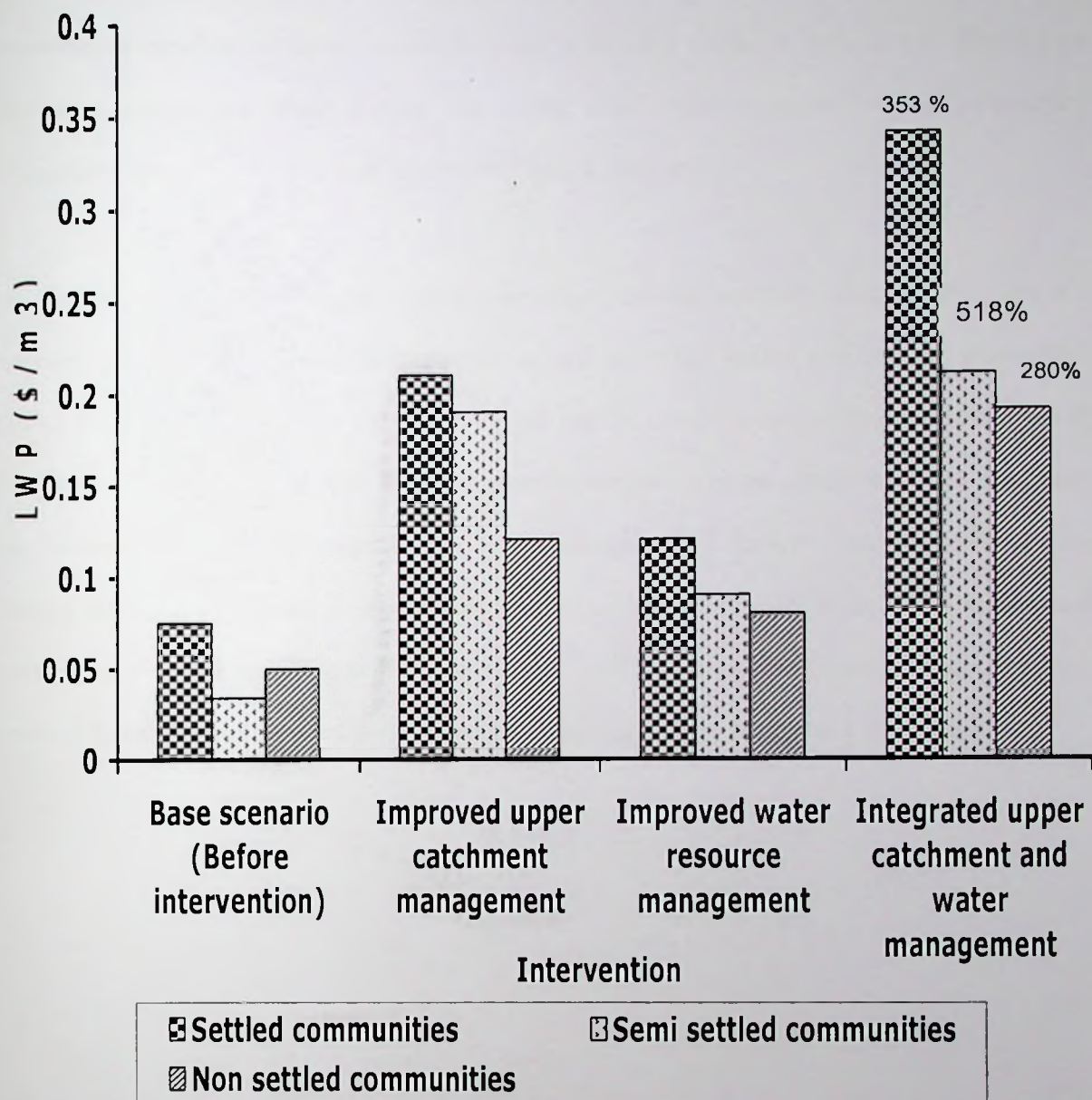


Figure 6: Effect of improved upper catchment and water resource management on LWP in different production systems.

The lower LWP value in the semi-settled communities before intervention was attributed to the low livestock numbers in these communities and little land available for grazing. This lowers livestock products and hence results into a low LWP value compared to the non-settled communities who have a lot of land and high livestock numbers.

Semi-settled communities had the highest percentage increase in LWP value (518%) after the integrated catchment and water management compared to the settled (353%) and non-settled (280%) (Figure 6). This can be explained by the fact that these communities cultivate a lot of crops whose residues have a high feeding value to livestock (sweet potatoes, maize, sorghum, rice, cassava) compared to crops in the settled communities (mostly bananas) whose crop residues, the banana peelings, are not usually utilized in the system since most of the bananas are exported into urban areas, thus limiting residue use for livestock feeding. Therefore, the increased integration of crop residues in livestock feeding greatly improves LWP values.

## CHAPTER FIVE

### CONCLUSION AND RECOMMENDATION

Although the volume of water in reservoirs varied with rainfall, high evaporation, sedimentation of reservoirs and degradation of water quality also prevail in the pastoral communities of Uganda. It can therefore be concluded that rainfall amount is not the only factor limiting the amount of water available in reservoirs to sustain livestock and human needs through dry seasons. It is thus recommended that management practices that reduce evaporation, sedimentation and degradation of water should be utilized to improve the quantity and availability water in pastoral production systems.

Water in reservoirs with un-vegetated upper catchments and open gullies is greatly impaired and the volume of reservoirs is greatly decreased through sedimentation. Proper upper catchment management is therefore a prerequisite for good reservoir water quality.

*Lemna spp*, was observed to have positive effects on the quality of water in reservoirs. The plant reduced the ammonium, total nitrogen, total phosphorus, total suspended solids, turbidity and coliform concentrations in water. Since *Lemna spp* is known to reduce evaporation by 10 to 20% from open water resources (Ramsey *et al.*, 2004), and has the same quantity and array of amino acids as soy beans (Culley *et al.*, 1981; Becarra *et al.*, 1995; Leng *et al.*, 1995), it can be of great importance in reducing evaporative water loss and solve the problem of protein deficiency in pastures if opportunities for harvesting and utilization are identified.

Water from all valley tanks had nutrient concentrations falling below the maximum recommended intake for livestock drinking water. However, only valley tanks receiving water from vegetated catchments and gullies and those covered by *Lemna spp* had faecal coliform counts falling below the recommended concentration (<100) for livestock drinking water (ANZECC, 2000).

- c Improved upper catchment and water resource management would increase livestock water productivity in the pastoral communities of Uganda. It is therefore concluded that a great potential for improving Livestock Water Productivity exists in rainfed pastoral communities.

The conventional approach to water resources management in pastoral communities of Uganda has been to focus on increasing water supply through creation of more surface water resources. However, this study revealed that high evaporation and reservoir sedimentation rates prevail especially under poor upper catchment management practices. Therefore, increasing surface water supply points without sound planning and management of catchments to increase vegetation cover and reduce surface runoff, will only provide a temporally solution to the problem of livestock water availability in the rangeland pastoral communities of Uganda.

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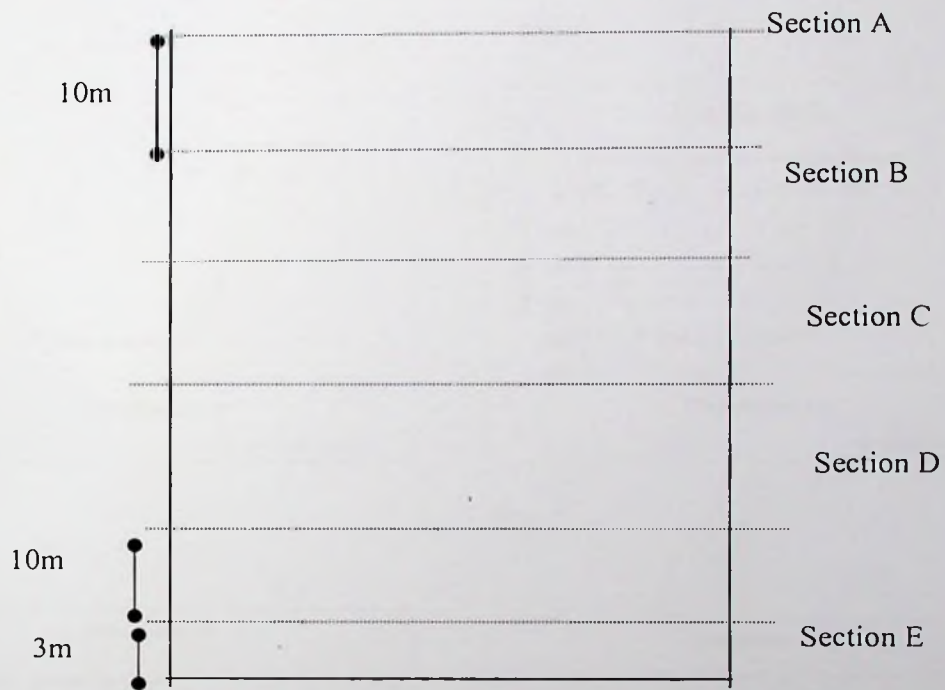
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## APPENDIX

Appendix, Figure 1: Schematic presentation of depth measurement across the width of the valley tank



Appendix, Figure 2 – 7: Establishing the depth profile of valley tanks

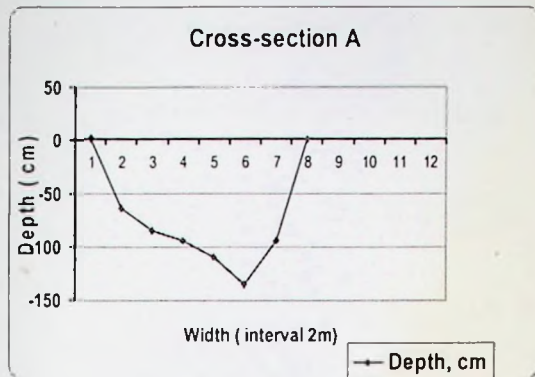


Fig. 2

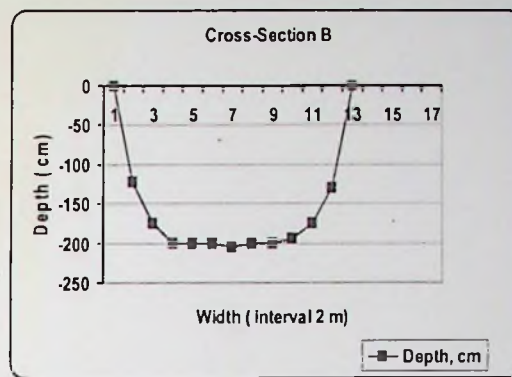


Fig. 3

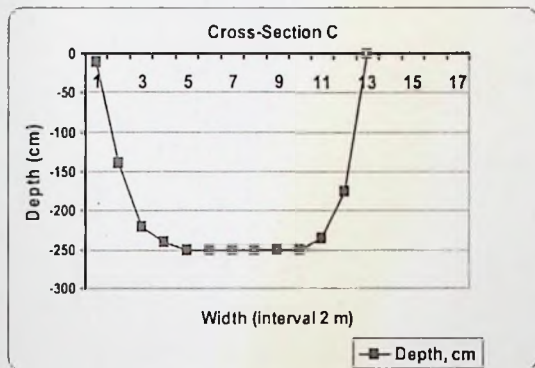


Fig. 4

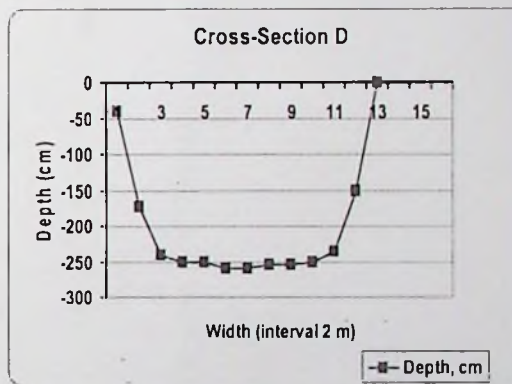


Fig. 5

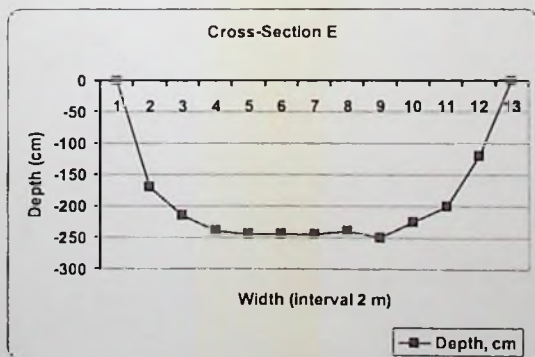


Fig. 6

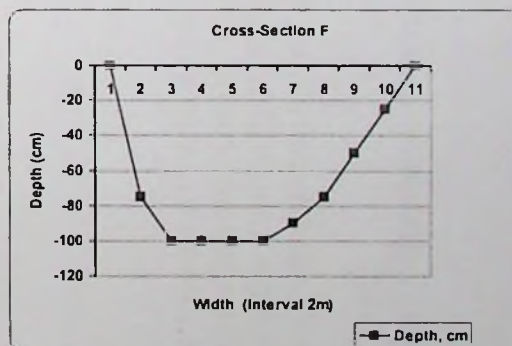


Fig. 7

| Section A |          |                                | Section B |          |                                | Section C |          |                                | Section D |          |                                | Section E |          |                                | Section F |          |                                |
|-----------|----------|--------------------------------|-----------|----------|--------------------------------|-----------|----------|--------------------------------|-----------|----------|--------------------------------|-----------|----------|--------------------------------|-----------|----------|--------------------------------|
| Width, m  | Depth, m | X-section Area, m <sup>2</sup> | Width, m  | Depth, m | X-section Area, m <sup>2</sup> | Width, m  | Depth, m | X-section Area, m <sup>2</sup> | Width, m  | Depth, m | X-section Area, m <sup>2</sup> | Width, m  | Depth, m | X-section Area, m <sup>2</sup> | Width, m  | Depth, m | X-section Area, m <sup>2</sup> |
| 0         | 0        | 0                              | 0         | 0        | 0                              | 0         | 0.12     | 0                              | 0         | 0.4      | 0                              | 0         | 0        | 0                              | 0         | 0        | 0                              |
| 2         | 0.65     | 0.65                           | 2         | 1.23     | 1.23                           | 2         | 1.4      | 1.52                           | 2         | 1.73     | 2.13                           | 2         | 1.7      | 1.7                            | 2         | 0.75     | 0.75                           |
| 4         | 0.85     | 1.5                            | 4         | 1.75     | 2.98                           | 4         | 2.2      | 3.6                            | 4         | 2.4      | 4.13                           | 4         | 2.15     | 3.85                           | 4         | 1        | 1.75                           |
| 6         | 0.95     | 1.8                            | 6         | 2        | 3.75                           | 6         | 2.4      | 4.6                            | 6         | 2.5      | 4.9                            | 6         | 2.4      | 4.55                           | 6         | 1        | 2                              |
| 8         | 1.1      | 2.05                           | 8         | 2        | 4                              | 8         | 2.5      | 4.9                            | 8         | 2.5      | 5                              | 8         | 2.45     | 4.85                           | 8         | 1        | 2                              |
| 10        | 1.35     | 2.45                           | 10        | 2        | 4                              | 10        | 2.5      | 5                              | 10        | 2.6      | 5.1                            | 10        | 2.45     | 4.9                            | 10        | 1        | 2                              |
| 12        | 0.95     | 2.3                            | 12        | 2.05     | 4.05                           | 12        | 2.5      | 5                              | 12        | 2.6      | 5.2                            | 12        | 2.45     | 4.9                            | 12        | 0.9      | 1.9                            |
| 14        | 0        | 0.95                           | 14        | 2        | 4.05                           | 14        | 2.5      | 5                              | 14        | 2.55     | 5.15                           | 14        | 2.4      | 4.85                           | 14        | 0.75     | 1.65                           |
|           |          | 0                              | 16        | 2        | 4                              | 16        | 2.5      | 5                              | 16        | 2.55     | 5.1                            | 16        | 2.5      | 4.9                            | 16        | 0.5      | 1.25                           |
|           |          | 0                              | 18        | 1.95     | 3.95                           | 18        | 2.5      | 5                              | 18        | 2.5      | 5.05                           | 18        | 2.25     | 4.75                           | 18        | 0.25     | 0.75                           |
|           |          | 0                              | 20        | 1.75     | 3.7                            | 20        | 2.35     | 4.85                           | 20        | 2.35     | 4.85                           | 20        | 2        | 4.25                           | 20        | 0        | 0.25                           |
|           |          | 0                              | 22        | 1.3      | 3.05                           | 22        | 1.75     | 4.1                            | 22        | 1.5      | 3.85                           | 22        | 1.2      | 3.2                            |           |          |                                |
|           |          | 11.7                           | 24        | 0        | 1.3                            | 24        | 0        | 1.75                           | 24        | 0        | 1.5                            | 24        | 0        | 0.9                            |           |          |                                |
|           |          |                                |           |          | 0                              |           |          | 0                              |           |          | 0                              |           |          | 47.6                           |           |          | 14.3                           |
|           |          |                                |           |          | 40.06                          |           |          | 50.32                          |           |          | 51.96                          |           |          |                                |           |          |                                |

$$\begin{aligned}
 \text{Volume, m}^3 = & ((\text{cross-section area A+B})/2)*10 + ((\text{section area B+C})/2)*10 \\
 & + ((\text{section area C+D})/2)*10 + \\
 & ((\text{section area D+E})/2)*10 + ((\text{section area E} \\
 & + \text{F})/2)*10 + ((\text{section F+0})/2)*3 = 2,051
 \end{aligned}$$

Appendix, Table 1: Calculation of water volume

Appendix, Table 2: Calculation of the amount of water depleted water in production of animal products and services (a case for pasture production systems)

| Farming system | Pasture land (m <sup>2</sup> ) | Total forage yield (kg/year) | Crop factor (Kc) | Evapotranspiration of reference crop (EPo) | Length of growing period (days) | Depleted water (m <sup>3</sup> ) |
|----------------|--------------------------------|------------------------------|------------------|--------------------------------------------|---------------------------------|----------------------------------|
| Non-settled    | 24,147,197                     | 10,208,200                   | 0.75             | 2.8                                        | 115                             | 5,831,548                        |
| Semi-settled   | 8,316,195                      | 3,242,200                    | 0.75             | 2.8                                        | 115                             | 2,008,361                        |
| Settled        | 2,584,387                      | 20,013,240                   | 0.75             | 3.17                                       | 115                             | 6,248,580                        |

Appendix, Table 3: Calculation of the beneficial livestock outputs

| Farming system | Livestock type | TLU          | Total energy requirement | Milk cost (USD) | Manure value (USD) | Off take rate | Meat value (USD) | Hides & skins (USD) | Traction value (USD) | Total beneficial output |
|----------------|----------------|--------------|--------------------------|-----------------|--------------------|---------------|------------------|---------------------|----------------------|-------------------------|
| Non-settled    | Cattle         | 3,846        |                          | 85,275          |                    | 0.11          | 19,168           | 1,666               | 154                  | 290,669.49              |
|                | Goats          | 39           |                          |                 |                    | 0.37          | 1,969            | 161                 | 0                    | 3,543.87                |
|                | Sheep          | 7            |                          |                 |                    | 0.29          | 275              | 23                  | 0                    | 549.74                  |
| <b>TOTAL</b>   |                | <b>3,892</b> | <b>40,722,768</b>        | <b>85,275</b>   | <b>186,073</b>     |               | <b>21,412</b>    | <b>1,850</b>        | <b>154</b>           | <b>294,763.10</b>       |
| Semi-settled   | Cattle         | 530          |                          | 19,890          |                    | 0.8           | 19,227           | 1,671               | 0                    | 66,221.86               |
|                | Goats          | 27           |                          |                 |                    | 0.37          | 1,389            | 114                 | 0                    | 2,499.94                |
|                | Sheep          | 2            |                          |                 |                    | 0.29          | 88               | 7                   | 0                    | 175.28                  |
| <b>TOTAL</b>   |                | <b>559</b>   | <b>6,116,208</b>         | <b>19,890</b>   | <b>26,512</b>      |               | <b>20,704</b>    | <b>1,892</b>        | <b>0</b>             | <b>68,897.08</b>        |
| Settled        | Cattle         | 5,898        |                          | 111,240         |                    | 0.2           | 53,078           | 4,644               | 0                    | 451,768.52              |
|                | Goats          | 122          |                          |                 |                    | 0.37          | 7,945            | 508                 | 0                    | 12,909.78               |
|                | Sheep          | 14           |                          |                 |                    | 0.29          | 725              | 46                  | 0                    | 1,289.90                |
| <b>TOTAL</b>   |                | <b>6,034</b> | <b>66,020,041</b>        | <b>111,240</b>  | <b>28,772</b>      |               | <b>61,748</b>    | <b>5,298</b>        | <b>0</b>             | <b>465,968.20</b>       |