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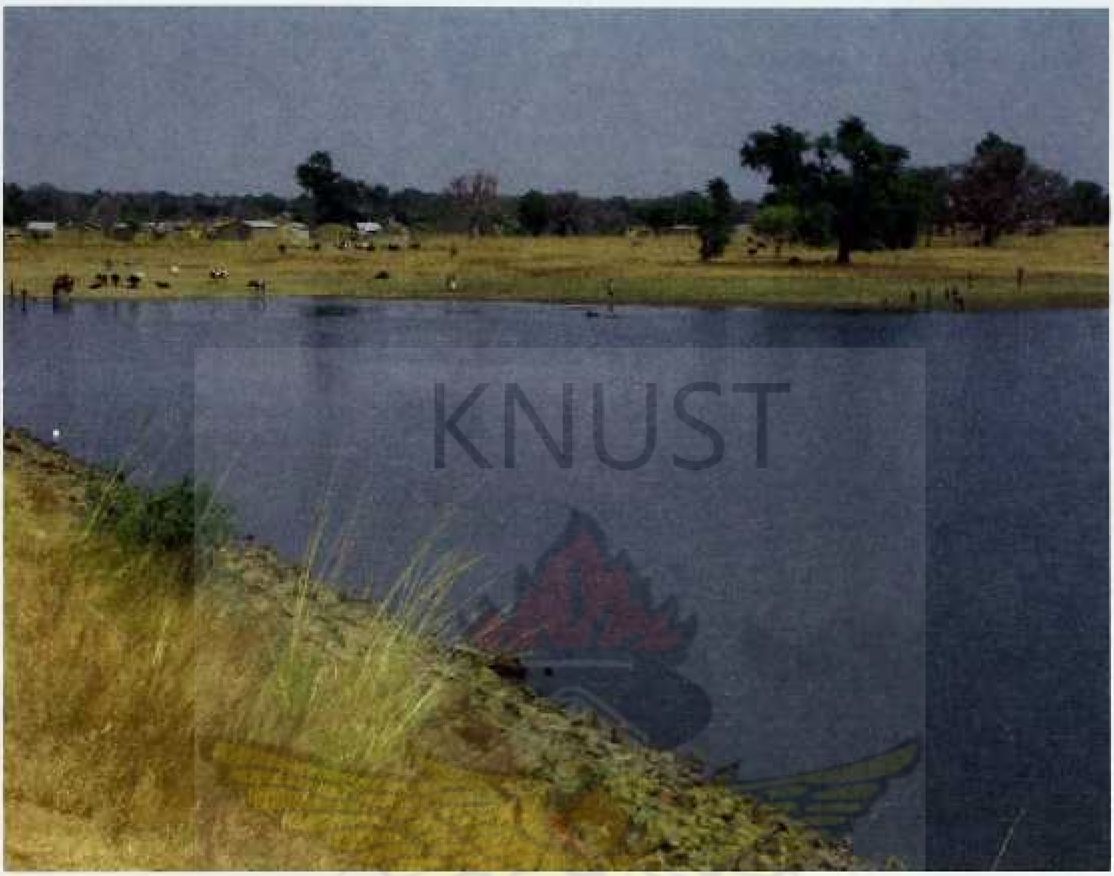

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PRODUCTIVITY OF STORED WATER IN SMALL RESERVOIRS FOR DRY SEASON AGRICULTURE IN THE UPPER EAST REGION OF GHANA

Dwuodwo Yamoah – Antwi

MSc Thesis

February 2009

Kwame Nkrumah University of Science and Technology

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Faculty of Civil and Geomatic Engineering

Department of Civil Engineering

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Master of Science Thesis

By
Dwuodwo Yamoah - Antwi

Supervisors
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Kumasi
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PRODUCTIVITY OF STORED WATER IN SMALL RESERVOIRS FOR DRY SEASON AGRICULTURE IN THE UPPER EAST REGION OF GHANA

By

Dwuodwo Yamoah-Antwi, BSc (Hons.)

KNUST

A Thesis Submitted to the

Department of Civil Engineering

Kwame Nkrumah University of Science and Technology

in partial fulfilment of requirements for the award of the Degree of

MASTER OF SCIENCE

in

Water Resources Engineering and Management

Faculty of Civil and Geomatic Engineering

College of Engineering

February 2009

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Certification

I hereby declare that this submission is my own work towards the Master of Science (MSc) and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text

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Prof. S. I. K. Ampadu 10/05/2009
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Dedication

I dedicate this thesis to my parents, Mr. & Mrs. Antwi, my brothers Fiifi and Paa Kofi, my dear sister Akosua and my lovely Stella for their immense support and sacrifice throughout the period of my study.

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Abstract

The Upper East Region (UER) of Ghana is a water stressed area with the main occupation of the people being agriculture. The importance of small reservoirs for the sustenance of the livelihood of the people in this part of the country during the dry season cannot be over emphasized. Most of these small reservoirs were constructed, in the 1960s, mainly with the aim of providing water for domestic use and livestock watering during the dry periods of the year. Over the years, however, these small reservoirs have been put to a variety of uses such as irrigation and livestock watering, some of which accelerate the depletion of the stored water during the dry season, resulting in the reservoirs not being able to serve the purposes for which they were constructed.

To address this situation, this study was conducted to determine the productivity of stored water in small reservoirs and to use this productivity values together with observations and interviews as a means of suggesting strategies for the improvement of water use so as to ensure water availability for the entire dry season period. Water productivity can be thought of as the output (product) that can be obtained per unit volume of water used or applied for either crop or livestock production. Data on crops and livestock were obtained through questionnaires administration, interviews, focus group discussions, physical measurements, official records as well as field observations from nine reservoirs in the UER.

Results of the study showed that donkeys have the highest water productivity value of (GH¢ 290 /m^3) followed by cattle (GH¢ 133 /m^3). Sheep and goat both have productivity values of (GH¢ 18 /m^3). Cattle and donkey have high water productivity values chiefly due to the variety of products and services they render. For crops, tomatoes have the highest productivity value of GH¢ 6.70 /m^3 as opposed to leafy vegetables and pepper with productivity values of GH¢ 2.90 /m^3 and GH¢ 1.40 /m^3 respectively.

Also productivity improvement strategies such as training of water user association (WUA) members, water conservation mechanisms, provision of standards for furrow formation and prevention of stored water from pollution were suggested based on the water productivities as well as physical measurements, interactions and observations made.

Key words: Small Reservoir, Productivity, Stored water, Ghana

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List of Abbreviations

AEZs	Agro-Ecological Zones
CWP	Crop Water Productivity
DWP	Domestic Water Productivity
FGD	Focus Group Discussion
FSL	Full Supply Level
GIDA	Ghana Irrigation Development Authority
GPS	Global Positioning System
GWCL	Ghana Water Company Limited
IFAD	International Fund for Agricultural Development
IFS	International Foundation for Science
ITCZ	Inter-Tropical Convergence Zone
LWP	Livestock Water Productivity
MOFA	Ministry of Food and Agriculture
PWP	Physical Water Productivity
UER	Upper East Region
VDWI	Voluntary Daily Water Intake
WP	Water Productivity
WUA	Water Users Association

Acknowledgement

I am grateful to GOD for His guidance, protection and grace that have helped and seen me through this programme successfully.

I wish to express my sincere appreciation to my supervisors, Dr. Samuel Nii Odai, Mr. Frank Ohene Annor and Mr. Kwaku Amaning Adjei for their constructive and invaluable contributions and guidance.

I am grateful to the International Foundation for Science (IFS) for funding this MSc Thesis.

I thank Mr. Aaron Aduna, The White Volta Basin Officer in Bolgatanga for his patience, support and cooperation during visits to his office. My appreciation also goes to Alhaji A.R.Z. Salifu, the acting regional director of MOFA and Mr. Ansah Manu, the regional director of GIDA for all the information that they unreservedly gave me to aid my research work.

I also acknowledge the support of staff of MOFA and GIDA, especially Engineer William Boakye-Acheampong and Mr. Thomas Ayamga (M&E) all of MOFA and Mr Prince Seidu of GIDA. I am also to grateful Dr. Barry of the GLOWA VOLTA project for providing the team accommodation at the GLOWA guest house at Navrongo for the entire data collection period not forgetting Mr. Mustapha, the care-taker.

My thanks also goes to my friends and course mates especially Mr. Emmanuel Kogo, Mr. Kofi Asante, Mr. Ebbin Abaka-Yankson and Mr. Eric Akomeah, for their support throughout the data collection and processing stages of this study. I also thank Mr. Gerald Forkour, IWMI, for his support during this study.

Lastly, my profound gratitude goes to my family, Mr. & Mrs. Antwi, Fiifi, Akosua and Paa Kofi and my girlfriend Stella for their immeasurable support and contribution.

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CHAPTER ONE

1 INTRODUCTION

1.1 Background

The Upper East Region of Ghana is one of the driest parts of the country. The region is also characterized by highly erratic rainfall patterns. According to Kranjac-Berisavljevic et al. (1998), more than 60% of the annual rain falls between July and September, with torrential rains generating high runoff due to the inability of the soils to absorb high intensity rains. This in essence means that, the rains fall for few months of the year and the runoff generated is drained out of the region by the White Volta River together with its tributaries. It is also estimated that annual potential evapotranspiration is about twice the annual precipitation (Mdemu, 2008). This, according to Mdemu (2008), is mostly true for the dry periods of the year with potential evapotranspiration being less than precipitation only during the wet seasons of the year. This phenomenon results in perennial drought in most parts of the region.

To forestall this occurrence, a number of small reservoirs (about 160) have been constructed in the Upper East Region (van de Giesen et al. 2002), with the aim of impounding the sporadic, partial and temporal precipitation from a given catchment area in the rainy season so that it can be used in the dry season. The water stored in these small reservoirs become extremely important in ensuring that water is available in the dry periods of the year to enable its use for activities such as irrigation, domestic use, livestock watering and other related uses. Because rural inhabitants usually have low income levels, high population, low development in terms of

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infrastructure and their livelihood depends mostly on agriculture, these small reservoirs, which support a variety of uses, are usually developed to provide them with water during the dry season in order to promote their living standards (Zirebwa and Twomlow, 1999).

During the dry periods of the year, most people who live in rural areas in semi-arid environments rely mostly on the water stored in small reservoirs for the sustenance of their livelihoods (Liebe et al, 2005; Poolman, 2005; Balazs, 2006) resulting in the use of the water for various activities such as domestic use, recreation, dry season irrigation, livestock watering, fish production, block-making, building, and other beneficial uses. This over-reliance on some of these small reservoirs coupled with inadequate capacity and high evaporation makes them unable to store water from one season to another (Manzungu, 2002; Keller et al., 2000). Although small reservoirs contribute significantly to the sustenance of the socio-economic livelihood of the people living in close proximity to the reservoirs and also to the country as a whole, they are mostly taken for granted, unappreciated and as a result not properly documented (GoB, 1993).

It is reported that the livelihoods derived from small reservoirs contribute enormously to the socio-economic development of rural communities (GoB, 1993) and their environment. Unfortunately, in semi-arid areas, the livelihoods derived from these small reservoirs are constrained by erratic rainfall patterns and high rates of evaporation. The lack of efficient management tools and procedures for assessing the sustainable use and planning of water resources in small reservoirs worsen the situation (Sawunyama, 2005). An appreciation of the positive contribution small multiple-use reservoirs have on the socio-economic livelihood of people who depend on them may lead to increased investment in the construction of such multiple-use small reservoirs (Mamba, 2007).

The challenge for water resources managers, therefore, is to be able to formulate strategies for the effective and efficient allocation and utilization of scarce water resources (Molden et al., 2001). An emerging strategy for allocating scarce water resources is through the quantification of water productivity for the various uses of small reservoirs (Mamba, 2007). Because water productivity can be used in comparing the various uses of stored water (Cook et al, 2006), it can be used as a means for allocating scarce water resources. It must be mentioned that the application of water productivity as a tool, for the allocation of scarce water resources, has to be integrated with societal values in order to produce the expected optimum benefits (Mamba, 2007). In order to manage and allocate the water effectively for the various competing uses, due to its scarcity, a fairly accurate estimation of the actual storage capacity of these reservoirs as well as the quantification of water productivity for the various uses is necessary. As a step in confronting this all important challenge, some work has been done by Mdemu (2008), Annor (2007) and other researchers on a number of small reservoirs in the UER.

This thesis aims at continuing the work that has thus far been done by finding out how water productivity improvement strategies can be derived based of the quantification of the productivities for the varied uses of small reservoirs in order to efficiently manage and allocate stored water for the optimum benefit of society. The study will be focused on two main areas; crop and livestock water productivities.

1.2 Problem Statement

Small reservoirs, although have multiple uses, were originally constructed mainly with the aim of providing water for domestic use and livestock watering during the dry periods of the year. Over the years, however, these small reservoirs have been put to a variety of uses, some of which accelerate the depletion of the stored water leading to water shortage during the dry season. This results in some reservoirs not being able to serve the purpose for which they were constructed. There is, therefore, the need to quantify the water productivities for the various competing uses of stored water and measures suggested on the basis of these productivities to ensure that scarce water resources are used in a manner that will result in higher productivities for the optimum benefit to society.

1.3 Justification

The Upper East Region is one of the driest regions of Ghana. It is estimated that annual potential evapotranspiration is about double the annual precipitation (Mdemu, 2008). This is reported to be mostly true for the dry periods of the year with potential evapotranspiration being less than precipitation only during the wet seasons of the year. As a result, a number of existing small reservoirs have been rehabilitated with new ones constructed this time with the aim of impounding and storing water in the wet season to be utilized in the dry season for irrigation, domestic use, livestock watering and other related uses.

The current uses of these rehabilitated small reservoirs, therefore, contrast the original purpose for their construction, which was mainly for domestic use and/or livestock watering. Currently stored water in small reservoirs is used for irrigated agriculture, domestic purpose, livestock watering, fishery and construction. The level of attention that government gives to the improvement of rural livelihoods using these small reservoirs (improved agronomic practices, animal husbandry, soil and water conservation mechanisms as well as technical support) to sustain the socio-economic conditions of rural inhabitants are often overlooked. In spite of this constraint, small reservoirs, according to Stevenson (2000), serve as a source of water for a variety of uses by rural inhabitants leading to improved livelihood.

In light of the varied uses of small reservoirs nowadays, together with their role in sustaining the socio-economic well-being of the people who depend on them, it is necessary to determine the water productivity for each varied use. This will enable the suggestion of appropriate water productivity improvement strategies to ensure that stored water is allocated and used efficiently to result in higher productivity and hence improvement in the socio-economic well-being of the people who depend on them especially during the dry periods of the year.

1.4 Objectives

The main objective of this research is to determine productivity of stored water in small reservoirs for dry season agriculture in the Upper East Region of Ghana towards the formulation of strategies for the improvement of water productivity.

The specific objectives of the research are to:

a) Identify and classify some selected small reservoirs based on their current uses
b) Quantify the productivities of stored water for crop and livestock watering.
c) Suggest strategies for the improvement of water productivities

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the definitions of small reservoirs, productivity, water productivity and Strategic Allocation. Various concepts of water productivity quantification will also be looked at.

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2.2 Definition: Small Reservoir

A small reservoir can be defined generally as a storage structure used to impound and store runoff generated as a result of rainfall. Small reservoirs have, however, been defined by various world organisations and countries mostly in terms of height of the dam wall and/or storage capacity of the reservoir (Table 2.1). The World Commission on Reservoirs, for instance, defines a small reservoir as a reservoir that has a height less than fifteen metres (15m) and a storage capacity that ranges from fifty thousand to one million cubic metres (50000 to 1×10^6 m^3).

Table 2.1: Some definition of Small Reservoir

Organization / Country	Height (m)	Capacity (m^3)
World Bank	< 15	
World commission on Reservoirs	< 15	50000 - 1×10^6
United State of America (USA)	≤ 6	0.123×10^6

Source: Senzanje and Chimbari (2002)

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Defining reservoirs in terms of height of the dam wall has constraints with respect to the study area because such information is either scantily documented or unavailable. Also because the volume of stored water in most small reservoirs varies with time mostly as a function of siltation, evaporation, seepage and the availability of rainfall and that most small reservoirs are not effectively monitored, de-silted nor gauged, a definition based on capacity will either be incorrect or misleading. It is worth noting that the known storage capacities of these reservoirs are those obtained at the time of their construction or after they had been rehabilitated. As a result of the above mentioned constraint, small reservoirs, in the context of this study, will be defined in terms of surface area as water storage structures whose surface area is greater than one hectare but less than a hundred hectares (Annor, 2007).

2.3 Definition: Productivity

Productivity is defined in a number of ways in different disciplines. Two of these definitions will be noted here. Firstly, the definition of productivity as it applies in the field of economics and secondly in business organizations. In economics, productivity is defined as the ratio of what is produced to what is required to produce. Productivity, in the context of economics, may, therefore, be thought of as a measure of production efficiency whereas in a business organization, productivity is viewed as a ratio that is used to measure how well an organization (or individual, industry, country) converts input resources (labor, materials, machines) into goods and services. This latter definition acknowledges that productivity on its own is not a measure of how efficient that conversion process is. It can be realized from the above definitions that productivity can be defined simply and in a more general form as output divided by input.

Productivity can also be computed in either of two ways; total productivity or partial productivity (Molden, 1997 cited in Cook et al., 2006). Total productivity is considered in general as total output divided by total input. Partial productivity as suggested by its name means the partial (or approximate) measurement of total productivity. Although partial productivity can be measured in a number of different ways such as value-added productivity and efficiency ratio, only the concept of single-factor productivity will be used for this study. Single-factor productivity refers to the measurement of productivity that is a ratio of total output and one input factor (Molden, 1997 cited in Cook et al., 2006).

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2.4 Water Productivity (WP)

Water productivity can be thought of as the output (physical or monetary) that is obtained per unit volume of water used or applied (Molden et al., 2001). The purpose of water productivity is to ensure that the comparisons between water use systems in space and time can be made as quickly as possible (Cook et al., 2006). Water productivity is a single factor productivity that measures how the systems convert water into goods and services (Molden et al., 2003). Water productivity can be distinguished as physical water productivity (Molden et al., 2001) or monetary water productivity (Hussain et al., 2007).

Physical water productivity has to do with obtaining more output for the same amount of water whereas monetary water productivity is the total amount of revenue (money) obtained per the amount of water used. Both productivities (Physical and Monetary) will be computed. Because the concept of water productivity can be used to evaluate and compare the various uses of reservoir water it will serve as a tool for the allocation of scarce water resources to uses that bring optimum benefit to society.

For this study, three water productivities will be quantified. These are domestic, crop and livestock water productivities.

2.4.1 Crop Water Productivity

Crop water productivity can be considered at different spatial scales. For example, plant, field, scheme and basin scale (Mdemu, 2008). In order for the CWP computed to be meaningful, it is important that the spatial scale under which it was computed be clearly defined. Productivity indicators (Cook et al., 2006), such as physical water productivity (PWP), available water, depleted water and process depleted water, are used to measure the water productivity of a system under this study. Physical crop water productivity, for instance, can be computed on the basis of the crop yield obtained, for a given amount of water applied over the crops growth period, in terms of transpiration, evapotranspiration, or amount of irrigation water applied (Mdemu, 2008).

The PWP based on the amount of irrigation water, applied for a crop's entire growth period at field scale, will form the basis for all CWP computations in this study. It is reported that water productivity estimates basically have two uses. That is, either as a means to evaluate the efficiency of water use in a system under study or to serve as a means for effective management of scarce water resources to ensure increased water productivity (Cook et al., 2006). However, estimation of CWP as a means for the effective allocation of scarce water resources in small multiple-use reservoirs for optimum benefit of society is the focus of this study.

To obtain the physical crop water productivity, the crop yield is divided by the volume of water applied during the crops entire growth period. This can also be computed as the amount of money which will be obtained from the sale of the crop yield divided by the volume of water applied to the crop during its entire growth period (Mamba, 2007). PWP is expressed as (kg/m^3) and monetary WP will expressed as (GH¢ / m^3). The formula by Lemoalle (2006) will be adopted for the computation of physical CWP.

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$$CWP = \frac{\text{Crop Yield [kg]}}{\text{Water Applied [m}^3\text{]}}$$ (Lemoalle, 2006)

OR

$$CWP = \frac{\text{Revenue obtained from Crop Yield [GH¢]}}{\text{Water Applied [m}^3\text{]}}$$

Where; CWP = Crop Water Productivity [kg/m^3] or [GH¢/m^3]

2.4.2 Livestock Water Productivity (LWP)

Livestock water productivity (LWP) is a ratio that is used to evaluate how productive a livestock has been for a given amount of water depleted over a specified period. LWP defined by Peden et al. (2002) as the ratio of the summation of livestock services and product divided by the volume of water depleted will be used in this study.

$$LWP = \frac{\text{Livestock Product [GH¢]} + \text{Livestock Services [GH¢]}}{\text{Depleted water [m}^3\text{]}}$$

(Peden et al., 2002)

Where; LWP = Livestock Water Productivity [GH¢/m^3]

Livestock services and product is defined to include among others meat, milk, hide, manure, ploughing and transport while the volume of water depleted may be considered as coming from their feed and from the direct intake of water from the reservoir. This definition of LWP, according to Mdemu (2008) is characterized by uncertainties, due to the relationship between livestock services and products and the agro-ecosystems that support them. It is also reported that LWP can be evaluated using water accounting tools, which clearly show the different paths of water under a defined system in time and space, by considering all livestock products and services together with direct water input (Molden et al., 2003).

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According to Mdemu (2008), LWP quantification based on water accounting are practical and applicable in systems where "livestock feeds are produced from well defined water system that facilitates the partitioning of water flow into feeds and fodder, and where inputs and outputs can be identified and quantified." Livestock drinking water, according to Peden et al., (2002) cited in Mdemu (2008), adds momentously to the production of livestock particular in hot semi-arid areas where it is reported that livestock feed/fodder water content may sometimes drop below 20% in the dry season. This is against the backdrop of the assertion, by Peden et al., (2002), that the daily livestock drinking water form a small portion of livestock water budget compared to the amount of water used for the production of their feed/fodder.

The Upper East Region, however, is characterized by peculiar circumstances that make the use of water accounting quite unpractical. These, according to Karbo and Agyare (1998), include the practice of free range livestock management in the dry season where livestock feed on grasses that grow naturally in the rainy season and also on the remains of crops; the use of livestock as assets and for security/insurance against unexpected occurrences such a crop failure and even the payment of children's school fees aside the services and products that are provided by livestock; and livestock products such as cow dung may be used for purposes such as plastering of walls of homes, manure and trapping of termites and ants (for use as poultry feed) while livestock services such as transport does not have distinctly defined charges. These above-mentioned circumstances, therefore, makes it practically challenging to obtain data on a variety of livestock product and services for the quantification of LWP (Mdemu, 2008).

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This study will focus on the quantification of LWP using some of the products and services provided by livestock in the dry season together with the amount of water they deplete over the same period.

2.5 Strategies for the Improvement of Water Productivity

Improving water productivity has to do with increasing the output per unit of water either delivered for a use or depleted by a use. Several methods of improving water productivity have been discussed by various authors including; (1) Improvement of water productivity with respect to evapotranspiration which includes strategies such as soil fertility enhancement and evaporation reduction. (2) Improvement of water deliveries system (3) increasing the productivity of livestock. (4) Adopting an integrated approach in order to increase the value per unit of water (Comprehensive Assessment of Water Management in Agriculture, 2007). The focus of this study will consider water productivity improvement strategies with respect to evapotranspiration (evaporation reduction) and livestock productivity increments.

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The types of agronomic practices adopted for crop cultivation have a direct bearing on evaporation (Burt et al., 2005). The amount and rate of evaporation also depends on climate, soils, and the extent of crop canopy. Therefore, water productivity can be improved by reducing evaporation and increasing productive transpiration through practices such as mulching. It is reported that 20% of agricultural evaporation, globally, goes into livestock production. Livestock water productivity is derived, to a large extent, from the food that the livestock eat. It is reported that, in comparison, the livestock drinking water requirement is very small and can be considered negligible. Considering the study area and the fact that this study is being carried out for the dry period of the year, this assertion may not be entirely true. Most of the grasses / fodder that livestock feed on in the dry season are mostly dry during this period. Therefore, livestock drinking water requirement is most gotten through stored water in small reservoirs. As a result the quantity and quality of available stored water have a consequential impact on livestock productivity. According to Adams and Alderman (1992), livestock "generate productive employment" for those without land in India and Pakistan resulting in income generation for the poor. This is also true for the study area where donkeys and cattle are used for ploughing and transport. It is, therefore, imperative that, to increase livestock productivity that quantity and quality of stored water in small reservoirs be adequate and preserved respectively.

CHAPTER THREE

3 STUDY AREA

3.1 Location and Population

The Upper East Region (UER) is located at the north-easternmost part of Ghana. It lies between latitude 10° 30' and 11° 15'North and longitude 0° and 1° 30' West. It has a total land area of about 8,842km^2 (IFAD, 1991). The UER shares international borders with Togo to the east and Burkina Faso to the north. Regionally the UER shares boundaries with the Upper West and North Regions to the west and south, respectively. It is administratively divided into nine districts; Bawku East and West, Bolgatanga, Bongo, Builsa, Garu-Tamparu, Kassena-Nankana, Kassena-Nankana West and Talensi-Nabdam.

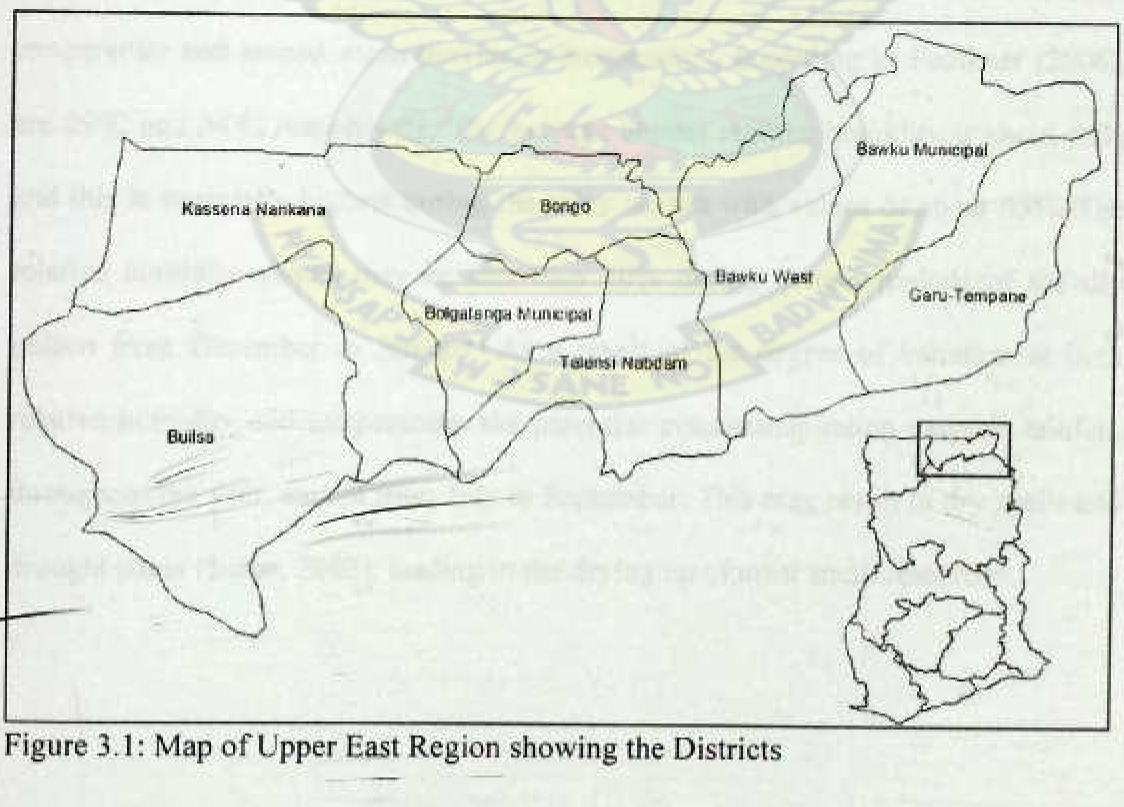

Figure 3.1: Map of Upper East Region showing the Districts

According to Ghana's population and housing census of 2000, the region has a population of 920,089 comprising 442,492 males and 477,597 females (GSS, 2005). The region has a mean population density of 125inhabitants per square kilometre (IFAD, 2007). The population of UER is ethnically diverse, comprising different ethnic groups that speak different languages (Birner et al., 2005).

3.2 Climate

The climatic characteristics of the UER belong to the semi-arid tropics. The region falls within the Inter-Tropical Convergence Zone (ITCZ) with a climatic boundary that oscillates annually between the south coast of Ghana and Latitude 20° N. The weather zones result from the north and south movement of this boundary. This results in a mono-modal rainfall pattern, which is erratic and spatially variable (Dittoh, 1998) lasting for about four months starting from April/May to mid-October.. The average annual rainfall ranges from 800 to 1100 mm per year. The annual mean temperature and annual mean maximum temperature, according to Faulkner (2006), are 29°C and 34°C respectively. The average annual relative humidity is about 55% and this is especially highest during the rainy season with values of about 65%. The relative humidity values may be less than 10% during certain periods of the dry season from December to January. As a result of the degree of variation in both relative humidity and temperature, the potential evapotranspiration exceeds rainfall, throughout the year, except from July to September. This may result in dry spells and drought stress (Liebe, 2002), leading to the drying up of most small reservoirs.

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3.3 Relief and Drainage

According to Kranjac-Berisavljevic et al., (1998), the UER has a topography which is gently undulating and has valleys which are broad and poorly drained with large flood plains adjacent to the White Volta. The slopes range from 1% to 5% but in some upland areas the slopes are as much as 10%. The area is also characterised by hills, some of which are formed by granite intrusion and others by Birimian rock outcrops. The region has a mean elevation of 197m above mean sea level (Liebe, 2002). The White Volta, together with its tributaries, the Red Volta, the Sisili, the Atankpiri and the Tono Rivers, drains the region.

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3.4 Geology and Soils

The UER is covered by three main geological formations; the Voltaian, Granitic and Birimian rock formations. The soils in the region are from granitic rocks formed mainly by the weathering of the bedrock. The region has areas where the soils are generally shallow, coarse textured, has low water holding capacities and as a result are usually unsuitable for agriculture. Also some of the soils in the area have light textured surface horizon with those of heavy texture being found in the bottom of valleys. These valley bottom areas have soil types which range from sandy loam to silty clays which, although are naturally fertile, are difficult to till and susceptible to perennial floods and water-logging. The majority of soils in the region are, however, infertile. This, according to Boateng and Ayamga (1992) may be compounded due to the perennial burning of vegetation throughout the area which reduces the amount of organic matter in the soils

3.5 Vegetation

The vegetation of the UER belongs to the Guinea and Sudan savannah Agro-Ecological Zones (AEZs) which is characterised by short sporadic drought and fire resistant trees and grasses. Needham (1993) reported that, as a result of exploitation of natural resources in the region for several hundred years, the natural vegetation of the region has long been extinct and therefore it is not possible to find any natural vegetation. Grasses that are mostly found in less eroded areas include *Andropogon gayanus* and those found in severely eroded areas include *Heteropogon spp.* and *Aristida spp.* Some of the economic trees in the areas are Acacia, *Alstonia digitata* (baobab), *Vitellaria paradoxia* (Sheanut) and Dawadawa (Hall and Swaine, 1981).

3.6 Socio-Economic Activities

The Upper East Region, unfortunate to say, is the poorest region in Ghana. The inhabitants who are mostly farmers engage themselves in both dry and wet season farming to generate income for their livelihood and sustenance.

During the wet season, farming is mainly done my land owners. Crops that are usually grown during this period include millet, sorghum, groundnut, maize and rice. Dry season farming is carried out only by members of the Water User Association (WUA) who have access to stored water. Crops such as tomatoes, pepper, onion and leafy vegetable are usually cultivated during this period of the season.

Livestock rearing is also common among the people of the Upper East Region. This also serves as another source of income generation. Livestock that are mostly kept include cattle, donkey, sheep, goat and guinea fowl.

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CHAPTER FOUR

4 METHODOLOGY

4.1 Introduction

The approach that was adopted in determining the reservoir water productivities involved the collection of data on multiple-use small reservoirs through the following methods outlined below.

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4.2 Desk studies and Literature Review

During desk studies, a number of articles, journals, thesis and reports on small reservoirs as well as work done on small reservoirs in the UER were reviewed. Documents on small reservoirs in the region were also collected from both the ministry of Food and Agriculture (MOFA) and the Ghana Irrigation Development Authority (GIDA) and reviewed. Nine small reservoirs were selected from these documents for the study. The suitability of these reservoirs was assessed through physical inspection in the reconnaissance survey. The criteria for the selection of these small reservoirs took into consideration the definition of small reservoirs (as defined in the context of this study), multiple use of the reservoir and the continuation of research on reservoirs previously studied by other researchers on different aspects. Table 4.1, below, shows the nine study reservoirs, the districts in which they are located and their geographical location.

Table 4.1: Study Reservoirs

Reservoir	**Nearest Town**	**District**
Anateem	Sumbrungu	Bolgatanga
Baare	Zuarungu	Talensi-Nabdam
Bongo Central	Bongo	Bongo
Bukere	Bolgatanga	Bolgatanga
Doba	Navrongo	Kessena Nankana
Dorongo	Bolgatanga	Bolgatanga
Nyangania	Navrongo	Kessena Nankana
Sumbrungu	Sumbrungu	Bolgatanga
Talenia	Navrongo	Kassena Nankana

4.3 Data Collection

Data was mainly collected through questionnaires, interviews, focus group discussions, official records and physical measurements as given below. Data was collected in two phases; firstly, towards the end of the rainy season (late September to November, 2008) and secondly, in the dry season (January, 2009). During the first phase, dry season cropping had not started but land preparation had begun in certain reservoir areas (e.g. Nyangania). Also, because some of the reservoirs were at full supply level (FSL), it was not possible to walk around them with the hand-held GPS to obtain the actual outline as of the time of the survey. Data on livestock prices reflects the average for the year 2008 while prices of crops reflect that of the 2007/2008 dry season cropping period.

4.3.1 Questionnaires, Interviews and Focus Group Discussions (FGDs)

In order to obtain the data required for the study, questionnaires, interviews and focus group discussions were conducted in all the study communities. Questionnaires were administered in all the nine small multiple-use reservoir catchment areas. For each reservoir site, questionnaires were administered to domestic water users, livestock owners and dry season farmers as well as members of the water users associations (WUAs). Interviews were held with various departmental heads at the regional office of GIDA and MOFA. Interviews were also held with the regional directors of the MOFA and GIDA in order to obtain general information about the various reservoirs in the region. Focus group discussions were also held with a mix of Water Users Association executives, dry season farmers, livestock owners and opinion leaders.

Plate 4.1: Questionnaire Administration and Focus Group Discussion

The questionnaires, interviews and focus group discussions were held in order to obtain the actual multiple-use nature of the reservoirs under study. The data collected included among others the quantity of water used for crop watering, the various crop-watering methods being used for dry season farming, growth periods and yields of dry season crops; livestock watering methods, products and services obtained from livestock; and prices of crops and livestock products and services. The data collected was supplemented by data obtained from official records from MOFA and GIDA.

4.3.2 Official Records

Data on some small reservoirs in the UER were obtained from MOFA and GIDA. The data provided very useful attributes about these reservoirs in the region. Some of these attributes included among others, the full supply level (FSL) surface area of reservoirs, catchment area of reservoirs, live and dead storages, storage capacity, types of dry season crops being cultivated, as well as spillway length, elevation and type. The document also provided information about the dams (reservoirs) destroyed as a result of the opening of the spillways of the Bagre dam in Burkina Faso in the year 2007 as well as those that have thus far been rehabilitated. Information was also provided on newly constructed reservoirs and those that are currently undergoing rehabilitation. Wholesale livestock prices were obtained through interviews with livestock-owners as well as owners of local butcheries, one of which was located in close proximity to the reservoir at Doba. Prices were also obtained from farmers and WUA executives for dry season agricultural produce obtained from the farms.

4.3.3 Physical Measurements

Physical measurements were carried out on the field because of the anticipated difficulty in capturing some data types through questionnaires, interviews and FGDs as well as to ascertain some of the data collected.

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(a) Measurement of Reservoir Surface Area

For each reservoir, it was necessary to determine its surface area. This was to ensure that it satisfied the criteria of being a small reservoir. In order to do this, a walk was taken round the entire periphery of each reservoir with GPS coordinates being taken at appropriate locations (i.e. whenever there was a change in direction while navigating round the reservoir) using a hand held GPS. The coordinates were taken at locations that ensured that the outline captured represented a true reflection of the shape of the reservoir as at the time of the survey. This was also done taking into account all the necessary procedure and precautions (such as a clear sky) to ensure that the GPS coordinates obtained were very reliable. The coordinates so obtained were then used to compute the areas of the respective reservoirs.

In order for the reservoirs to be plotted on the Upper East Regional map, and also for ease of locating the reservoirs by other researchers, one key GPS coordinate was taken at each reservoir site to represent the location of each reservoir. The GPS coordinates were processed using the GPS TrackMaker version 13.2 and the final map output was made using ArcGIS 9.2 software. Table 4.2, shows the nine study reservoirs and their geographical location.

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Table 4.2: Locations of Study Reservoirs

Reservoir	Location	
	Longitude (N)	Latitude (W)
Anateem	10° 49' 07"	0° 56' 57"
Baare	10° 44' 28"	0° 47' 36"
Bongo Central	10° 54' 34"	0° 47' 27"
Doba	10° 51' 59"	1° 02' 12"
Dorongo	10° 46' 54"	0° 53' 21"
McClean	10° 47' 51"	0° 50' 54"
Nyangania	10° 50' 59"	1° 11' 35"
Sumbrungu	10° 49' 45"	0° 56' 16"
Talenia	10° 55' 32"	1° 03' 32"

The nine key coordinates, representing the locations of the study reservoirs were then superimposed on the Upper East Regional map using ArcView (Figure 4.1).

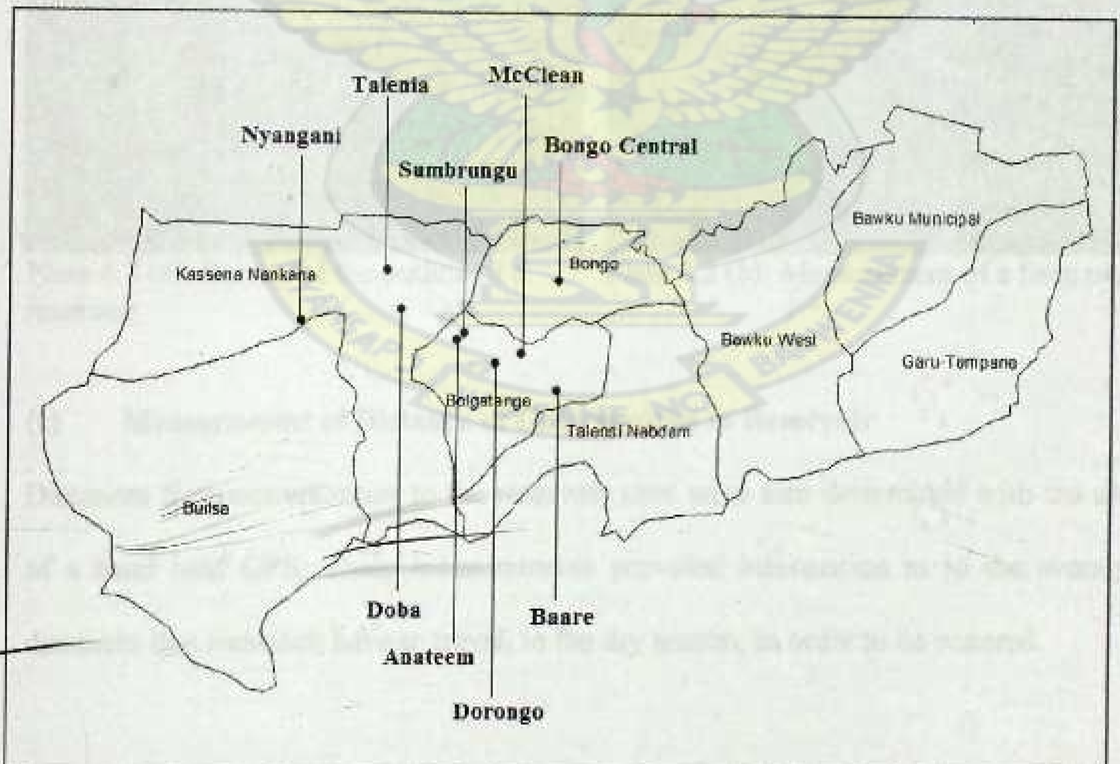

Figure 4.1: Map of the Upper East Region Showing the Study Reservoirs

(b) Measurement of Farm Plots

Also, with the use of a tape measure, the dimensions of some farm plots were measured. The areas of these farm plots were computed from these measurements to give an idea of the average farm plot sizes allocated to farmers for dry season gardening. The areas computed from the field measurements were then compared with those provided by official records from MOFA and GIDA. The dimensions of furrows on some farm plots as well as the depth of water in these furrows were also measured with the use of a tape measure. Measurements were also carried out to determine the discharge of water through the furrows. This was used to estimates the average volume of water used for irrigating the plot per each watering.

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Plate 4.2 (a): Survey of the outline of a reservoir

Plate 4.2 (b): Measurement of a farm plot

(c) Measurement of Distance of Communities to Reservoir

Distances from communities to the reservoir sites were also determined with the use of a hand held GPS. These measurements provided information as to the average distances that livestock have to travel, in the dry season, in order to be watered.

4.4 Productivity Improvement Strategies

This section describes approaches employed in coming out with strategies for the improving of water productivities.

4.4.1 Field Measurement and Observation

During the visits to the various reservoirs sites in the study area, measurements were carried out to determine the volumes of water being used for crop watering on a number of plots. The methods by which water was distributed through furrows and other watering methods (use of calabash or bowl) around the plots was observed and recorded. Furrow and bed dimensions were also measured and recorded. The modes of releasing water from the main canal to the laterals and then onto the field were also observed and noted. The field measurements were to find out the variations in irrigation practices between the various reservoir sites.

4.4.2 Interviews and Interactions with Officials and Farmers

Interviews were held with officials of MOFA who had had experiences working with dry season farmers and livestock owners. Since MOFA played a lead role in the establishment of the WUAs at the various reservoirs sites as well as the provision of extension services and training to farmers, the interviews were aimed at getting first hand information on the impacts the training and extension services have had on farmers and farmer-practices and also the challenges that were being faced at the various reservoirs sites. Interactions were also held with some farmers and WUA executive members at the various reservoirs sites visited. These interactions were aimed at finding out from the farmers themselves, the kinds of training and extension services they had received and how effective these have been implemented or otherwise and why. The interactions were also aimed at finding out first hand information from farmers, the reason(s) behind their current irrigation practices (use of stored water from the reservoir).

4.4.3 Multiple Uses of Reservoir

The various reservoir uses were first obtained through interviews with staff of MOFA and GIDA as well as through official records obtained from these organizations. Nine reservoirs were then selected from the official data. All of these reservoirs were visited, physically inspected and surveyed. Interviews were then conducted with members of the communities to determine at first hand the actual current uses of these reservoirs. This was then compared with the uses as stipulated by official records.

4.4.4 Quantification of Water Productivities

Domestic and livestock water productivities were quantified and expressed in monetary terms per cubic metre of water used. Crop water productivity, on the other hand, was expresses in both physical and monetary terms per cubic metre (i.e. kg/m^3 and GH¢ /m^3). The water productivities, in the context, of this study are computed over a period of five months (dry season water use period).

(a) Livestock Water Productivity (LWP)

The livestock considered for this study were cattle, donkey, sheep and goat. The method defined by Peden et al. (2002) was adopted for the computation of LWP.

$$LWP = \frac{\text{Livestock Product [GH¢]} + \text{Livestock Services [GH¢]}}{\text{Depleted water [m}^3\text{]}}$$

Where; LWP = Livestock Water Productivity [GH¢ /m^3]

The LWP was computed using the average livestock sales, ploughing and transport cost. The cost of a full grown livestock and the cost of services provided by them (livestock) were obtained through questionnaires, focus group discussions and interviews conducted with members of the communities including livestock owners. Estimates of the volume of water consumed by livestock, per day, were obtained through interview with some very old and experienced livestock owners. For example, it was gathered that a cattle could consume about two buckets of water (approximately 30 litres) per day. A comparison of these estimates with official data on the voluntary daily water intake (VDWI) by livestock (Table 4.3), showed no significant difference.

Table 4.3: Estimated water requirement and voluntary intake of livestock under Sahelian Conditions (litres per tropical livestock unit per day)

Animal	Tropical Livestock Unit per head	Wet season and air temperature of 27°C		Dry season and air temperature of 15-21°C		Dry season and air temperature of 27°C	
		Needed	Voluntary intake	Needed	Voluntary intake	Needed	Voluntary intake
Sahalian livestock							
Camels	1.6	31	9	23	22	31	31
Cattle	0.7	36	14	29	27	39	39
Sheep	0.1	50	20	40	40	50	50
Goats	0.1	50	20	40	40	50	50
Donkeys	0.4	40	13	30	28	40	40

Source: Comprehensive Assessment of Water Management in Agriculture (2007)

The data from Table 4.3 were, therefore, used for the computation of the livestock water productivity. Because of the difficulty in obtaining data on the number of livestock at the various study communities, livestock water productivity was computed per head. The parameters considered for the purpose of this research included the livestock sale price and cost of services (ploughing and transportation). Products such as milk, hides and manure were not considered in the quantification due to unavailable data. Livestock water productivity was then computed as the ratio of the cost of product and services rendered by the livestock and the volume of water depleted over the period (Peden et al, 2002) and expressed as cost per volume of water consumed (GH¢/m^3). In estimating the cost of product (in this case, the meat), the price of the livestock (Table 4.4) was divided by its maturity age to obtain the average annual cost. Maturity ages of 5, 5.5 and 1.5 years were used for cattle, donkey and sheep/goat respectively. This was then further reduced to five months, the period of the dry season.

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The reduction to five months was done to ensure that the water productivities computed, reflected that for the dry season and also to ensure an equal base for comparison with the crop water productivity. Because donkeys were rarely sold for their meat, the computation of the water productivity for donkey did not take into consideration the cost of its meat but only the cost of the services it provides. Table 4.4 shows the computation of the livestock water productivity.

Table 4.4: Computation of Livestock Water Productivity

	a	b	c	d	e	f	g	h= (a * g)	i =(h /1000)	j = (i * D)	K = (d+e+f) / j
Livestock Type	Tropical Livestock Unit / head	Price (Full grown) (GH¢)	Av. Annual Price (GH¢)	Av. Prices (reduced to five months) (GH¢)	Transport (GH¢)	Ploughing (GH¢)	VDWI / TLU (l)	VDWI (per Livestock) (l)	VDWI (m^3)	VDWI (for period) (m^3)	Productivity (GH¢ /m^3)
Cattle	0.7	250	50.00	20.83		520	39	27.02	0.027	4.08	132.56
Donkey	0.4	160	29.09	12.12	180	520	40	16	0.016	2.42	289.74
Sheep	0.1	50	33.33	13.89			50	5	0.005	0.76	18.40
Goat	0.1	50	33.33	13.89			50	5	0.005	0.76	18.40

D = 151 (Number of days from November to March)

(b) Crop Water Productivity (CWP)

A number of interviews and focus group discussions were held together with the administration of questionnaires in the study communities to obtain data for the computation of the crop water productivity. The data collected included the main type of crops grown, the length of the growing season, the number of bowls harvested per season, the type of irrigation methods and systems used, the time it takes to irrigate a plot, the irrigation frequency and the average plot size per farmer among others. Physical measurements were also carried out to collect as well as verify some of the data that was collected through questionnaires, interviews and FGDs. These included among others irrigation methods and system, irrigation frequency, furrow dimension and discharge measurements.

For example, measurements on the field showed that four bowls of harvested tomatoes filled the standard crate used for its packaging and transportation. The total yield for tomato was, therefore, calculated by dividing the number of bowls of tomato harvested over the entire season by four (4), to obtain the number of crate harvested. This was extremely important as the price of tomatoes was quoted per crate. The total quantity of water applied to the field was calculated using two approaches. For tomato and pepper, the water supplied to the field was directed into furrows and allowed to fill the furrow after which the supply was shut. As a result, the approach employed was to measure the volume of water contained in each of the furrows. This was done by measuring the length, width and depth of stored water contained in each furrow to obtain the volume of water contained in each furrow. The amount of water lost through seepage was not considered. The volumes of water contained in the furrows per plot were summed up to obtain the total amount of water in the plot.

Leafy vegetables, because they are grown on beds, are irrigated by fetching water, flowing through furrows, onto the bed using a bowl or calabash. In such cases, discharge measurements were carried out at appropriate portions (where the flow was fairly steady) of the furrows. On average the discharge was between 0.00294 – $0.0042m^3/s$. The total volume of stored water applied was computed as the discharge multiplied by the time it took to irrigate the entire field and the number of times the field was irrigated over the entire growing season. In determining the total volume of stored water on the field, the volume of water lost through seepage was not considered. The physical water productivity (kg / m^3) was computed as the total mass of yield (kg) divided by the total quantity of water (volume) applied (Lemoalle, 2006).

$$CWP = \frac{\text{Crop Yield [kg]}}{\text{Water Applied [m}^3\text{]}}$$

The monetary water productivity (GH¢ $/m^3$) was also computed as the price of the total mass of yield (GH¢) divided by the total quantity of water (volume) applied.

$$CWP = \frac{\text{Revenue obtained from Crop Yield [GH¢]}}{\text{Water Applied [m}^3\text{]}}$$

Where CWP = Crop Water Productivity [kg/m^3] or [GH¢ $/m^3$]

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CHAPTER FIVE

5 RESULTS AND DISCUSSION

5.1 Identification and Classification of Reservoirs

From the data collected from the field through questionnaires, interviews, FGDs as well as physical observations, it was realized that stored water in the various reservoirs was mainly used for crop productions, livestock watering and domestic purposes. Other uses, though, included block making and fisheries. The reservoirs were, therefore classified under these uses. These classifications are shown in Table 5.1 below.

Table 5.1: Reservoir Classification

Reservoir	Surface Area (ha)
Used for Domestic, Irrigation, Livestock Watering	
Anateem	5.3
Baare	14.2
Bongo Central	5.8
Sumbrungu	5.2
Doba	6.2
McClean	8.8
Nyangania	15.5
Used for Domestic, Irrigation, Livestock Watering & Fisheries	
Dorongo	21
Talenia	16

5.2 Water Productivity Quantification

This section presents and discusses the results obtained from the study with respect to the quantification of water productivities for the various uses.

5.2.1 Livestock Water Productivity (LWP)

According to the analysis of the questionnaires, donkeys and cattle were both used extensively for ploughing during the land preparation period. On average, donkeys and cattle were used five to six days per week for ploughing during the dry season land preparation period after which their workload reduced to about two to three days per week. Donkeys were, however, also used for transporting goods and farm produce during the entire period of the dry season.

In most of the communities visited during the study, livestock (donkeys and cattle) were hired out to family members and friends at virtually no cost. It was, however, gathered also that, it was a normal practice for the family member/friend whose goods/produce was being carted to give to the livestock owner some of the goods or produce in appreciation of the service rendered them. This seemed to be like some kind of batter trade with no fixed conditions. The degree of the relationship between the livestock owner and family member/friend, to a large extent, determined the willingness of the owner to release the livestock and also for how long.

Analysis of the results further shows no significant difference in the livestock water productivity for the various reservoir areas. Figure 5.1, shows the water productivity for cattle in all the nine reservoir areas. For this reason, average water productivities were computed for the different livestock (Cattle, donkey, goat and sheep) using the results for all nine reservoir areas.

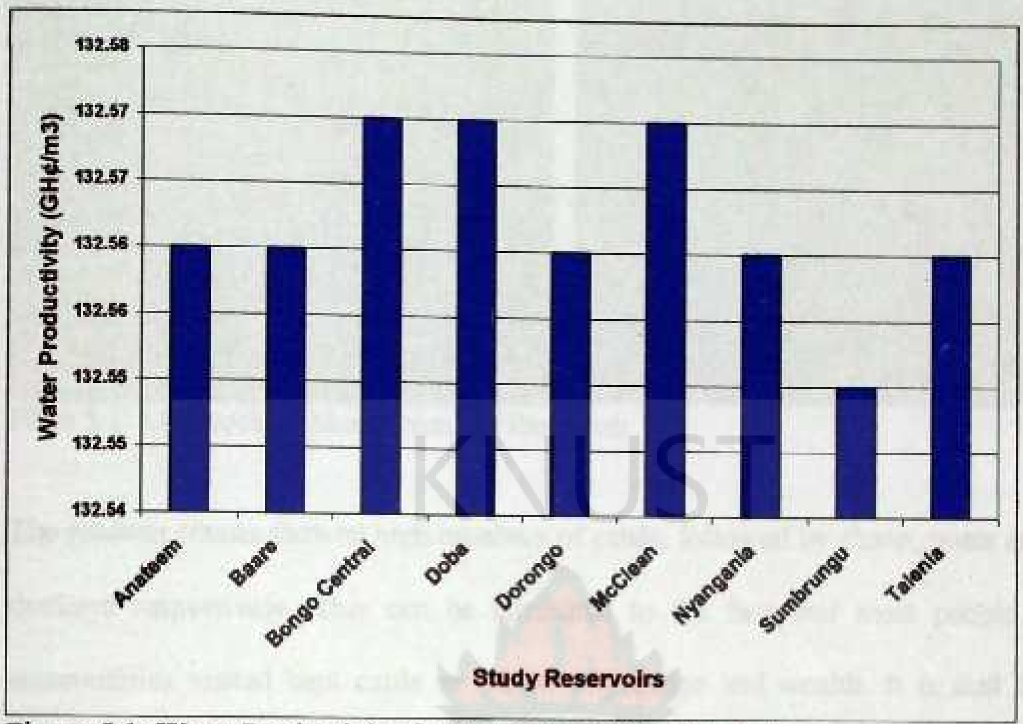

Figure 5.1: Water Productivity for Cattle in all Nine Study Areas

Results of the computations (Table 5.2) show that donkeys have the highest productivity value of (GH¢ 289.74/m^3) followed by cattle (GH¢ 132.56/m^3). Sheep and goat both have the same productivities (GH¢ 18.40/m^3).

Table 5.2: Computed Livestock Water Productivity (LWP)

Livestock Type	LWP (GH¢ /m^3)
Cattle	132.56
Donkey	289.74
Goat	18.40
Sheep	18.40

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During the study, random livestock counts were made at each reservoir site visited.

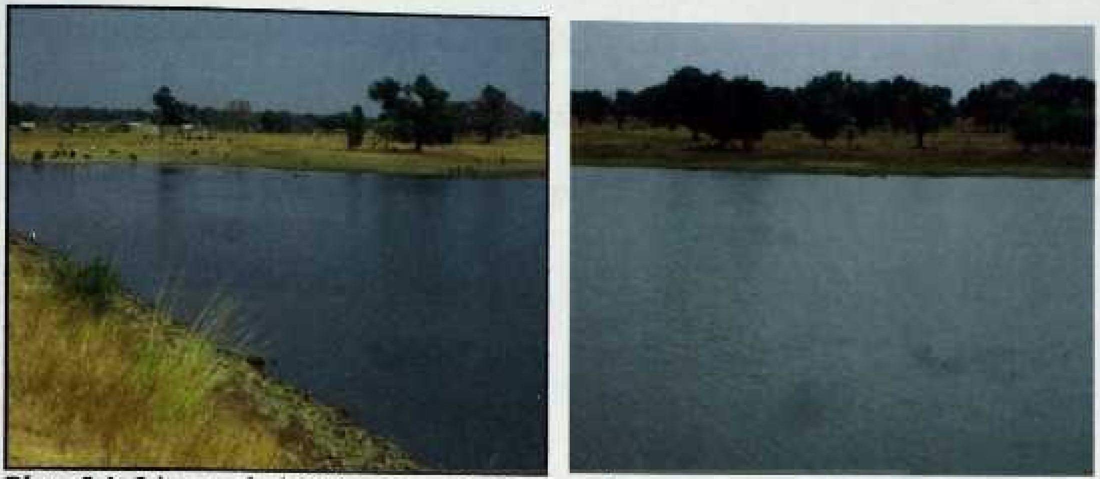

Plate 5.1: Livestock drinking from the Reservoir

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The random counts showed high numbers of cattle, followed by sheep, goats and then donkeys respectively. This can be attributed to the fact that most people in the communities visited kept cattle as a sign of prestige and wealth. It is said that the number of cattle that one has, to a large extent, speak volumes about his status in the community. This notwithstanding, donkeys had the highest productivity value although they had the lowest number of counts at all the reservoir sites visited. This is mainly due to the extra service (transportation) that they render. In all the study communities, donkeys are mostly used for transportation and ploughing which gave them a lot of preference. It is, however, worth noting that the sale of donkeys for their meat is rarely done. It was gathered that donkeys were sold for their meat only when they were unable to renders enough services due to old age. Sheep and goats both have the same productivity value. This is because the data gathered on the field showed that both sheep and goats sell at the same price. They also have the same Voluntary Daily Water Intake (VDWI) (Table 4.3). Since they both do not render any services, their water productivity was computed simply by dividing their price by the volume of stored water that they consume over the period of the dry season.

Although sheep and goats do not render any services, they served as a source of quick income for households as they could be quickly and easily be sold out to raise money in times of emergency. The results obtained corroborate that of a similar research carried out by Mamba (2008) in the Avoca area of the Mzingwane catchment in Zimbabwe.

5.2.2 Crop Water Productivity (CWP)

An analysis of the data collected from the field through interviews, questionnaires and FGDs showed that the types of dry season crops that are cultivated in the communities visited include tomatoes, pepper, onions (*Allium cepa*) and leafy vegetables (e.g., Kenaf (*Hibiscus sabdarifa*), cowpea leaves (*Vigna unguiculata*), Ayoyo (*Cochorus olitorius*)). The types of crops that are grown each season, however, depend on the market prices of the previous season or perceived market price of the forthcoming growing season. Interviews with the farmers revealed that tomato and leafy vegetables had very good market price in the last three years and for that reason were the main crops that were cultivated in all of the study areas, although some farmers cultivated other crops such as onion and pepper on a limited scale. Results of water productivity of tomato for eight of the reservoir areas, except Nyangania, showed slight variation (Figure 5.2). An average productivity value was, therefore, computed to represent the eight reservoirs.

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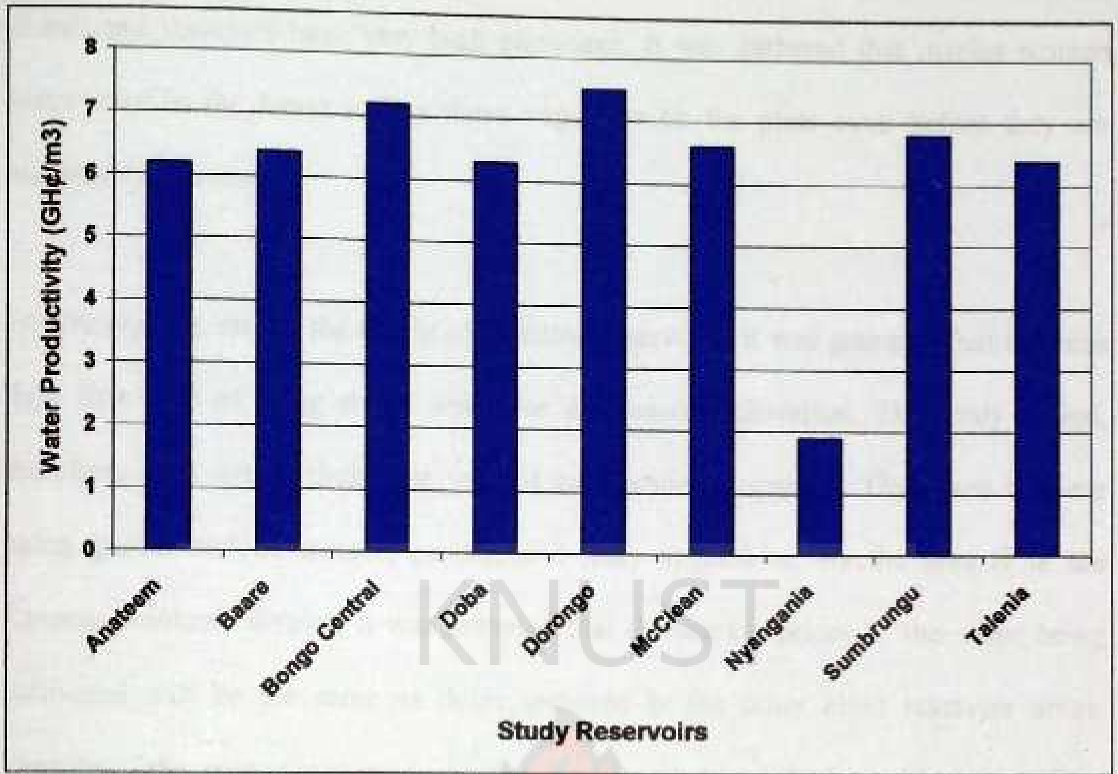

Figure 5.2: Tomato Water Productivity

The same analysis was done for leafy vegetables and pepper. On average, for the eight communities under study, tomato had the highest productivity value of GH¢ 6.70 /m^3 followed by leafy vegetables (GH¢ 2.90 /m^3) and then pepper (GH¢ 1.40 /m^3). The high water productivity of tomato is chiefly due to the high market price that tomatoes have in the study areas compared to leafy vegetable and pepper. Market women from all over the country troop to the Upper East Region during the harvest periods to buy tomatoes for re-sale around the country. The establishment of the Pwalugu Tomato Factory has also had a significant impact on the cultivation of tomatoes. As a result of these influences, more farmers in the study area tend to grow tomatoes as against other crops during the dry season.

Leafy vegetables play an important role in the local diet of the communities as well as that of surrounding towns and cities. These vegetables are used to prepare many local dishes and therefore have very high patronage. It was gathered that market women come over to the farms to buy these vegetable on the plots even before they are matured for harvesting.

For Nyangania, one of the newly constructed reservoirs, it was gathered that this was their first time of using stored water for dry season cultivation. The study period, therefore, falls within their first year of cultivation (cropping). The crops that are being grown include tomato, pepper, and leafy vegetables. As the area is in the Kassena-Nankana district, it was assumed that the market prices of the crops being cultivated will be the same as those gathered at the other eight reservoir areas. Therefore, the crop water productivities were computed based on this assumption. Over here, tomato also had the highest water productivity of GH¢ 1.90 /m^3 (Figure 5.2) compared to an average of GH¢ 6.70 /m^3 for the other reservoirs sites, followed by leafy vegetables.

The low water productivity value for the Nyangania study area compared with that of the other eight study areas is mainly due to high amount of irrigation water that is used per each watering section. For instance, crop water requirement for tomato which is equal for all the reservoirs sites is 157m^3 per plot for the period whilst water abstracted for tomato in Nyangania was computed to be 733m^3 per plot for the same period. This clearly indicates that a lot more stored water is being abstracted than is needed. Therefore, for a reservoir site where water abstraction for tomato per plot is lower (e.g., 254m^3 for Talenia), crop water productivity will be higher not necessarily because of high yields but rather efficient water use. Table 5.3 shows crop water requirement and field abstractions for Nyangania and average values for other eight reservoir sites.

Table 5.3: Comparison of Field Abstraction and Crop Water Requirement

Crop	Field Abstraction (m^3/period)		Field Water Requirement (m^3/period)	Water Use Efficiency	
	Nyangania	Average (Other Sites)		Nyangania (%)	Other Sites (%)
Tomato	733	254	157	21.42	61.81
Pepper	733	254	130	17.74	51.18

Plate 5.2 (a): Furrows filled with Stored water at Nyangania Reservoir Site

Plate 5.2 (b): Dry Furrows at Talenia Reservoir Site

Measurements made on the field (Table 5.4) showed that the furrow dimensions at Nyangania were much larger than those at all of the other eight areas and hence high abstraction of stored water per each irrigation section. Nyangania, therefore, had very low water use efficiency especially for pepper as compared to the other eight areas (Table 5.4).

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Table 5.4: Furrow Dimensions at the various Reservoir Sites

Reservoir Area	Top Width (m)	Bottom Width (m)	Depth (m)	Cross Sectional Area (m^2)
Anateem	0.28	0.21	0.13	0.03
Baare	0.17	0.14	0.05	0.01
Bongo Central	0.18	0.12	0.11	0.02
Doba	0.15	0.1	0.04	0.01
Dorongo	0.24	0.18	0.12	0.03
McClean	0.27	0.19	0.13	0.03
Nyangania	0.47	0.28	0.19	0.07
Sumbrungu	0.19	0.13	0.05	0.01
Talenia	0.23	0.17	0.07	0.01


Plate 5.3: Measurement of the volume of stored water in furrows

The high field abstraction of stored water at Nyangania could be attributed to the fact that, being their first season of using stored water for dry season gardening, the farmers have not been trained on the proper construction of furrows for the effective and efficient utilisation of stored water as well as farm land. It was also gathered that, being the first time of cultivation, not all the demarcated irrigable land was being used, hence fewer farmers. This may account for the perceived abundance of stored water and therefore its "wastage".

It was also observed during the fieldwork that similar irrigation methods were employed for most of the crops being cultivated in the other irrigation sites except for leafy vegetables where beds were used. The beds were then irrigated from the furrows by the use of calabash or bowl. Plot sizes ranged between 0.01 – 0.08 ha and varied from one reservoir site to the other. Table 5.5 shows details of plots sizes for the various reservoir sites.

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Table 5.5: Plot Sizes at the various Reservoir Sites

Study Reservoir	Length (m)	Width (m)	Area (m^2)	Area (ha)
Anateem	12.2	10.3	125.66	0.01
Baare	26.6	13.7	364.42	0.04
Bongo Central	85.3	2.3	196.19	0.02
Doba	27.6	13.7	378.12	0.04
Dorongo	12.5	10.3	128.75	0.01
McClean	30.2	25.6	773.12	0.08
Nyangania	24.5	19.8	485.1	0.05
Sumbrungu	12.8	9.8	125.44	0.01
Talenia	27.5	12.5	343.75	0.03

Plate 5.4 (a): Beds with Leafy Vegetables

Plate 5.4 (b): A Farmer Irrigating Beds with Leafy Vegetables

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It was gathered through the interviews and interactions that some level of training is usually given to dry season farmers with respect to farming and irrigation practices. Training is mainly done through extension officers from MOFA. Data from the field further showed that the level of extension services varied from reservoir to reservoir. For example, at the Bongo Central reservoir area, it was gathered that the extension officer lived a few yards from the fields and therefore she was almost always available to render much needed services to farmers and even at times when she had closed from work. At other places, extension officers visited once a month whilst others also visited upon the request of farmers. An interaction with MOFA officials in the region revealed that there are existing structures to ensure that every reservoir community has adequate contact with extension officers; however this is not practiced due to financial constraints on the part of MOFA to support the extension agents to perform their duties successfully.

In order to combat the above mentioned problem it is suggested that contributions be made by farmers each growing season to help provide them with the much needed extension services. This can be done by increasing the levies they pay for water use in the various schemes. It is believed that once farmers take part in assisting extension agents, they will in turn fully utilize the services they provide to improve their crop yields and hence productivity.

It was also observed that, though there were some similarities in the types of irrigation practices being employed in most of the reservoir areas, the dimensions of the furrows and beds varied greatly. This was mainly because of the absence of laid down standards that farmers must conform to. Farmers were left to subjectively determine the dimensions of their furrows and this, the study gathered, was based on the volume of water the farmer wanted to have on his/her field. The formation of furrows as well as irrigation practices by farmers did not really take into account the amount of water required by the type of crop that was being cultivated. This practice may have a detrimental effect on yield and hence physical water productivity (especially at Nyangania) as lands that otherwise may have been used for cropping were "wasted" in forming furrows to store water which may not be put to "productive use" other than evaporation.

There is, therefore, the need for MOFA to provide standards for furrow preparation which will depend on the type of crops being cultivated. The farmers should then be adequately trained and educated for them to understand the need to conform to these standards as a means of utilising stored water more efficiently. It was also observed that with the exception of a few areas (Bongo Central and Talenia) visited, water conservation mechanism (e.g., mulching) (Plate 5.5) were not being practiced.

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Plate 5.5: A farmer at Bongo Central mulching his bed with dry sorghum stocks

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Practices such as mulching and other water and soil conservation mechanisms to reduce the rate of water loss through evaporation and the improvement of soil fertility can be incorporated into farmer training programmes.

Mindful of the scarce nature of stored water in the study area, and as a result, the need to regulate stored water in order that it lasts the entire dry season period to serve a variety of purposes, stored water is released two to three times per week in some reservoir areas and once a week at other places for crop production. Stored water allocation was carried out by a water bailiff appointed by the WUA executives at the various reservoir areas. Field observation, however, showed that the amount of stored water released from the reservoir was not based on the types of crops and area of land to be irrigated. Stored water was released for farmers to use as much as they desired after which the main valve was shut. Such practices, it is believed resulted in the early depletion of stored water in the reservoirs during the dry season which was very much reported in the questionnaires administered as well as through the interviews and interaction held with farmers and community members.

WUA executive members who are responsible for the management of the various reservoirs as well as the irrigable area should be trained and tasked with the mandate of ensuring that farmers conform to standard furrow formation based on the type of crop being cultivated as well as ensuring that farmers irrigate their fields with the accepted volumes of water. This will ensure that stored water is utilised efficiently so it can last the entire dry season and as a consequence lead to high physical crop water productivity.

5.3 Strategies for the Improvement of Water Productivity

This section discusses some strategies that have been suggested based on interactions, interviews and observations that were made during the study.

5.3.1 Livestock Water Productivity Improvement

In the dry periods of the year, small reservoirs become the main source of livestock watering. Livestock water intake is mainly through either direct water intake or as part of their feed (Woodford *et al.*, 1984). The water contained in livestock feed according to Sirohi *et al.* (1997), may range from as low as 5% in dry feed to as much as 90% or more in succulent feed. Considering that livestock in the study area mainly depend on dry feed during the dry period of the year, stored water in small reservoirs become an extremely important source of water intake to offset the remaining about 95% of water deficit. Therefore, in order to improve livestock productivity, water has to be available in sufficient quantity and quality as the lack of sufficient drinking water will result in low productivity and decreased health (Sonder *et al.*, undated). This can also be done if a conscious effort is made to prevent practices such as bathing and washing of clothes in or close to the reservoir which tends to pollute stored water. For instance, a buffer zone, of say 20m, could be created around the reservoirs by the WUA executives in consultation with the leaders of the communities within which activities such as bathing and washing of clothes is prohibited. The creation of such buffer zones could also be incorporated into policy as conditionality for the construction of small reservoirs in beneficiary communities. Sanitation and hygiene education should also be undertaken periodically by the appropriate health agency under the district health directorate to sensitise farmers and community members on the harmful effect of inappropriate waste disposal and its consequential effect on stored water and hence livestock productivity.

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5.3.2 Crop Water Productivity Improvement

Measurements made on the field revealed that dimensions of furrows did not follow any laid down standards with respect to the type crop being cultivated. For example, tomato and pepper were grown using the same furrow dimensions although pepper requires less water than tomato (Table 5.3). It can also be observed that the irrigation efficiency for pepper is lower than that of tomato (Table 5.3) although the frequency of irrigation is the same for all crops. It is, therefore, suggested that MOFA needs to provide standards for the formation of furrows which takes into account the type of crop being cultivated as a way of increasing irrigation efficiency. This will go a long way to help ensure that stored water is used efficiently. Also WUA executive members together with dry season farmers should be trained to understand the need to adhere to these standards as a way of ensuring that stored water remains available for the entire duration of the dry season.

Observations made on the field also showed that basic water conservation mechanisms were not being practiced. It is also being suggested that a simple but efficient water conservation mechanism such as mulching be encouraged on the field. This will be extremely useful considering that the study area records high temperatures and hence high evapotranspiration.

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CHAPTER SIX

6 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

There are competing uses for scarce water resources in small reservoirs in the Upper East Region of Ghana for crops and livestock which leads sometimes to early depletion of stored water. Therefore, the most productive allocation of stored water, according to this study would be to give priority to tomato in the case of crops as it was found to be the most productive among the three crops.

However, although donkeys had the highest water productivity value, it was gathered through the study that societal values and perceptions of the people in the study communities with respect to livestock, ensured that water allocation priority was given to cattle in times of stored water scarcity.

6.2 Recommendations

Based on the results and observations made during the study the following are recommended.

- To ensure that the right volumes of water are used per the type of crop(s) being cultivated, furrow standards should be developed by MOFA and implemented through their Extension Agents during the land preparation stage of each dry season cropping period.

- Water User Association (WUA) Executives and Farmers should be given adequate training on water conservation mechanisms and the need to use stored water more efficiently by MOFA and other stakeholders.

- Veterinary services should be made available to livestock farmers at a reasonably low cost to ensure their willingness to have their livestock screened regularly, but not when they are unwell.

- Community members should be educated by the WUA Executives in conjunction with the leaders of the community on the need to avoid the pollution of stored water.

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