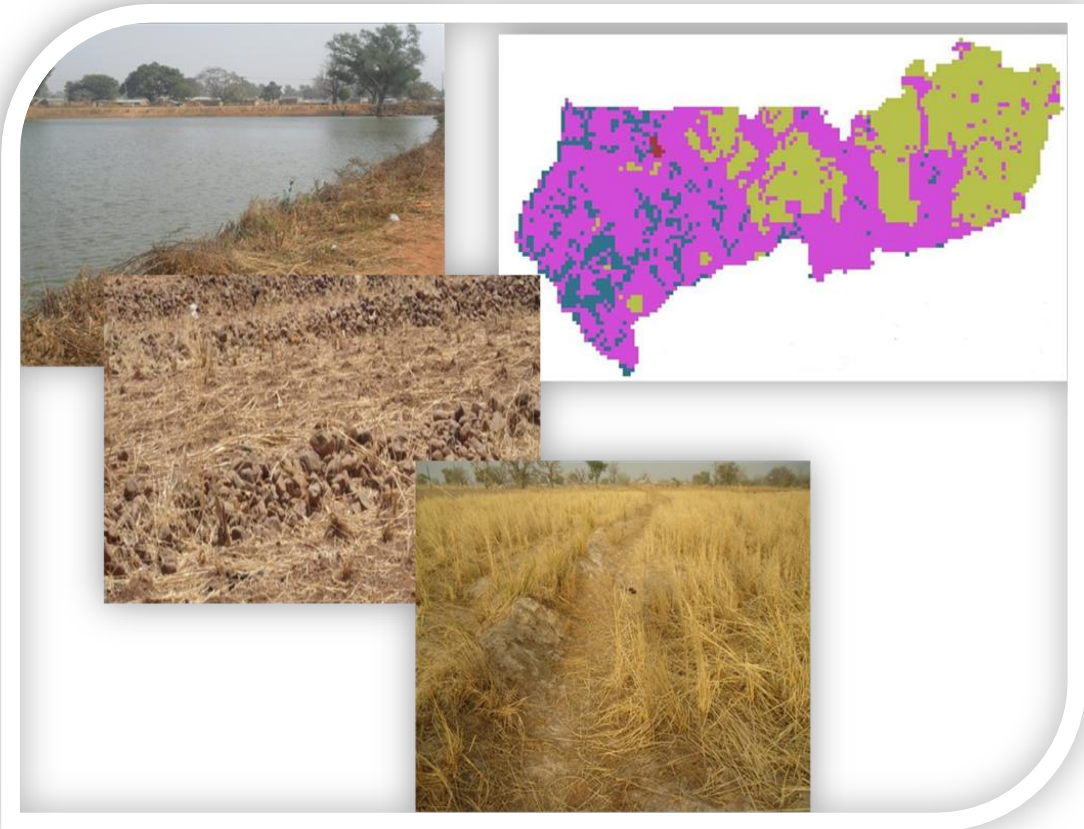
Kwame Nkrumah University of Science and Technology

College of Engineering

Department of Civil Engineering

Kumasi – Ghana

TARGETING AND SCALING UP OF AGRICULTURAL WATER MANAGEMENT INTERVENTIONS IN THE WHITE VOLTA BASIN, GHANA



Patricia Granaham

MSc. Thesis

August, 2012

Kwame Nkrumah University of Science and Technology

TARGETING AND SCALING UP OF AGRICULTURAL WATER MANAGEMENT INTERVENTIONS IN THE WHITE VOLTA BASIN, GHANA

By

Granaham Patricia, BSc (Hons.)

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

College of Engineering

August, 2012

Certification

I hereby declare that this thesis is my own work towards the Master of Science (MSc) degree in Water Resources Engineering and Management 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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(Second Supervisor)	Signature	Date
Prof. M. Salifu	………………………....	………………….............
(Head of Department)	Signature	Date

Dedication

I dedicate this work to the Almighty God for His Grace, strength, enablement, goodness and protection throughout my studies.

Abstract

The White Volta Basin (WVB) is one of the four main sub-basins of the Volta River system located in the semi-arid and sub-humid zones of West Africa. The majority of the population in the basin are small scale farmers who rely on rain fed agriculture for their livelihood. Since agricultural practice is dependent on the uni-modal nature of rainfall, farmers suffer significant loss when the rain fails. This has resulted in the introduction and development of different Agricultural water management interventions (AWMI) in the area. The objective of this study is to identify suitable areas for successful AWMI in the UER using Geographic Information Systems (GIS). In addition, a survey has been conducted using PGIS in selected communities of the UER to identify and evaluate qualitatively recent AWMI and to support the prioritization of the suitability criteria. A GIS-based model has been developed to generate suitability maps for small earth reservoirs, stone bunds and earth bunds by using multi criteria evaluation. Four criteria were considered, i.e. soil, rainfall, slope and land cover for small earth reservoirs, stone bunds and earth bunds. For each criterion five suitability levels were identified and weights were assigned to the criteria based on their relative importance for AWMI using an analytical hierarchical process. Using ArcGIS, maps for each criterion was prepared and suitability maps for small reservoirs, stone bunds and earth bunds prepared. From the PGIS survey, six of the interventions (two small reservoirs, earth bunds, stone bunds, treadle pump, water pumps and shallow wells) were identified with the help of key stakeholders to the study. The result show that farmers using these interventions have increased income, increased yield to about 300%, and increased in crop diversity. These outcomes were attributed to the involvement of community in project design, implementation, giving out ownership of AWMI, market access and training them on the management. The developed suitability maps indicated that optimally/highly suitable areas for small reservoirs, stone bunds and earth bunds are located in the eastern part of UER as 5766km^2 (66%), 4410km^2 (50%) and 6071km^2 (69%) of the total area respectively. This can be attributed to the rainfall distribution in the region which increases from the eastern part and decreases to the north–western part. The optimally suitable areas found in the eastern part of UER. This shows that, UER has a large potential for AWMI Implementation which could be tapped. The results of this study could guide policy decision making, NGO and individual on which of the interventions, they can invest in their areas and in all help improve livelihood, food security and reduce poverty in the area.

TABLE OF CONTENT

List of Plates

List of Tables

List of Figures

Abbreviations

AWMI	Agricultural Water Management Intervention
FAO	Food Agricultural Organization
GIDA	Ghana Irrigation Development Authority
GIS	Geographic Information System
GDP	Gross Domestic Product
GoG	Government of Ghana
IDE	International Development Enterprise
IFAD	International Fund for Agricultural Development
IIRR	International Institute for Rural Reconstruction
LANDSAT TM	Land Satellite Thematic Mapper
MCE	Multi Criteria Evaluation
MFIs	Micro Financial Institutions
MOFA	Ministry of Food and Agriculture
NGO	Non-Governmental Organization
RWH	Rainwater Harvesting
SSA	Sub Saharan Africa
SWC	Soil and Water Conservation
UER	Upper East Region
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
WOCAT	World Conservation Approaches and Technologies
WRC	Water Resource Commission

Acknowledgement

I thank God for carrying me through this programme successfully, granting illumination in all facets of my life and teaching my hands to do this research. May His name be glorified.

This study has been one of the most significant academic challenges that I have had to face. I could not have done it alone without the suggestion, advice and guidance of Prof. S. N. Odai my principal supervisor and Mr. Frank O. Annor my second supervisor. I want to say God bless you for being friends and fathers to me.

I am thankful to the Challenge Programme for Food and water (CPWF) V1 'Targeting and scaling out" for funding this research work. To SARI Tamale, especially Dr. Mathias Fosu and his team, I thank you for your assistance during the data collection.

Mr. Aaron Aduna the White Volta Basin Officer, who gave a very warm reception during my data collection in my study area and people to contact for the other data I needed to collect. Thank you very much.

I want to appreciate the contribution of the four District Directors and Agricultural extension officers, especially Mr. Thomas Kambonga of Navrongo, Mrs. Yvonne Ayaribil of Bongo, Mr. Matthew Sulemana of Paga and Philip of Talensi Nabdam and Anna Minkah of IDE.

My appreciation also goes to all my friends for their support, especially Charles Gyamfi, Lily, Grace Eshun, Labaran Musah, Samuel Nyarko and Andy of GIDA. My sincere appreciation goes to all my lecturers for their encouragement and support throughout my studies. To Dr. Edward M. Osei Jnr. of Geomatic Engineering and Louis Addai Wireko of Natural Resource all of KNUST I want to say a big thank you for your assistance in the use of ArcGIS and for the image processing.

My special thanks and appreciation goes to mum, daddy and my family especially my uncle and auntie, Mr. Isaac Adjei and Mrs. Monica Osei Poku, for their love, patience and support throughout my studies.

CHAPTER ONE

INTRODUCTION

1.1Background of the Study

Agriculture is the main source of livelihood for the world's rural poor and is pivotal to the economies of many developing countries of which women contribute an estimated two-third of food produced (UNDP, 2006; World Bank, 2005). Rural people are the trustees of much of the world's land and water resources, and thus are central to achieving the sixth Millennium Development Goal, to "ensure environmental sustainability" (see World Bank 2005). IFAD (IFAD, 2001) estimated that 50% or more of the poor people will remain in rural areas by 2035, even with the diversification of rural livelihoods and increasing urbanization.

According to Bruinsma (2009), the future of agriculture and the ability of the world food system to ensure food security for this growing world population are closely tied to improved stewardship of natural resources. Good water management in agriculture is required for the Millennium Development Goals for poverty, hunger, and a sustainable environment to be met.

Water scarcity and land degradation strongly affect the livelihoods of millions of households in Sub-Saharan Africa. Water for agriculture used to grow the food to feed the people, and animals' needs consumes 70 to 90% of all the water resources used in the region (Aggarwal, 2003). A large body of country-level studies have confirmed that the impacts on agriculture due to changes in precipitation patterns and water stress caused by warming temperature are expected to be negative, with the most severe losses occurring in Africa, Latin America, and India (Parry *et al.*, 2004). According to Sally *et al.* (2003), low agriculture productivity and strong dependence on limited and highly variable rainfall in arid and semi-arid areas in Africa, render poor people extremely vulnerable to risk.

Incidence of poverty in sub Saharan Africa is lower in irrigated farming than other farming systems, and the absolute number is relatively small (Dixon and Gullier, 2001). Irrigated agriculture is an important driver of rural growth and an instrument of poverty reduction through increased food security, higher demand for employment, and higher real incomes, and also drives a local multiplier effect to increase non-farm rural output and employment in the regions where it is developed.

The Volta River Basin (VRB) located in the tropical zone in West Africa covers an estimated area of 400,000km^2. Extensive crop farming coupled with variable and unreliable rainfall patterns in the VRB where poverty is predominant has far-reaching implications on the environment and food availability (Barry *et al.*, 2005). The basin has six riparian countries (43% in Burkina Faso, 42% in Ghana, and 15% in Togo, Benin, Cote d'Ivoire and Mali) and four sub basins namely White Volta basin, Black Volta basin, Oti and Lower Volta. Populations in the Volta Basin are generally rural farmers (64-88%) (Barron *et al.*,2003). Since agricultural practice is dependent on the availability, distribution and uni-modal nature of the rainfall, farmers suffer significant loss when the rain fails. Poor water resources management in the area has also resulted in an inability to bridge these intra-seasonal dry-spells, and this often causes the large share of all yield reductions commonly ascribed to drought. This could be avoided with better water management-a great opportunity for agriculture in the tropical drylands (Andah *et al.*, 2005; Barry *et al.*, 2005; Gyau-Boakye and Tumbulto, 2000).

For instance in Ghana, due to the long dry seasons in the North (Northern Region, Upper East Region and Upper West Region), Agricultural Water Management with different interventions have been introduced and developed as poverty reduction strategy for the farmers by the Government, Non-Governmental Organisations (NGOs) and even by the farmers themselves. Moreover, unfavourable socio-economic conditions over the past decades have caused decline in the use of these interventions, but recent increased water scarcity in these areas has necessitated the revival of these interventions.

One promising way to raise productivity and incomes and enhance resilience in the UER is to better target interventions for particular environments. This will help to overcome the limited success and impact of many past agricultural development efforts.

1.2 Problem Statement

Agriculture in the northern part of Ghana is basically rainfed under uni-modal rainfall regime that favours only single cycle crops production. In addition, since the agricultural practice is dependent on the availability and distribution of rainfall, farmers suffer significant loss when the rain fails. This also results in low productivity.

Since 1957 the Government of Ghana (GoG) has invested in the construction of many water-retaining structures such as small reservoirs and dugouts for water supply for livestock, domestic use and downstream irrigation purposes in the Upper Regions of Ghana (Ofosu, 2008). As at 2008, there were two large reservoirs, 160 small reservoirs and 96 dugouts in the Upper East Region of Ghana (Ofosu, 2008).

Moreover, within the past twenty years, the prospects of horticultural production (onions, tomatoes, pepper and leafy vegetables) also triggered the introduction of other irrigation interventions such as shallow wells (temporary and permanent) with different water lifting mechanisms and water pump irrigation in addition to reservoirs for dry season farming by GoG, NGOs and farmers (MOFA, 2010).

However, agricultural production, consumption, employment and food security in the region is still low. Majority of inhabitant of the UER constituting about 88% live in poverty and the region has the highest rural population density of about 104 person/ha (GLSS, 2008). The study therefore seeks to assess the success of the various interventions of AWM and upscale them.

1.3 Justification of the Study

On the broader view, the findings from the study will be of major significance to policy makers, the government, Non-Governmental Organizations and the farmers.

To begin with, the management of available surface water and groundwater resources for irrigation throughout the year will reduce crop failure and improve the standard of living or livelihood of the people including farmers in the Upper East region.

In addition, the Government and NGOs will also be able to identify the various interventions required in specific areas in the northern part of Ghana and hence implement the required policies.

Moreover, the identification of the successful interventions and the mapping of those interventions elsewhere would aid in increasing agricultural productivity, consumption and employment, and hence poverty reduction throughout the northern part of Ghana. This in the long term would reduce the high rate of rural-urban migration by the youth in search of non-existent jobs and income. The increase of agricultural productivity in the region will also contribute immensely to the gross domestic product (GDP) growth, foreign exchange reserve and government revenue.

1.4 Research Objective

The main objective is to target and scale up successful Agricultural Water Management (AWM) interventions in the Upper East region (UER) in the White Volta sub-basin (WVB) to improve the livelihood of rural poor through improved and sustainable agricultural practices for small holder farmers.

Specific objectives of the study are to:

i. Identify existing AWM interventions in Upper East region
ii. Assess the biophysical and socio-economic indicators that influence the success of the identified interventions in the study area.
iii. Identify potential areas in UER where successful AWM interventions could be scaled up.

1.5Research Questions

- What are the existing AWM Interventions in the Upper East region?
- What biophysical and socio-economic factors exist and/or affect the identified AWMI?
- Which areas within the UER could the successful AWMI be up-scaled to and what could be the challenges?

CHAPTER TWO

LITERATURE REVIEW

2.1Agricultural Water Management

The term "Agricultural Water Management" (AWM) is a broad term covering an increasingly wide range of interventions and practices available for improving water and land management. AWM includes "all deliberate human actions designed to optimize the availability and utilization of water for agricultural purposes and its, objective is to ensure that adequate water is available in the root zone of crops when needed (Awlachew *et al.,* 2005; CAADP, 2009; Merrey *et al.*, 2006).

2.2 What is Successful AWM Interventions?

According to WOCAT (2006), successful AWMI proved to be those initiated to improve existing farming systems and which continue to be under the full control of the communities, individuals or private organization. It enables households to improve crop productivity, grow high-value crops, generate high incomes and employment, and earn a higher implicit wage rate. It should increase production and be profitable, be cost efficient with short payback (economic viability), easy to learn, accepted, effectively adopted and taken up (socially and culturally accepted), environmentally friendly (contributing to the improvement of soils, water, and flora and fauna (biodiversity)) and represent all stakeholders including socially marginalized groups.

2.3 Scaling-up

Up-scaling is dependent on putting in place measures, practices and associated investments that can work synergistically to expand the adaptation and uptake of AWM in a rapid and cost-effective manner at higher scales, as appropriate. Up-scaling leads to more quality benefits to more people over a wider geographic area more quickly, more equitably and more lastingly (IIRR, 2000).

2.4 Overview: Agricultural Water Management of Sub-Saharan Africa

The first goal of the Millennium Development is to eradicate extreme poverty and hunger, with targets of halving by the year 2015 the proportion of people whose income is less than $1 per day and who suffer from hunger. In order to meet this Goal, it requires a renewed focus on agricultural water management and institutional innovations for managing water. In most developing countries, agriculture is the dominant user of water, accounting for more than 85% of all water use (World Bank, 2005). Agricultural water use raises significant issues dealing with water scarcity, competing demands from other sectors, irrigation service delivery and system management, water use efficiencies, and so forth.

The importance of rainfed agriculture varies regionally but produces most food for poor communities in developing countries. In sub-Saharan Africa more than 95% of the farmed land is rainfed (FAOSTAT, 2005), and a key challenge is to reduce water-related risks posed by high rainfall variability in the semi-arid areas (Rockström *et al*., 2007). Despite large strides made in improving productivity and environmental conditions in many developing countries, a great number of poor families in Africa and Asia still face poverty, hunger, food insecurity and malnutrition where rainfed agriculture is the main agricultural practice.

2.5Types of AWM Interventions and Their Suites for AWM and Adaptation

The AWM and related interventions may be classified depending on operational objectives as follows (Awulachew *et al*., 2005):

- According to functions: Those used for crops, livestock, fisheries, and soil and water conservation
- According to stage of water management: Rainfall/runoff capturing, storage, lifting, conveyance and water use/applications

- According to application: Supplementary irrigation, full irrigation or drainage
- According to water sources: Rainfall, runoff, ground water, natural or manmade sources
- Spatial scale of management: Single farm/field, scheme, watershed and basin scale
- Scale of users: Household/ community/ large scale.
- Ownership: Small holders, private, public, commercial and public private partnership

All the above classes of categories are used in describing AWM and the related interventions. While technologies can be specific interventions, we also describe technology suites as combination of technologies that are used in the water quantification and control, conveyance, field application, and drainage and re-use as shown in Fig. 2.1.

The net impact of agricultural water management interventions on poverty may depend individually or synergistically on the working of these technologies (Namara *et al.*, 2010). Some examples of AWM technologies/ interventions are discussed below.

2.5.1 Water Control and Storage Technologies/Interventions

In situ Soil and Water Conservation (SWC) refers to activities that reduce water and nutrient losses and maximize their availability in the root zone of crops where rainwater and nutrients are conserved where it falls, whilst rainwater harvesting (RWH) seeks to transfer run-off water from a "catchment" to the desired field or a storage structure (Mati, 2006). RWH includes a range of micro-catchment systems, earthen bunds and other structures to capture and store run-off from elsewhere (hence, ex- situ) for use when needed.

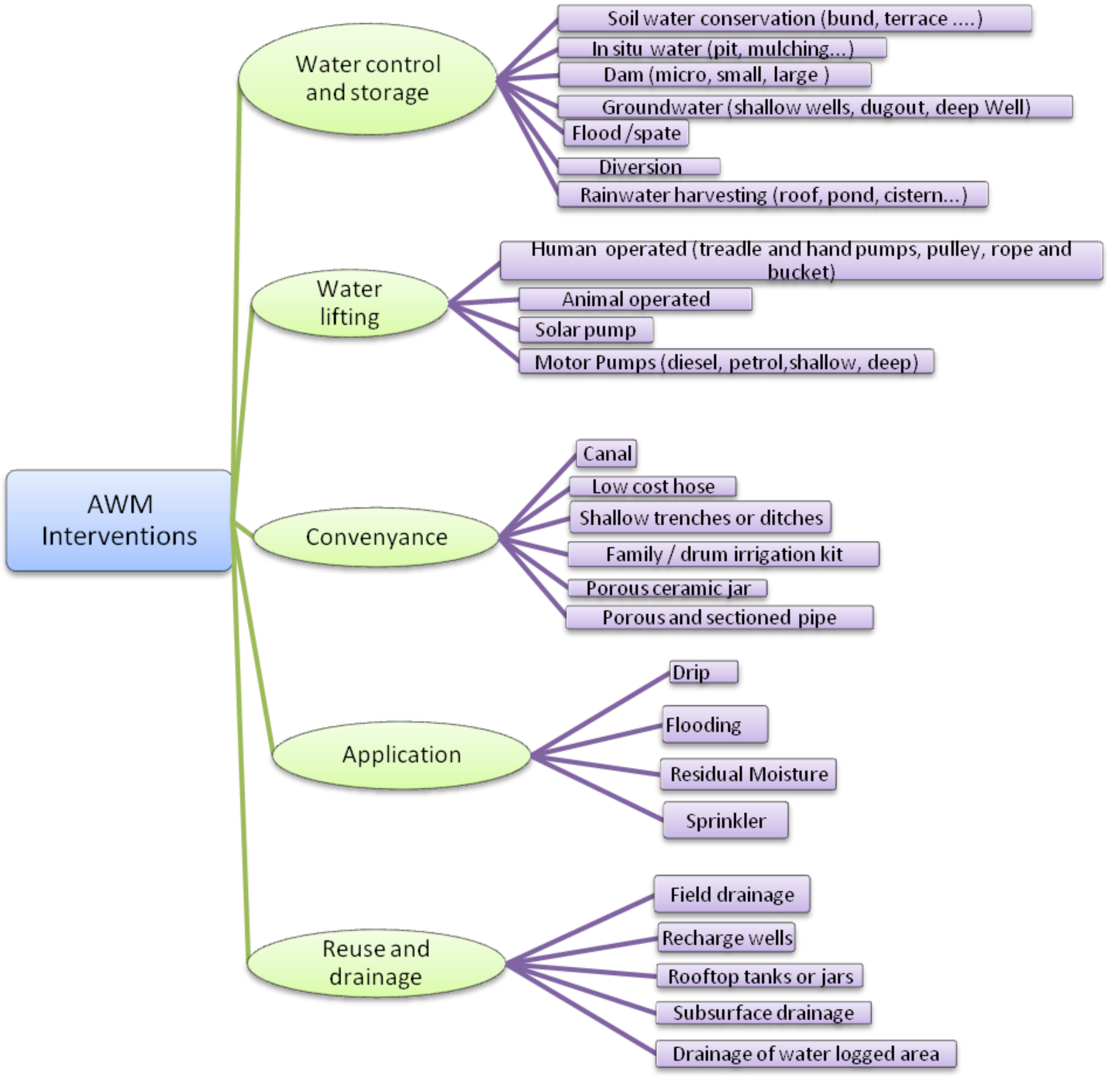

Figure 2. 1: A typology of AWM interventions showing the diversity of options

(Adapted from FAO-AQUASTAT (2008))

As Mati (2006) notes, the line between SWC and RWH technologies is very thin, and also provides a good source on experiences with a large number of RWH and SWC technologies in eastern and southern Africa. Through researches, Rockström (Rockström *et al*., 2003; Falkenmark and Rockström, 2004), Ngigi (2003) and others demonstrate a doubling of rainfed crop yields in the semi-arid tropical regions of SSA is possible with currently known technologies for improving water and nutrient management.

FAO (2002) suggest a definition for conservation agriculture as: Involving a process to maximize ground cover by retention of crop residues and to reduce tillage to the absolute minimum while exploiting the use of proper crop rotations and rational application of inputs (fertilizers and pesticides) to achieve a sustainable and profitable production strategy for a defined production system. In practical terms, examples of conservation agriculture techniques are tied ridges, mulching, contour ridges, storm drains, grass strips, Agro-forestry and green manure.

According to Namara *et al.* (2010), minimum or no tillage technologies, which are forms of conservation agriculture, are seen as ultimately labor saving while improving household food security and incomes. Daka (2006) mentions that in Zambia micro-basins prepared by hand hoes to capture and store rainfall lead to a doubling of maize yields to 3tons/ha and this performance has led to accelerated adoption such that small farmers cultivating an estimated 200,000ha of rainfed land have adopted such conservation technologies.

There are a variety of technologies for harvesting rainwater from roads, foot-paths and household compounds. Many of these water run-off harvesting systems have been developed by farmers themselves, for example those capturing "sheet and rill" runoff generated by compacted surfaces like roads, paths and household compounds (Namara *et al.,* 2010). Water is harvested and directed either directly onto cropped fields, or into various types of natural or man-made storage structures. Some of the technologies that will be considered are small reservoirs, shallow wells, and boreholes, roof top water harvesting, and above- and below-ground storage tanks.

2.5.2 Water Lifting and Conveyance Technologies/ Interventions

Treadle pumps are a potentially high-return, high-impact AWM intervention. More specifically, they are especially appropriate where there is a water source close to the surface (less than 7 meters) and close to the field to be irrigated (less than 200 meters), and they will be especially profitable when farmers have access to markets where they can sell high-value fruits and vegetables (Namara *et al.,* 2010). They can be used for many purposes where water needs to be lifted; they are not limited to irrigation. Providing packages that combine treadle pumps with water efficient application technologies such as low-cost drip systems can further enhance the returns, especially where either water is scarce, or labor shortage limits the capacity to pump.

2.5.3 Field Application Technologies/ Interventions

Drip irrigation enables the farmer to make use of limited amounts of water and fertilizer which can be applied together with the irrigation water to grow high value crops. Drip irrigation allows precise application of small amounts of water directly to the root zone and reduces losses from evaporation, weeds, runoff and percolation. Drip irrigation is popularly viewed as one of the most water efficient types of irrigation, but Laker (2006) warns that in large areas the soils are not suitable for drip irrigation, notably coarse sands and severely crusting soils. Simple drip irrigation systems are now available which would cost a farmer US$15 to cover 15m^2, or US$200–400 for a bigger system covering 500m^2 (Sijali, 2001; Sijali and Okumu, 2002, 2003).

2.6Agricultural Water Management Development in Ghana

Ghana is endowed with sufficient water resources and estimates of Ghana's irrigation potential range from 0.36 to 2.9million ha depending on the degree of water control, according to IWMI (2009). However, according to the same report (IWMI, 2009), the country faces significant variability in water resources, both spatially and temporally, such as periodic floods and droughts, and uneven distribution of annual precipitation. The dependence on rainfed agriculture, particularly in the north, means that even though production of the major staple food crops is adequate in most years, seasonal food insecurity is widespread.

Ghana is drained by the Volta, South Western and Coastal River systems, with a mean annual runoff of 39.4billion m^3, if adequately managed, is enough to support most domestic and irrigation uses. In 2000, about 652million $m^3$of water was used for irrigation, approximately 66% of total withdrawals. Ghana as at 1995 (Kortatsi *et al*., 1995), had over 56,000 groundwater abstraction systems but its use is still less than 5% of the average annual groundwater recharge in most of the basin.

The initial plan of irrigation was to play significant role in achieving the goal of agriculture in the country which include food and raw materials security, increase employment, creation of wealth and poverty alleviation, increased contribution to GDP, foreign exchange reserve and government revenue.

However, over the years, irrigation has been significantly limited to small scale (informal) undertakings with few large scales (formal) and commercial development (Dovie, 2011). Informal irrigation is irrigation practised by individual who cultivates an area of up to about 0.5ha or more by using simple structures and equipment for water storage, conveyance and distribution as stated in the national irrigation policy (GoG, 2010). Capital investments are relatively very small and are provided from the farmer's own resources. The informal operators have currently dominated the irrigation sector in Ghana (Dovie, 2011). It is estimated by GIDA that about 12,700 smallholder informal operators with more than 11,900ha management units operate in dry season around Kumasi. Lack of recognitions of the importance of informal irrigation has resulted in several challenges, such as limited access to credit, and tenure insecurity. However there is a considerable potential to increase irrigation and the informal sector is rapidly expanding and making use of a variety of water resources and technologies.

According to GIDA, with the assistance of FAO (GoG, 2010), four key problem area concerning the formal and the informal irrigation development were identified as:

- Low agricultural productivity and slow rate of growth
- Constraints of socio-economic engagement with land and water resources
- Environmental degradation associated with irrigated production
- Lack of irrigation support services.

The AWM Interventions used in Ghana according to IWMI (2009) report are numerous and can be grouped as:

- Shallow groundwater irrigation; Seasonal and permanent shallow wells, shallow tube well, pilot community bore well
- River and stream lift systems; Hand pump, treadle pump, motorized pump
- Private, small reservoirs and hand dug out
- Conventional irrigation systems including run of river diversion scheme and gravity fed systems.

2.6.1 Strategies and AWM Development in Northern Ghana

Northern Ghana (Upper East Region, Upper West Region and Northern Region), by many poverty indicators, are the poorest and comparable in poverty to some of the poorest countries in the world (GLSS, 2008). Due to this, IFAD (1991) had projects in each of them: the Upper East Region Land Conservation and Smallholder Rehabilitation Project **(**LACOSREP) for the UER, the Upper West Agricultural

Development Project (UWADEP) for UWR and the Northern Region Poverty Reduction Programme for the NR, to help them reduce poverty.

The first phase of LACOSREP for UER was designed in1990, became effective by 1991/1992 and was given an interim evaluation in 1998. LACOSREP II was appraised in December 1998, became effective in January 2000 and closed in December 2006, after a one-year extension. The main objective of LACOSREP II project was to enhance food security, improve incomes and general livelihood of the farmers in its mandate area through the promotion of reservoirs, reservoir construction and proposing the use of tube wells for irrigated agriculture.

Moreover, other project such as Savannah Accelerated Development Authority (SADA) has been established by the government to coordinate the Sustainable Development Initiative for the Northern Savannah. Its focus is on improved management of water resources, greening of the north through promoting tree crops production and other environmentally sound livelihood activities. Again, Northern Rural Growth Programme is also established to integrated agricultural led rural development programme within the three northern regions and the northern part of Brong Ahafo region. It aimed at increasing rural income through development and enhancement of agricultural productivity.

2.7 Remote Sensing and Geographical Information System (GIS) for the Identification of Potential Areas for Up-scaling

Remote sensing is the instrumentation, technique and method used to observe the earth surface at a distance and to interpret the images or numerical values obtained in order to acquire meaningful information of particular objects on earth (Bakker *et al.*, 2000) Remote sensing devices capture information by sensing, recording reflectance of emitted energy, processing, analyzing and applying that information (Lilles and Kiefer, 2005).

Geographic Information Systems (GIS) techniques are very useful for site selection studies due to their excellent capabilities in storing, analyzing and displaying spatially distributed data according to user defined specifications (Falbo *et al.*, 2002). GIS techniques are increasingly used for planning, development, and management of natural resources at regional, national, and international levels.

An important source of information on land characteristics is remotely-sensed data, especially satellite imagery. Devices which can collect information about an object from a distance, without touching it, except perhaps with energy emitted from the sensor are referred to as remote sensors. Remote sensors include near and far remote sensors. ‘Near’ remote sensors are ‘close’ to the object, example, infrared heat detectors for home insulation and ordinary photographs. ‘Far’ remote sensors are sensors from aircraft and spacecraft that study areas of the earth’s surface. The products of remote sensing are usually not direct samples of the phenomena of interest, so must be calibrated against reality in order to be useful.

2.7.1 Applications of Remote Sensing and GIS

They have been applied for the assessment of several water related environmental challenges such as soil erosion, degradation of land by water logging, contamination of ground and surface waters, and changes in ecological parameters (Jasrotia and Dhiman, 2002). Sherda *et al.* (1993) studied the application of GIS in catchment prioritization and Raes (1998) also provided evidence for successful cases in catchment management and other related issues on an individual catchment basis such as reservoir system management, irrigation scheduling and risk management.

2.8 Parameters for Intervention Site Selection

The identification of potential areas suitable for AWMI is the key for successful AWM interventions. One of the main reasons for failure of AWM intervention is the lack of scientifically verified information which could be used to identify areas where RWH can be applied and for which type of RWH techniques.

The potential of areas for AWMI depends on a multitude of parameters, either biophysical factors like rainfall, land use, soil and topography and/or the combination of the biophysical factors and socio-economic factors. Kahinda *et al.* (2008) lists six key factors: climate (rainfall), hydrology (rainfall–runoff relationship and intermittent watercourses), topography (slope), agronomy (crop characteristics), soils (texture, structure and depth) and socio-economic (population density, work force, people’s priority, experience with AWMI, land tenure, water laws, accessibility and related costs) to be considered when identifying AWMI sites.

Rao *et al.* (2003) use land use, soil, slope, runoff potential, and proximity to the utility points (like irrigation and drinking water supply schemes), geology, and drainage as criteria to identify suitable sites for RWH. To develop a GIS-based RWH model (RSM) that combines a Multi-Criteria Evaluation (MCE) process, Kahinda *et al.* (2008) used physical (land use, rainfall, soil texture and soil depth), ecological (ecological importance and sensitivity category) and socio-economic factors.

United Nations Environment Programme (Mati *et al.*, 2006) conducted a study to determine if AWM technologies can be mapped at continental and country scales. The project utilized a number of GIS data sets including rainfall, land use, land slope, and population density to identify four major commonly adaptable AWM technologies:

Roof top AWM, surface runoff collection from open surfaces into pans/ponds, flood flow storages and sand/sub-surface reservoirs and in-situ AWM.

Ramakrishnan *et al*. (2008) used slope, porosity and permeability, runoff potential, stream order and catchment area as criteria to select suitable sites for various RWH recharging structures in the Kali watershed, Dahod district of Gujarat, using remote sensing and GIS techniques. Mbilinyi *et al*. (2005) performed another study to understand the role of indigenous knowledge in identifying potential sites for AWM in Tanzania. The study concluded that farmers have a substantial amount of knowledge on RWH systems and identification of potential sites for different RWH systems. Akomeah (2009) used physical factors: soil (texture, depth and type), land use, slope, rainfall and stream flow, to map irrigation potential in the Upper East region of Ghana.

Most indigenous knowledge (although varies among locations) are based on biophysical factors, including topography, soil type and distance from water sources.

CHAPTER THREE

STUDY AREA

3.1Geographical Location and Administrative Boundaries

The White Volta Basin (WVB) is one of the four main sub-basins of the Volta River system located in the semi-arid and sub-humid zones of West Africa (Awotwi, 2010). The White Volta covers mainly the north-central parts of Ghana and the central part of Burkina Faso (Barry *et al.,* 2005). The White Volta River Basin in Ghana is located between latitudes 8°50’N and11°05’N, and longitudes 0°06’E and 2°50’W; and bounded to the east by the Oti River Basin, to the west by the Black Volta River Basin and to the south by the Main/Lower Volta sub-basins. Burkina Faso forms its northern boundary (WRC, 2008) as shown Fig. 3.1. The Ghana portion has a total catchment area of about 50000km^2 and spans 3 administrative regions, i.e. all of the Upper East Region (UER), 70% of the Upper West Region (UWR) and about 50% of the Northern Region (NR), (WRC, 2008).

The Upper East Region is situated in the north-eastern corner of Ghana, bounded on the north by the Republic of Burkina Faso, in the west by Upper West Region, in the south by the Northern Region and in the east by the Republic of Togo. It covers an area of 8,842 km^2 (Ndemu, 2008). The UER has nine administrative districts: Bawku Municipal, Bawku West, Bolgantanga Municipal, Bongo, Builsa, Garu Tempane, Kassena Nankana East, Talensi Nabdam and Kassena Nankana West.

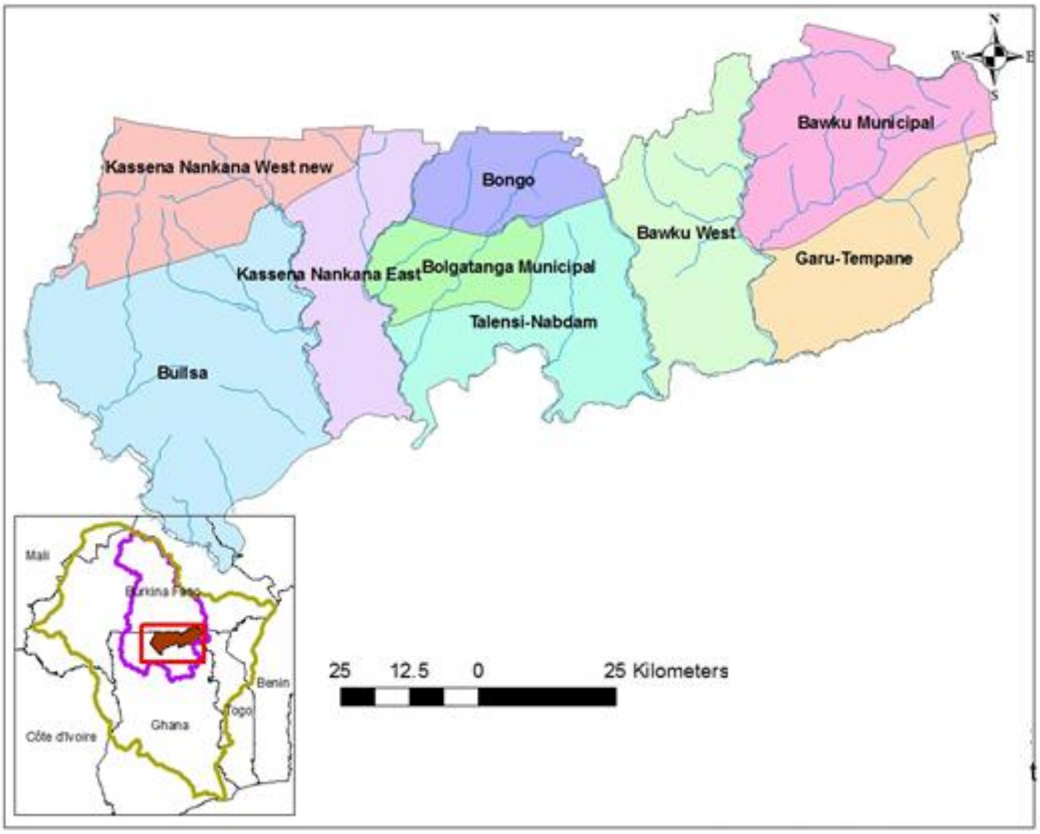

Figure 3.1: The districts in Upper East Region of Ghana within the WVB

3.2Climate

The climate of the region is influenced by the movement of the Inter-tropical Convergence Zone (ITCZ) that controls the climate of the entire West African region. The ITCZ is the inter-phase of the hot, dry and dusty northeast trade wind that blows from the Sahara in the north of the region and the cool and moist southwest trade wind that blows over the sea from the south Atlantic. The ITCZ moves across the Volta Basin in a complex manner resulting in a uni-modal rainfall pattern in areas that it crosses once such as UER, and a bi-modal rainfall pattern in areas that it crosses twice. The movement of the ITCZ is associated with vigorous frontal activities, which influence the amount and duration of rainfall over the basin (Amisigo, 2005; Andah *et al*., 2003).

Due to this, the rainfall in UER occurs May to October with annual mean ranging between 800 mm and 1100mm, and long dry season from November to mid-April, characterized by cold, dry and dusty harmattan wind. Relative humidity fluctuates considerably from less than 10% during the dry season to more than 65% during the rainy season. The region is generally characterized by low wind speed varying between 0.4 and 2.5m/s. Evapotranspiration is generally high during the dry season and this affects crop water requirements (Mdemu, 2008).

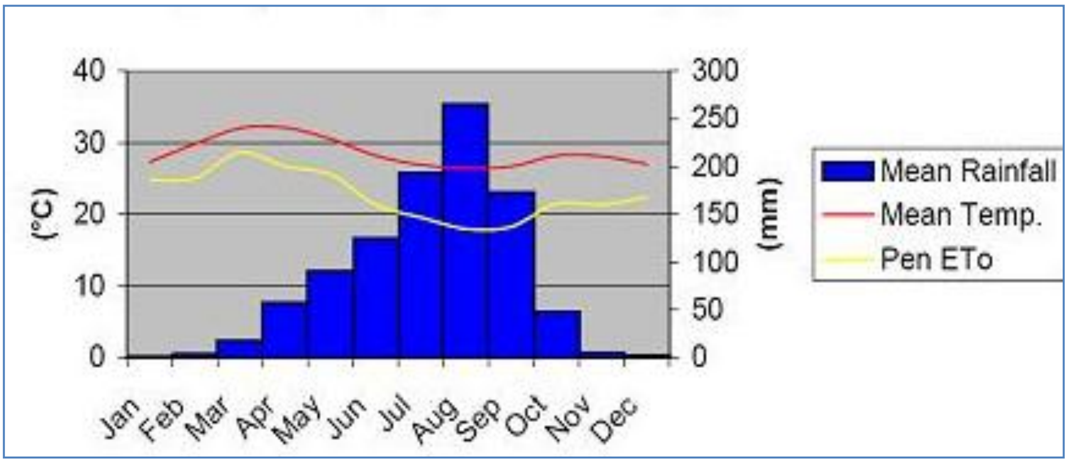

Figure 3.2: Climatic Data at Navrongo Weather Station
(*Source: Liebe, 2005***)** *State Data-Navrongo/ Ghana, lat/long: 10°50'N/1°06'W, altitude: 201.3m, avg. Temp. 28.6° C, avg. Rainfall 986m, avg. ETo 2050mm*

3.3 Geology and Soils

The geological formations covering the UER are mainly divided into three groups, the Granite, Voltaian, and Birimian (Quansah, 2005). According to Adwubi (2008), Soils in UER are generally formed by the weathering of the bedrock which is mainly granite, where some drift of soil transported by wind and water is also found. The soils have predominately light textured surface horizons, shallow and low in soil fertility, weak with low organic matter content, and predominantly coarse textured. Erosion is a serious problem on these soils. Soils in the valley bottoms are heavy textured. Valley areas have soils ranging from sandy loams to salty clays. They have higher natural fertility but are more difficult to till and are prone to seasonal water logging and floods

3.4 Relief

The relief of the area is generally flat, gently undulating with slopes ranging from 1 to 5% except in a few uplands where slopes are about 10% (Adwubi, 2008). The granite areas are generally of low, gently rolling relief ranging from 122m to 260m above sea level. The relief under Voltaian rocks has similar characteristics to granites, with few escarpments rising above 518m near the border with Togo in the east. The mean elevation for the region is 197m above sea level (Mdemu, 2008).

3.5 Vegetation

The UER belongs to the Guinea and Sudan Savannah Agro-Ecological Zones (AEZs). The Guinea Savannah covers large parts of the UER in the western half and southern part of the region, while the Sudan Savannah covers the north-eastern part. The natural vegetation in both zones is that of the savannah woodland characterized by short scattered drought-resistant trees and grass that gets burnt by bushfire or scorched by the sun during the long dry season. The natural vegetation has been modified by human activities resulting in near semi-arid conditions. The most common economic trees are the sheanut, dawadawa, boabab and acacia. Common grasses include *Andropogengayyanus* in the less eroded areas and *Hyperrhenia spp*., *Aristida spp*. and *Heteropogen spp.* in the severely eroded areas (Adwubi, 2008).

3.6 Drainage

The area is mainly drained by the White Volta River (WVR) and its major tributaries, the Red Volta, the Sisili River, Atankwidi River and Tono River (Asante, 2009). The WVR within the UER starts from northeast along the border with Burkina Faso draining all areas along Bawku municipal and West down south. All tributaries south of the WVR in the Gambaga escarpment drain southward away from the WVR (Liebe, 2005). Most of the sub catchments in the UER have developed inland valleys of different sizes and shapes. Small and medium-sized reservoirs have been constructed (Liebe, 2005) in these inland valleys to supply water for crop irrigation, livestock, domestic, fishery and other uses during the dry season.

3.7 Socio-Economic Activities

UER has the highest rural population densities of the country with 80% of the 972,000 inhabitants employed in agriculture with 88% living in poverty (GLSS, 2008). The main crops grown during the raining season by land owners are millet, guinea-corn, maize, groundnut, beans, sorghum, rice while in the dry season, tomatoes, pepper, onions and leafy vegetables are grown. Livestock and poultry production are also important. Irrigation schemes in the area are vital for increasing food security and rural income by providing water for dry season farming, livestock and fisheries (Gyasi, 2005). Industrial activity in the region is generally low, with two industries in operation at the moment. These are the newly built cotton ginnery at Pusu-Namongo (near Bolgatanga) and the Northern Star Tomato at Pwalugu. Other existing industries are the Meat Processing Factory (GIHOC) at Zuarungu and the Rice Mills at Bolgatanga.

CHAPTER FOUR

METHODOLOGY

4.1Introduction

This chapter discusses the selection criteria, materials and the methodologies for the study. The data required for the analysis were obtained using Participatory Geographic Information System (PGIS) tools namely, key informant interview and questionnaire, focus group discussions, mental mapping, observation and transect walk with GPS, and GIS and Remote Sensing for identifying the suitable areas for AWMI.

4.2 Desk Studies

Relevant literature study on Agricultural water management interventions was carried out during the desk study. Among which were articles, journals, thesis, published and unpublished government reports, and reports from NGOs as well as work done by researchers on Agricultural water interventions in the UER were reviewed. The CPWF protocol was studied and used in the questionnaire design.

4.3 Criteria for Selection of AWM Interventions

The study focussed on AWM interventions cases on cropping, livestock or mixed systems in the Upper East Region. The following criteria were used for the selection of AWM interventions during the PGIS data collection in the selected communities:

- Availability of data
- Adoption rate of intervention
- The age of the project completions is more than 18 months to know how the people have sustained the project without any external support
- It focuses on smallholder farming systems in crop, livestock and mixed systems in the area

The measure of success of the AWM interventions in the communities was based on the overall increase in:

- Adoption of intervention
- Economic output- well being of farmers; income, increase yield, crop diversity

Based on the above criteria, seven communities in four districts in UER were identified by key stakeholders during a consultative workshop as successful AWM interventions' communities and used for the study.

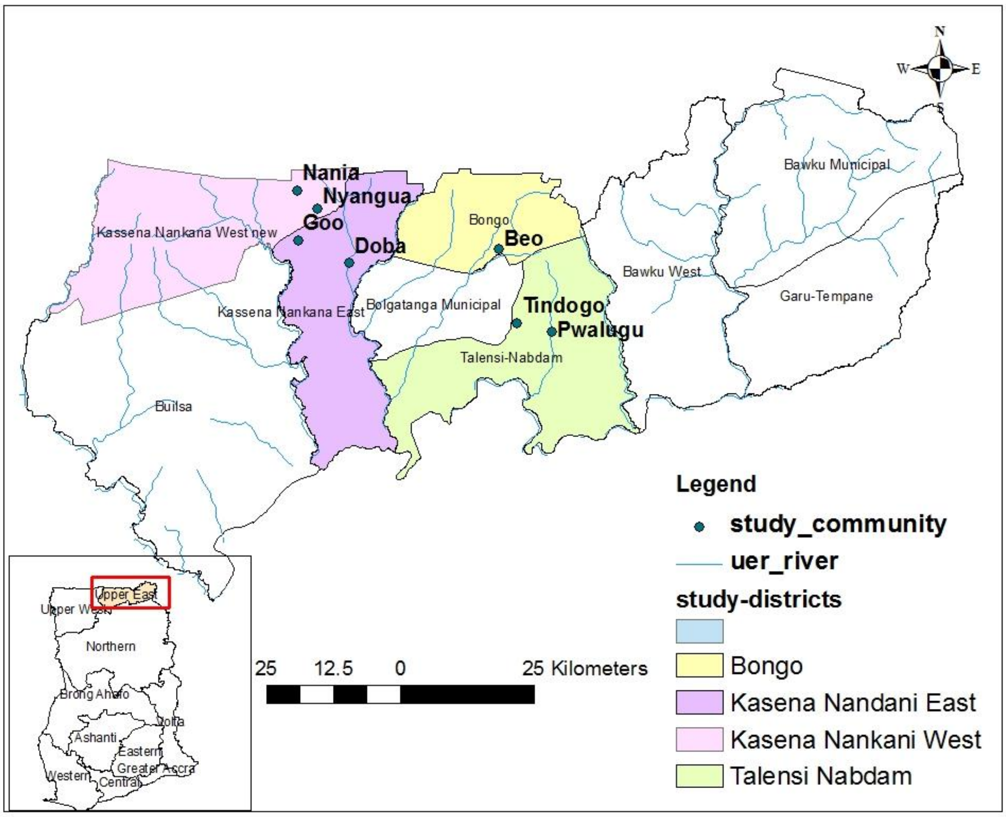

Figure 4.1: Map of the UER showing the study communities

4.4 Identifying and Assessing Existing AWM Interventions

In order to make use of the knowledge acquired by local communities and to understand socio-economic circumstances relating to AWMI, Participatory Geographic information System (PGIS) tools were used.

4.4.1 Key Informant Interviews and Focus Group Discussions (FGD's)

The interview was complemented by focus group discussions and questionnaires to explore further the existing AWMI in the area with the help of maps from Google Earth as shown Plates 1 to 3. The relevant stakeholders considered were grouped into two, the experts or the projects level stakeholders and the community level stakeholders. The project level stakeholders involved in the FGD were Ministry of Food and Agriculture (MOFA), Ghana Irrigation Development Authority (GIDA), Water Resource Commission (WRC), Savannah Agricultural Research Institute (SARI) and International Development Enterprise (IDE). The members involved at the community level were the chief or his representative, assembly member, women's leader, chief farmer, chief fishermen (if applicable), opinion leader, two WUA executives and four additional farmers using the interventions. The field survey focused on the type of AWM practiced, farmers' experiences and constraints, duration of water storage, water uses and application methods. This helped to understand the bottlenecks and successes of AWM interventions in UER. The socio economic assessment of interventions also helped to identify the type of AWM interventions for which the suitability map(s) were developed.

Plate 4.1: Interview and questionnaire administration to a farmer at Nyangua

Plate 4.2: FGD with communities' stakeholders at A- Doba and B- Beo

Plate 4.3: FGD with community stakeholders at Pwalugu.

4.4.2 Mental Mapping

Mental mapping uses satellite images (Google maps) whereby experts and community members are encouraged to participate in the location of prominent features and landmarks on the maps. A tracing sheet was overlaid on the photomap and geo-referenced. Key features were identified with GPS during the field survey and marked on the photomap. Some of the features mapped included their farmlands, the type of crops grown, suitable area for crops, good soil, slope levels and others.

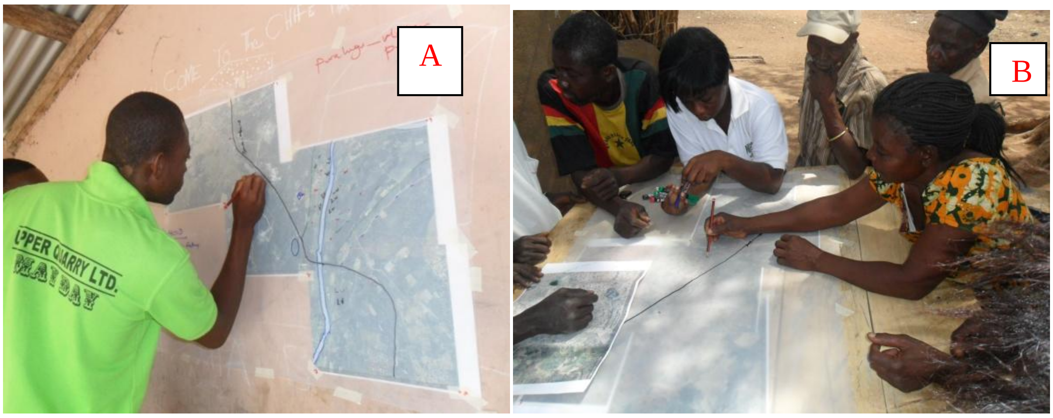

Plate 4.4: Mental Mapping at A- Pwalugu and B- Doba.

Plate 4.5: Mental Mapping for Nyangua.

4.4.3 Field Observations and Transect walk with GPS

A series of random visits to selected communities, such as the treadle pumps at Nyangua, Nania reservoirs site, Goo reservoirs and others, were made to collect information on the production, livelihood improvement as a result of AWMI. Transect walk with GPS was used to collect coordinates of interventions sites, landmarks and key features.

4.5 Mapping of Agricultural Water Management Interventions Potential

4.5.1 General Approach

The identification of suitable areas for AWMI is a multi-objective and multi-criteria problem. Literature reviewed and information obtained from experts on the biophysical and socio-economic factors (criteria) ware complemented by the farmers during the focus group discussion.

The field survey indicated that most of AWM interventions in the UER focused on small reservoirs, earth and stone bunds. Four suitability criteria (rainfall, soil, land use/cover and slope) for small reservoirs, earth and stone bunds were identified. The methodology employed are as follow: Selection of criteria and assessment of suitability level; assignments of weights to these criteria; collection of spatial data for the criteria including GPS survey to supplement and generating maps for each using GIS tools; developing a GIS-based suitability model which combines maps through Multi Criteria Evaluation (MCE) process to generate suitability maps.

4.5.2 Criteria Selection and Assessment of Suitability Level

Four criteria were selected for the identification of potential areas for small reservoirs, i.e. soil information, rainfall data, topography (slope and aspect), and land use and land cover. For stone and earth bunds, the same criteria were considered. Because of the different scales on which the criteria are measured, MCE requires that the values contained in the criterion map are converted into comparable units. Therefore, the criteria maps were re-classed into five comparable units based on Table 4.1. The suitability classes were then used as bases to generate the criteria maps (one for each criterion). Shown in Fig.4.2 is the flow chart for AWMI suitability maps identification.

Table 4.1: Overall suitability rating and score classes

Suitability rating	Score (1 to 9)	Score (1 to 5)
Optimally suitable	9	5
Highly suitable	7- 8	4
Moderately suitable	6- 5	3
Marginally suitable	4- 3	2
Not suitable	2-1	1
restricted	0	0

Source: Adapted from Girma (2009)

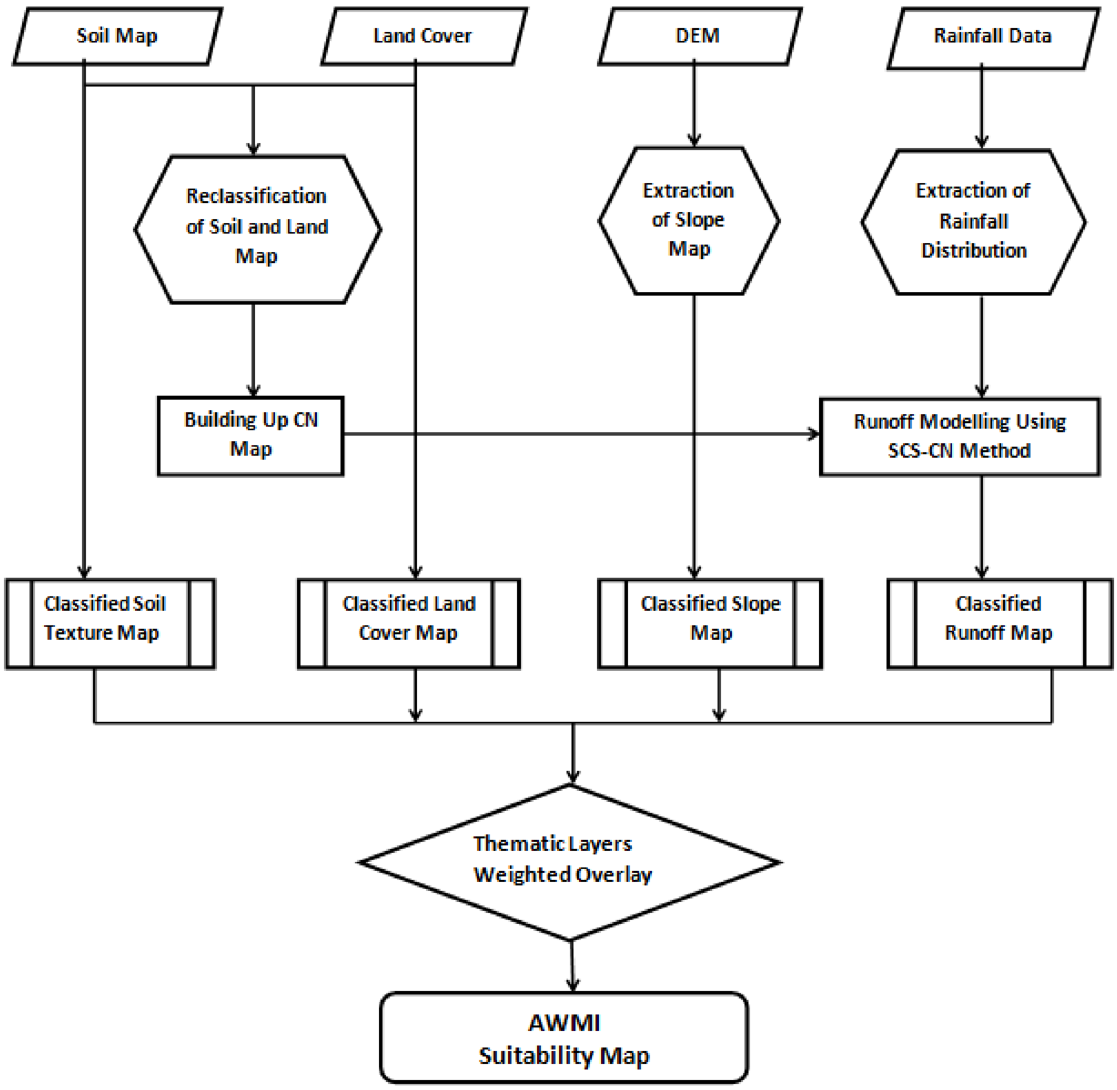

Figure 4.2: Flow Chart for the AWMI suitability identification

4.5.2.1 Rainfall-Runoff Modelling

Rainfall is one of the important parameters that influence water harvesting and storage systems. Apart from rainfall characteristics such as intensity, duration and distribution, there are a number of site specific factors which have direct bearing on the occurrence and volume of runoff. For this study, a variety of data concerned with runoff estimation such as satellite images, Digital Elevation Model (DEM), soil map and rainfall data were used. Soil Conservation Service - Curve Number (SCS-CN) (United States Department of Agriculture, 2007) equations (1 and 2) were used in calculating and generating the runoff map (Fig.4.3).

$$s = \frac{25400}{CN} - 254 \qquad (1)$$

$$Q = \frac{(P - Ia)^2}{(P + Ia + S)} \qquad (2)$$

Where, *Q* is Runoff depth in mm; *P* the Rainfall, mm; *S* the Maximum recharge capacity of watershed after 5 days rainfall antecedent; *Ia* the Initial abstraction of rainfall by soil and vegetation, (=0.2S) and *CN* is the Curve Number. *CN* is determined from the tables below which are based on land-cover, Hydrological Soil Group, and Antecedent Moisture Content (AMC).

The land cover was reclassified according to hydrological condition based on USGS land use and land cover classification system. The hydrologic soil group A to D in the table refers to the infiltration potential of the soil after prolonged wetting. Application of *CN* requires that the soil in the study area be reclassified into four categories (A, B, C and D) as shown in Table 4.2. AMC is expressed in three levels (I, II and III), according to rainfall limits for dormant and growing seasons.

Table 4.2: Curve Number for Hydrologic Soil Group

Description for land use	**Hydrological Soil Group**			
	A	**B**	**C**	**D**
Cultivated (agricultural crop) land*:				
Without conservation treatment (no terraces)	72	81	88	91
With conservation treatment (terraces, contour)	62	71	78	81
Pasture or range land				
Meadow (grass, no grazing, mowed for hay)	30	58	71	78
Brush (good, >75% ground cover)	30	48	65	73
Woods and forests				
Poor (small trees/brush destroyed by over-grazing or burning)	45	66	77	83
Fair (grazing but not burned; some brush)	36	60	73	79
Good (no grazing; brush covers ground)	30	55	70	77

(Source: Chow et al., 1988)

Table 4.3: Main characteristics of Hydrological Soil Groups

Soil Group	**Descriptions**
A	High infiltration (low runoff). Sand, loamy sand, or sandy loam. Infiltration rate > 0.75 cm/hr when wet.
B	Moderate infiltration (moderate runoff). Silt loam or loam. Infiltration rate 0.375 to 0.75 cm/hr when wet
C	Low infiltration (moderate to high runoff). Sandy clay loam. Infiltration rate 0.125 to 0.375 cm/hr when wet.
D	Very low infiltration (high runoff). Clay loam, salty clay loam, sandy clay, silty clay, or clay. Infiltration rate 0 to 0.125 cm/hr when wet.

(Source: Chow et al., 1988)

Although, SCS method is originally designed for use in watersheds of 15km^2, it has been modified for application to larger watersheds by weighting curve numbers with respect to watershed/land-cover area. In this study, the curve numbers were weighted with respect to the micro-watershed area (generally<5km^2) using the following equation;

$$CN_w = \frac{\sum(CN_i * A_i)}{A} \qquad (3)$$

Where CN_w is the weighted curve number; CN_i is the curve number from 1 to any number n; A_i is the area with curve number CN_i; and A the total area of the micro watershed.

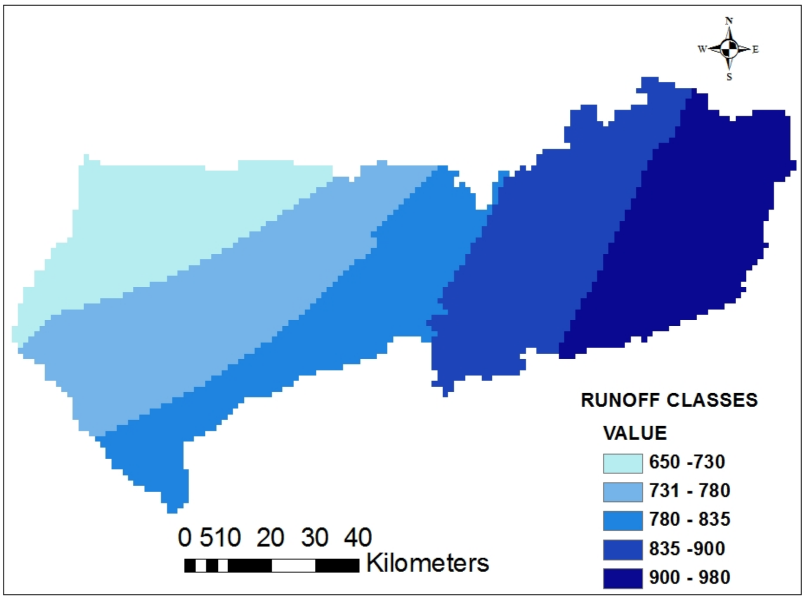

Figure 4.3: Runoff map.

4.5.2.2 Soil Type and Texture

The suitability of a certain area either as catchment or as cropping area for AWMI depends strongly on its soils characteristics. The infiltration rate of the soil determines the type of structure to be located and the surface runoff potential also depends on the soil texture of the area (Jasrotia and Dhiman, 2002; Majhi *et al*., 2009; Ngigia *et al.*, 2005). The soil texture attributes was based on the dominant soil type map and extracted from the FAO/UNESCO soil. These characteristics were identified based on the soil class attributes on FAO Guidelines (DSMW, 2007) as shown in Fig.4.4.

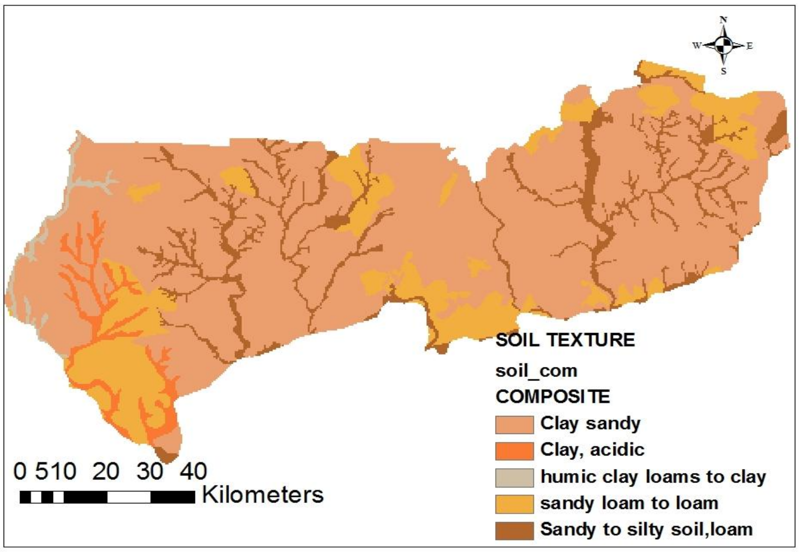

Figure 4.4: Soil texture map ***(Source: FAO, 2012)***

4.5.2.3 Land Use and Land Cover

Land use/cover is the parameter that affects surface runoff and the area for AWMI. As this study focused on AWMI for crop production, both in-situ and reservoirs should be located close to agricultural areas or croplands. The land cover was obtained from supervised classification Landsat ETM + of 2003 of the Volta Basin. Five main land cover classes (cropland (>50%), cropland with open woody vegetation, deciduous shrub land, deciduous woodland and water body) were obtained from the classifications (Fig. 4.5).

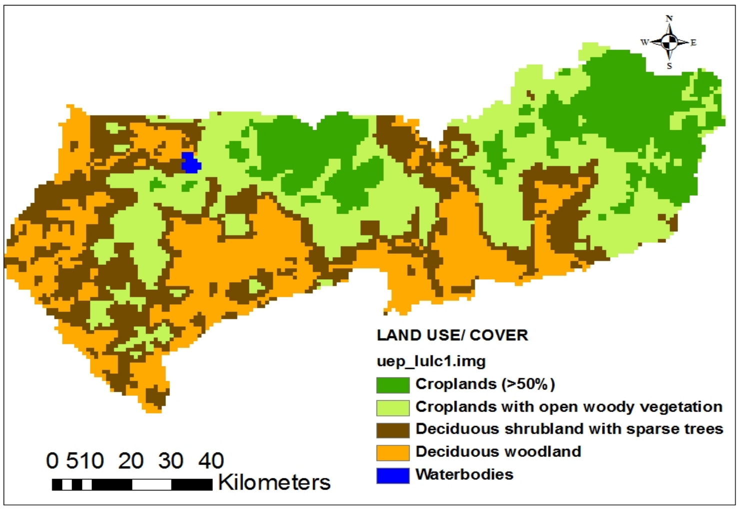

Figure 4.5: Land use/cover map of the study area

4.5.2.4 Slope

The slope of land is important in site selection and implementation of all ground-based AWM systems, especially small reservoirs, weirs, stone and earth bunds. Slope data was generated from the DEM grid corresponding to the boundary of the region. The slope (in percentage) data is then classified into five categories according to FAO guidelines (FAO, 2002). The derived slope map (Figure 4.6) was categorized into five classes and has different percentages of the study area such as Flat (0–2%), Undulating (2–8%), Rolling (8–16%), Hilly (16–30%) and Mountain (30-100%).

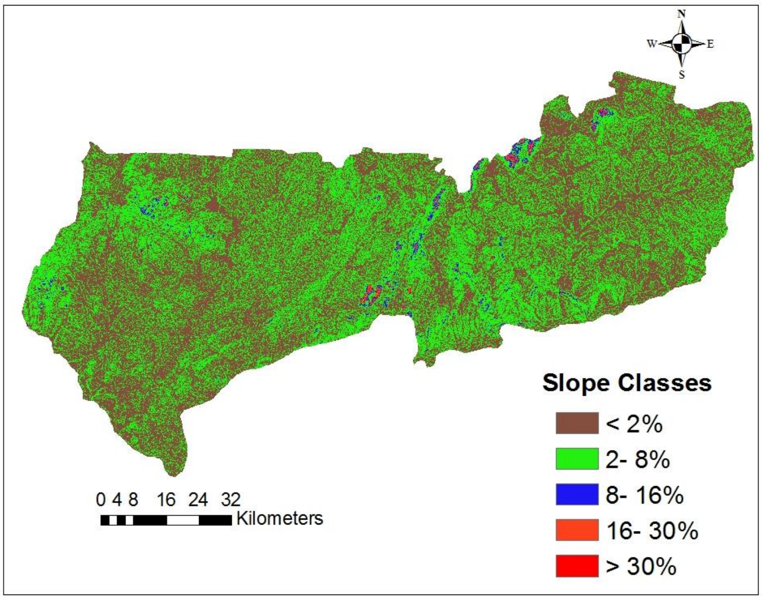

Figure 4.6: Derived slope map of the study area

4.5.2.5 Socio-Economic Factors

The socio-economic condition of an area considered for AWMI plays very important role in planning, designing and implementation. Some of the socio-economic factors considered for the evaluation criteria include: distance to road, river, market place and forest area. To achieve this, 1km, 200m and 100m buffer zones were created around road, river and forest in the region. Proximity to road was considered a benefit as road generate runoff which can be diverted to either cultivated land or to reservoirs for storage at minimal cost (Mutiga, 2011).

4.5.3 Establishing the Criteria Weights

Since not all the criteria are equally important for the identification of potential AWMI areas, different weights were assigned to the criteria. For the development of weights, the pair wise comparison known as the Analytical Hierarchy Process (AHP) developed by Saaty (1977) was used. Pair wise comparison concerns the relative importance of two criteria involved in determining the suitability for a given objective. The rating between two criteria is provided on a 9-point continuous scale ranging from extremely less important to extremely more important. The weight index of comparative importance is estimated using the pair-wise comparison matrix (Tables 4.4, 4.5 and 4.6) by computing the principal Eigen vector (Table 4.7). The relative importance for each intervention was based on the various studies, including Mbilinyi *et al*. (2005) and Prinz, (1996).

Table 4.4: Pair-wise Comparison matrix for Small reservoirs site selection

	Runoff	**Soil**	**LULC**	**Slope**
Runoff	1	9	9	9
Soil	1/9	1	7	1/8
LULC	1/9	1/7	1	5
Slope	1/9	8	1/5	1

Table 4.5: Pair-wise Comparison matrix for Earth bund site selection

	Runoff	**Soil**	**LULC**	**Slope**
Runoff	1	8	8	8
Soil	1/8	1	7	1/6
LULC	1/8	1/7	1	5
Slope	1/8	6	1/5	1

Table 4.6: Pair-wise Comparison matrix for Stone Bunds site selection

	Runoff	**Soil**	**LULC**	**Slope**
Runoff	1	7	7	7
Soil	1/7	1	6	1/5
LULC	1/7	1/6	1	5
Slope	1/7	5	1/5	1

Table 4.7: RIW percentage influence of parameters

Parameter	**Relative Importance Weight(RIW)%**		
	Small Reservoir	**Stone Bunds**	**Earth Bunds**
Runoff	59%	56%	58%
Soil	14%	15%	15%
LULC	12%	14%	13%
Slope	15%	15%	14%

All the processing in finding AWMI suitability map has been implemented in a suitability model developed in the model builder of ArcGIS 9.3. The suitability model generates suitability maps for AWMI by integrating different input criteria maps using Weighted Overlay Process (WOP) also known as Multi-Criteria Evaluation (MCE). MCE can be achieved by a weighted linear combination (WLC) wherein continuous criteria (factors) are standardized to a common numeric range, and then combined by means of a weighted average.

With a weighted linear combination, criteria are combined by applying a weight to each followed by a summation of the results to yield a suitability map using the following equation:

$$S = \sum W_i X_i$$

Where S = Suitability; W_i = weighted factor i; X_i = criterion score of factor i

4.5.4 Validation

Validation of the suitability maps was done by cross-checking the suitability map with existing AWM interventions. Testing aimed at checking the quality performance and reliability of the system. Global positioning system (GPS) readings were taken on existing AWM systems and incorporated in the ArcGIS environment for analysis. During the GPS survey, readings were taken from both successful and failed areas.

CHAPTER FIVE

RESULT AND DISCUSSIONS

5.1 Identification of the Agricultural Water Management Interventions

From data collected from the field survey, more than 30 Agricultural water management interventions sites in UER were identified. For the purposes of this study, seven sites with six interventions were selected for further discussion based on the criteria. The interventions selected for further studies are displayed in Table 5.1 while Fig. 5.1 shows map of the location of the interventions and the communities.

Table 5.1: The identified Interventions, their Districts and Communities

INTERVENTION	COMMUNITY	SOURCE/OWNERSHIP	Service providers
Stone Bunds	Tindogo	Indigenous/Individual	Farmers
Motorized Pumps	Pwalugu	Imported/Individual	MOFA/ Farmers
Earth Bunds	Beo	Semi-indigenous/ individual	MOFA(NRGP)/ Farmers
Shallow Wells	Doba	Indigenous/Individual	Farmers
Small Reservoir	Nagalkania(Goo)	Imported/community	MOFA/WUA
Small Reservoir	Nania	Imported/community	MOFA/WUA
Treadle Pumps	Nyangua	Imported/Individual	IDE-Ghana

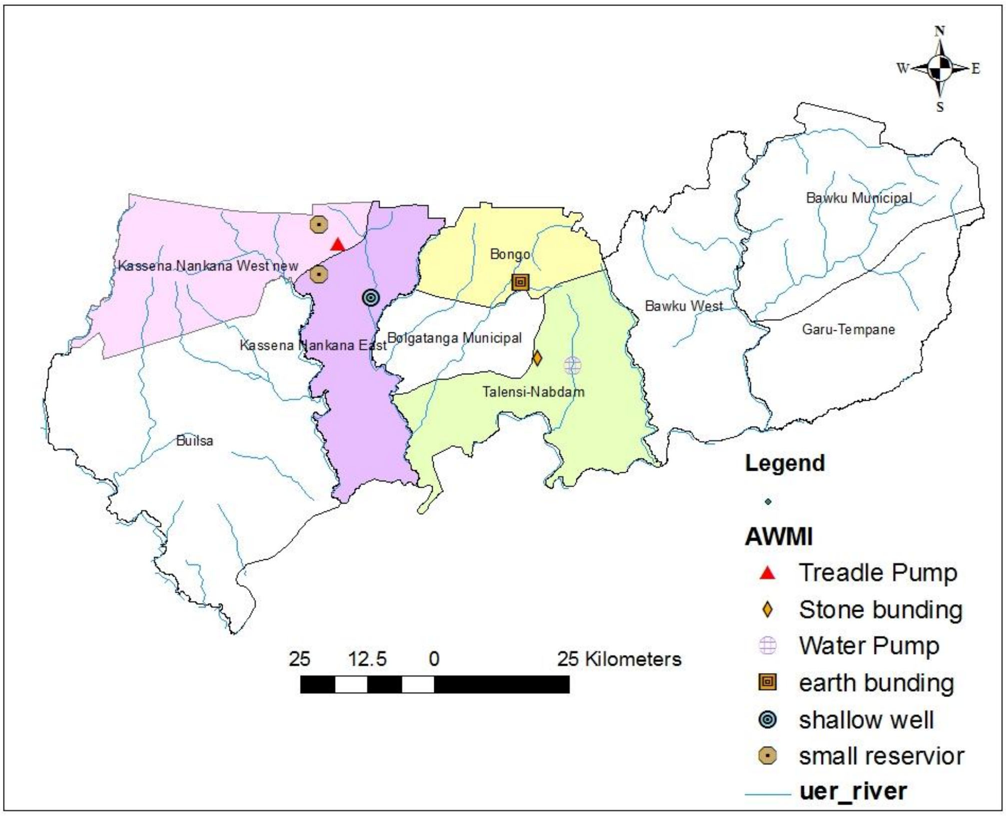

Figure 5.1: Map of UER showing AWMI of the study area

5.1.1 Source and Ownership of the AWM Interventions

According to the survey, the identified AWM interventions used in UER are mostly imported interventions, even though commendable effort has been made for adapting most of them into local conditions except shallow well and stone bund which are indigenous.

These are owned and managed differently. The shallow wells, treadle pumps and some small motorized pumps are owned by individuals and for that matter their management in terms of operation and maintenance, and control of water is quite easy. In contrast to the small reservoirs they belong to communities and thus managed by those communities or Water User Association (WUA) of the community. The management system of small reservoir irrigation schemes employed within the region is communal with the set-up of Water User Association (WUA) being the managers of the system.

5.1.2 Main Use of the AWMI

The uses of these interventions with other agricultural production techniques have improved the livelihoods of the local people during the raining season and the dry season. This is shown in Figure 5.2 below. Eighty three percent of the people practise rainfed farming (WRC, 2008), while 38% and 35% of the total population also practice irrigation and livestock respectively. It is important to mention that some farmers engage in more than one of the activities such as irrigation and livestock, rainfed farming and livestock keeping or rainfed farming and irrigation.

Some patterns in the use of the AWM interventions with respect to crop choice are evident (Table 5.2). During the dry season, farmers use the AWMI to grow high value crops and horticultural seedlings. The earth and stone bunds are used by farmers, mainly to cultivate staple food crops such as maize, sorghum, millet, rice, beans, soya beans and cassava. The two selected reservoirs used in this study are for multiple purpose uses such as livestock watering, domestic purpose, cropping and construction during the dry season, whilst, treadle pumps and motorized pumps are used for growing high-value crops and raising seedlings for the raining seasons.

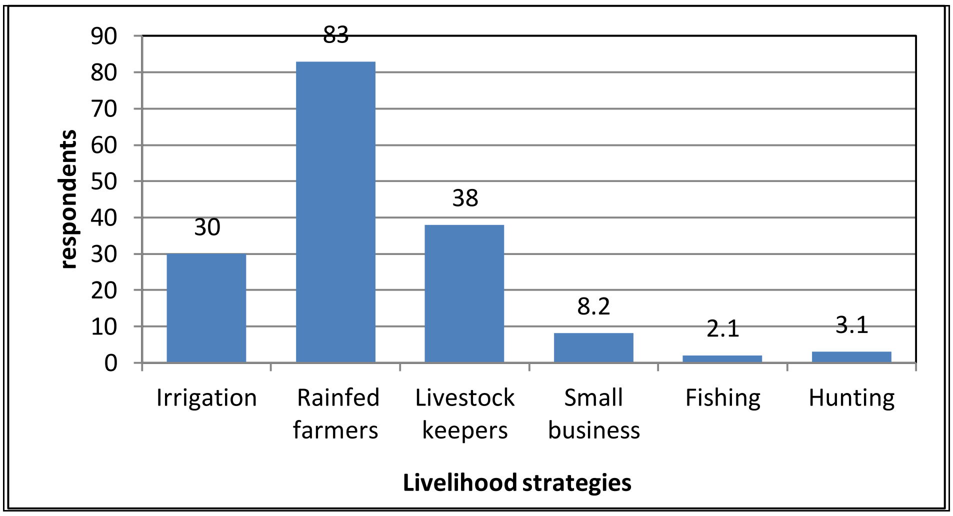

Figure 5.2: Livelihood strategies in the study area.

Table 5.2: Study communities with their AWMI and their crops produced

INTERVENTION	COMMUNITY	CROPS/ENTERPRISES
Stone bunds	Tindogo	Millet, sorghum, maize, soya beans, okro, garden egg
Water pump	Pwalugu	Vegetable (tomatoes, onions, leafy, pepper, okro) and maize
Earth bunds	Beo	Rice, maize,
Shallow well	Doba	Tomatoes, onion, sweet pepper, okro, garden egg
Small reservoirs	Nagalkania (Goo)	Livestock, vegetables (pepper, tomatoes and okro) and for domestic
Small reservoirs	Nania	Livestock, vegetables (pepper, leafy and okro), constructions and domestic (washing)
Treadle pump	Nyangua	Vegetables (tomatoes, leafy, pepper, okro)

5.1.3 Adoption and Adaptation of Interventions

Conditions for adoption of AWM interventions vary according to local settings and agricultural conditions. It was observed that, AWM interventions identified by experts are adopted by farmers on a greater scale because of their suitability to the local conditions, i.e. addressing farmer's needs, capacities and the service that are realistically available.

The results from Figure 5.3 show that the number of households using treadle pump in Nyangua has not changed since 2009. The reason is due to cost of treadle pump and the unreliable water source during the dry season. In Doba, the adoption rate for shallow wells has increased tremendously from 20 households to 330 households. The high adoption was due to increase population, migration of some Burkinabe into the area and the high water table during the early dry seasons. Again, the Doba reservoir and irrigable lands have not been able to satisfy farmers, and this has caused most of them to adopt shallow wells on the flood plains of the Nayari River for dry season farming. In Nania and Goo, the adoption rates increased after rehabilitation of the reservoir in 1997 and 1994 respectively. Adoption increased from 38 to 43 households and 80 to 125 households in Goo and Nania respectively. Moreover, the stone and earth bunds adoption have also increased from 3 to 45 households and from 1 to 145 households respectively. The reason is mainly due to the availability of the construction material and the apparent improvement in livelihoods of those who started first. The adoption of the motorized pumps in Pwalugu has also increased from 2007 to 2011. However, due to the cost of pump, 3 women out of the 143 farmers are using pumps.

Some of the AWMI are dominated by men and others by women. Example at Nania Reservoir, 350 women against 300 men are into dry season farming. Other constraints are lack of finance, unreliable water sources from the shallow wells, land tenure problem and high cost of labour involved in stone and earth bunds.

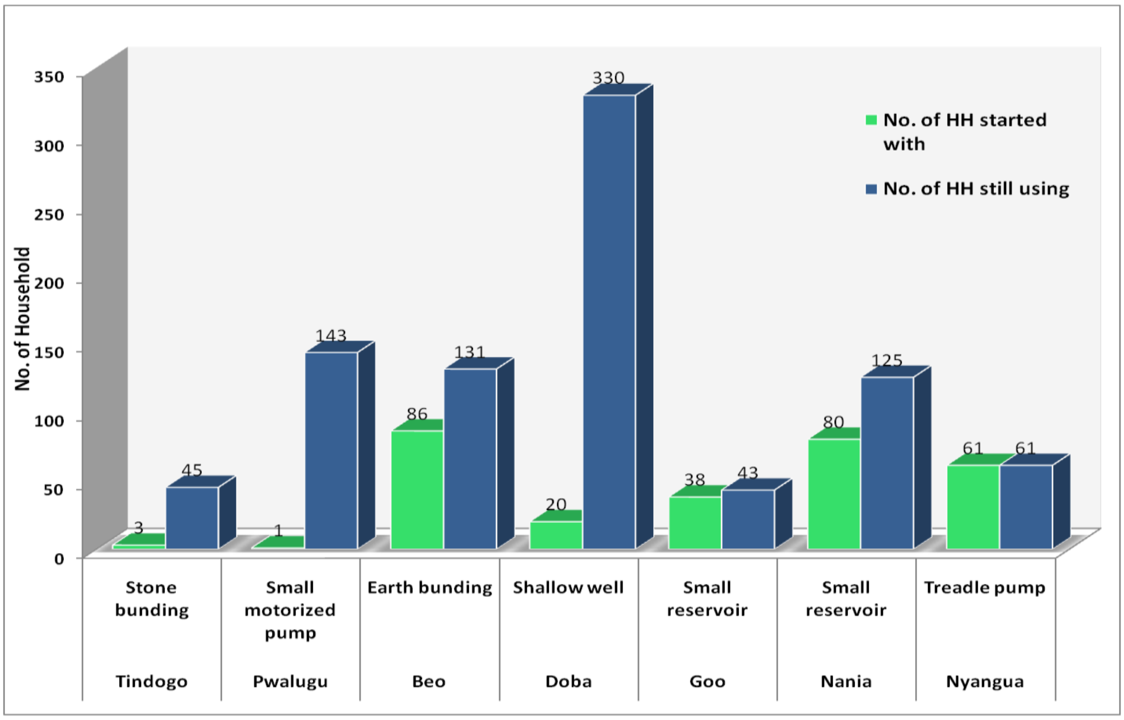

Figure 5.3: Number of Household (HH) started and still using AWMI

5.1.4 Performance and benefit of AWMI

Most of the Agricultural water management interventions have performed well possibly due to different uptake and water availability. Due to the limited amount of resources, farmers manage and conserve water, e.g. shallow wells farmers at Doba use sunken bed with bucket to water their crops for effective water use. Again, farmers at Pwalugu always pump what they need and save fuel for next use due to the cost of fuel. The hunger gap reduced from 5 months (February to June) to 2 months (May to June) due to the increased crop yield in maize, sorghum and onion (MOFA, 2006).

According to the survey, the livelihoods of the farmers have improved in so many ways. However, the drawback has been that it has not always been possible to quantify this economic contribution. Cash earnings from the sale of produce are used to supplement grain deficits from rain fed harvests and also used to finance other domestic needs such as health (NHIS), education, transport, housing and investing in livestock as security. The reservoir serves as a source of water for livestock in the communities, and the fisher folks which helps them to increase their catches which are sold in the communities to improve nutrition.

5.1.5 Cost

The operation and maintenance for most systems are solely done by farmers, with the exception of the small reservoirs and the primary canals which the government through GIDA assists with repairs. The spare parts of treadle pump and motorized pump are available on the markets, and farmers only buy them to undertake repairs.

5.1.6 Environmental Impact

There have not been any severe environmental issues with the exception of the small reservoirs, which aid in the breeding of mosquitoes. The stone and earth bunds have helped in the reduction of soil erosion, retain water, promote better vegetation cover and increase the protection of drainage basins. The surface water is usually of good quality for irrigation. The people use ground water for domestic purposes and for that matter the livestock droppings in the surface water have not been a problem but rather a source of nutrient for the crops. The problem associated with the small reservoir most of the time is siltation and evapotranspiration.

5.1.7 Enabling Environment

The Irrigation policy for the county which was formulated in line with existing legislature governing land and water resources management in Ghana has helped the activities and growth of the sector. NGOs/CBOs have been involved in the formation and development of credit groups. Their role was very important in strengthening the capacity of the rural poor to access and manage credit. The farmers also agreed that the fertilizer subsidy also contributed to the improvement.

Access to market is a critical precondition for the success of any intervention. Because of varying local conditions and changes in the road network, different market opportunities exist in different locations. According to the survey, farmers at Pwalugu have market because of the Tamale to Navrongo road that passes through their community.

There has not been an issue of conflict in relation to selected interventions and between different livelihood strategies or different users. During the dry season, livestock are not tethered and for that matter, farmers either stay on their farms or fence their farms to prevent them from being destroyed.

The land tenure system is viewed by most farmers as a limitation. Ownership of land is not guaranteed so farmers are unable to make long term plans. This is especially true for places like Doba where the original land owners leased out their land in the dry season and take them after the season to do rainfed farming. Farmers destroy the temporal shallow well interventions and rebuild in the next dry season if they get land to farm.

5.2 Earth Bunds

The earth bunds intervention was introduced by the Ministry of Food and Agriculture through the Northern Rural Growth Projects (NRGP) in the three northern regions and northern part of Brong Ahafo region of which Beo in the Bongo district of UER was included according to the monitoring and evaluation officer of MOFA. The Beo community was selected based on the availability of material for the construction of the intervention. About 86 household benefited from the project and now the whole community benefit from it. The name of the project was Soil and Water Conservation through earth and grass bunds (Plate 5.1).

Plate 5.1: Earth Bunds at Beo in the Bongo.

5.2.1 Level of Community Involvement

Through meetings and trainings, the people in the community got involved in the use of the intervention; they formed groups which enabled them to get loans to practice the intervention successfully. Again through consultation, the community was given the chance to select the interventions that suited the area. The project team and other partner organizations periodically educate community members on how to raise the bunds. They also give them support on credit facilities in the form of farm inputs and grants. As a result, the farmers are always willing to make investment in the AWM interventions improvements.

5.2.2 Impacts on Crop and Livestock Production

Overall, the intervention resulted in improvement of cropping in the community, though the number of harvests after the intervention for rice still maintains once every year. The average yield of rice after the intervention has increased from 0.55 metric tons per hectare to 1.59 metric tons per hectare (Figure 5.4) and average yield of maize and millet increased from three (3) bags to six (6) bags, while that of groundnut increased from five (5) bags to ten (10) bags per/acre.

The introduction of the intervention has changed the water management system in the community. Before the intervention, a short period of draught caused the crops to show signs of water stress, but after the intervention they still stayed green during short draught periods. The improvement was linked to other farm inputs like fertilizer subsidies and improved seeds. By 2010, farmers started realizing improvement in their farms. Overall, the project increased sustainability of crop production and improved soil moisture and fertility by preventing soil erosion and maintaining soil moisture. The residue from harvested crops supplement livestock feed especially during the dry season thus reducing the risk of them getting lost or dying.

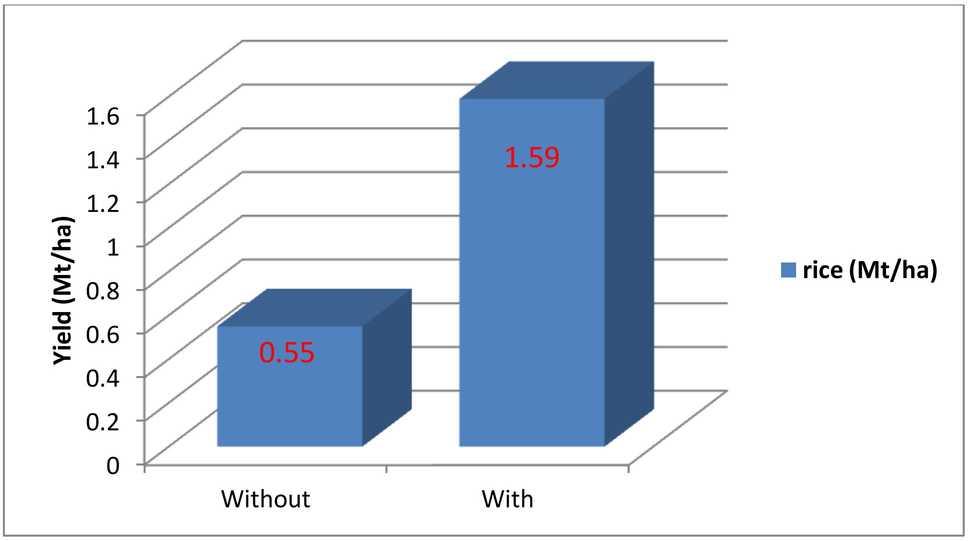

Figure 5.4: Changes in rice yields with use of earth bunds in Beo.

5.2.3 Cost of Intervention

According to the farmers, initial investment would cost seventy Ghana Cedis (GH¢70.00) while that of maintenance could be about fifty Ghana Cedis (GH¢50.00) per season. Farmers use their family and friends to build the bunds to make it affordable.

5.2.4 Conflict Management

The severity of conflicts in the community between livestock owners and crop farmers have increased since some of livestock owners leave their livestock on free range when the crops are not yet harvested. Farmers in the community always settle the disputes themselves but when the dispute gets out of hand, the chief intervenes and the offenders are punished.

5.2.5 Enabling Environment

Farmers sell their crop and livestock produce at Bolga, Akanyange, Soe and Guelwongo markets. They normally transport their produce to the market centers by walking, cycling, use of donkey carts and the few vehicles that ply the road. The provisions of new roads as well as the fertilizer subsidies also helped in the achievement of the successful implementation of the intervention.

5.3 Motorized Pump

Small-motorized pumps are quite popular among vegetable producers throughout the country. The motorized pump was introduced at Pwalugu by one farmer in 1977, hitherto, the use of watering cans along the White Volta River was more common (Plate 5.2). Because of the returns made that year, other farmers joined in the use of the motorized pump. Some of the communities along White Volta River such as Arigu, Bisigu, Yaridure, Gua, and Karimehga also joined.

The small motorized pump is solely powered by fuel (diesel). The government subsidises cost of fuel, which has made it more affordable for farmers. The water pumped from White Volta River is used for crop irrigation, whilst natural ponds close to the river are used for watering livestock. There is no restriction to the water usage. Farmers use bunds, basin and ridges which help the soil to conserve and retain water.

Plate 5.2: Small motorized pump used along WVR.

5.3.1 Level of Community Involvement

In 2007, MOFA gave four (4) water pumps under the FAO project to some group of farmers at Pwalugu. These have helped them to purchase their own water pumps numbering 143.

The project team provided practical training in proper water use, soil and farm management to the farmers, to ensure successful implementation. They were also introduced to early maize, and production of more leafy vegetables for the local market during the dry season. The farmers were quite willing to make investment in the AWM intervention's improvements. However, the project team assisted some of them with loans, but some farmers defaulted in payment and this has affected others. All the same, MFIs and MOFA have tried to support farmers with some loans.

5.3.2 Cost of Intervention

The initial investment cost of a motorized pump with all the accessories such as water hose and PVC pipe of length 300m, according to farmers will be about GH¢730.00 with maintenance cost of about GH¢50.00 per year. Fewer women have involved themselves in the use of the motorized pump due to the high cost involved.

5.3.3 Impacts on Crops and Livestock Production

Overall, the intervention has helped in crop production in the community; this has brought about three times cropping in the year. Before the intervention, farmers were using water cans and for that matter, small areas were cultivated mainly for home consumption.

The introduction of the intervention has also helped in water management. Farmers now grow different crops (tomatoes, onion, maize and leafy vegetable) in large quantities. The improvement was linked to other farm inputs like fertilizer, pesticides and improved seeds. Overall, the project improved sustainability of crop production by increasing crop production and also improved soil fertility by preventing soil erosion.

5.3.4 Enabling Environment

Farmers mostly have ready markets. Market women from the southern part of the country buy their produce at the farm gate. Farmers sometimes transport their produce either on bus, motorbike, bicycle or cart/donkey to the Pwalugu market, the Tomato Factory and Bolga to sell. The construction of the Tamale-Navrongo road, with changes in governmental policies as well as the fertilizer subsidies have helped in the achievement of the successful implementation of the intervention according to farmers.

5.3.5 Impacts of the Motorized Pump: Environment and Human

The farmers engage in collective farming as a result of farmers grouping. They have the vegetable farmers association, livestock farmers association and the cereal farmers association.

The key lesson learnt was that due to the perennial and reliable nature of the river, more water pumps are being used which has resulted in an increase in crop production. The key factors for wider uptake could be the good supply of input and the extension of education.

5.4 Treadle Pump

The treadle pump intervention is solely a private initiative undertaken by the International Development Enterprise (IDE) in the Upper East region. The project was started in the year 2009 and it is still on–going. So far, this have been established in about five communities, namely Navio, Nyangua, Doba, Teshie (Bawku), and other communities where they have permanent wells and the water table is not less than seven metres. The Treadle Pump has paddles like bicycles where farmers paddle to pump water from shallow wells where the water table is high, and with a suction depth of about 7m. There are two types of the treadle pump used in UER namely the fixed wood treadle and the movable metal treadle pump as shown in the Plate 5.3.

Plate 5.3: A- Movable metal treadle pump and B- Fixed wood treadle pump.

There are no water quality issues regarding the use of the technology. It is also a very resilient intervention because it is not easily reservoirs aged. The inputs required to utilize the intervention successfully are; flexible hose, PVC pipes, wood, and treadle pump machine. The intervention is man powered and can be utilized successfully by men, women and even children.

5.4.1 Level of Community Involvement

IDE assisted and facilitated formation of groups of farmers who were willing to use it and introduced them to a Micro Finance Institution (MFI) for them to access loans to purchase the pumps.

Farmers and local agents were given training on the proper installation techniques, use, maintenance and repairs of the treadle pump. It was quite easy for farmers to adopt the intervention and did not modify their farming/cropping system. The community used local materials to modify the physical outlook of the pump by the construction of seat for people to sit and operate the pump. In order to have access to the loans, the farmers formed groups and this enabled them gain ownership of the pumps as well.

5.4.2 Cost of Treadle Pump

According to farmers, the cost of using the fixed wood type is about GH¢94.00 and GH¢164.00 for movable metal treadle pump. With assistance from MFI, farmers were able to purchase treadle pumps and some other inputs. According to IDE, the maintenance required was provided by a locally trained person at a small fee (GH¢5-15) depending on the fault.

5.4.3 Impacts on Crop Production

The introduction of the intervention has resulted in the improvement of cropping diversity, thus farmers now grow pepper, tomatoes, okra, and garden eggs as compared to the crops grown before. The critical crop growth stage is when the crops are maturing which did not change after the introduction of the intervention

The community realized this improvement in the year 2009. The improvement was also linked to other farm inputs such as fertilizer and pesticides. In general the project has increased the sustainability of crop production.

5.4.4 Enabling Environment

Farmers go to the Paga central market, Navrongo market, Manyoro and Navio markets to sell their produce. They do so by means of carrying head loads and walking or by using bicycles or carting with the donkey or power tiller-trailer.

5.4.5 Impacts of the Treadle Pump on Environment and Human Being

The available water is of good quality hence its use is not hindered in any way. The amount of farm labour has changed after the introduction of the intervention in the community because the wells are lined and pumping to lift water is easy which also controls erosion of the walls and contamination of water by soil particles.

The farmers now spend less time in watering the crops, and get more time for other pressing things. Farmers are able to expand their farms provided the water table is high. Farmers have gained knowledge on farm management as a result of the intervention. The community was also quite willing and able to make financial and other investments in AWM interventions.

With regards to the intervention, there are no clearly defined roles for men and women. The treadle pump intervention is gender friendly especially to women and children because it is very easy to use (Plate 5.4).

Plate 5.4: A- An old woman and B- A small boy using treadle pump

5.5 Small Reservoirs

The selected small reservoirs for this study were projects undertaken by MOFA under LACOSREP at Nangalikinia– Goo in Navrongo and Nania in Paga in 1996 and ended in 1997 (Plate 5.5). The intervention is used multipurposely for irrigation, fishing, livestock watering, washing and building. The water flows under gravity to the irrigable area. The intervention is working well due to water availability as a result of high water table and siting of the reservoirs in the main watercourse (Fig. 5.5).

Plate 5.5: Goo dam at Navrongo.

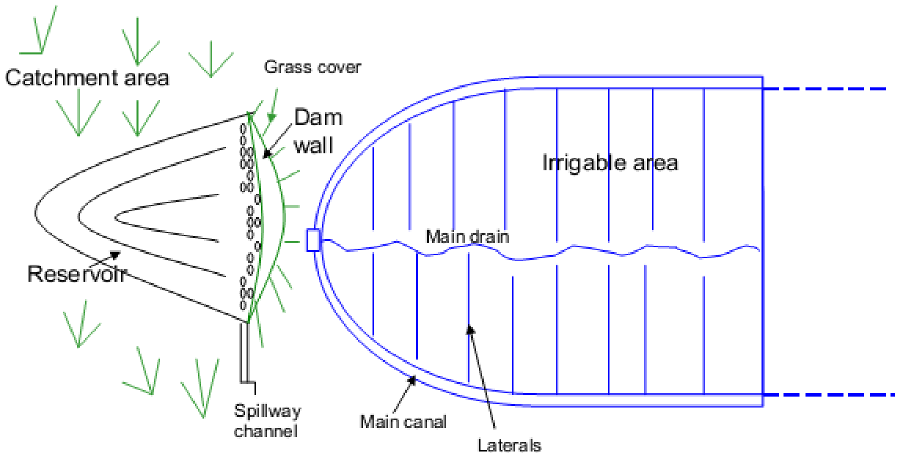

Figure 5.5: Schematic presentation of a small reservoir system.

Source: Gyasi, 2005

5.5.1 Level of Community Involvement

The interventions started at Goo and Nania with 38 and 80 households respectively, have now increased to 43 and 125 respectively. The communities were involved right from the conceptual stage, thus the community submitted proposals and wrote letters requesting for the reservoirs to be rehabilitated and its capacity increased.

The usage of the intervention had specific considerations for men and women. The men were not to dominate the leadership roles of the committees formed to manage the resources. The women were to be allocated to about 40% of the available irrigable areas and given specified positions on the committees formed.

The adoption of the intervention by the communities were enhanced through the organization of meetings, training sections and formation of water user associations (WUA’s), this then made the adoption very easy. But this did not affect the farmers’ cropping system or work approach in any way.

The Water User Association (WUA) organise, register and share plots for farmers who express interest in using the small reservoirs, and decide on water levies and collect water levies for the maintenance of canals and other infrastructure. They again manage the use of water by controlling the release of water to the farm plots. The project was handed over to the formed WUA’s and the communities.

5.5.2 Impacts on Crop and livestock Production

Overall, the intervention has resulted in the improvement of cropping and livestock keeping. The major impact was felt a year after the commencement of use of the intervention in 1999. This is so because there has been increase in terms of average yields after the intervention. The crops grown are mainly vegetables during the dry season. Farmers sometimes harvest twice if there is adequate water before the season ends. The livestock also gets fed after harvesting and water during the season.

5.5.3 Enabling Environment

The closest market for farmers to sell their produce (crops and livestock) is the Navrongo market about 2km from the community and or the Bolga market which is about 32km from the community. They do so by bicycle, motorbike, lorry/bus, donkey cart, or walking, and even sometimes at the farm gate.

5.5.4 Conflict Management

There have been instances of conflict among different users as a result of the intervention. Vegetable farmers wanted to use the water to the last drop while livestock owners wanted the crop production halted for animals to be watered till the beginning of the main season and fishermen also wanted to fish at all times. These conflicts were resolved through educating the various users.

5.5.5 Environmental and Human Impacts

The intervention has impacted positively on the lives of the community members. Thus the consumption of vegetables has improved the nutritional status of the people. This has also helped in bringing the people together and through the WUA's they are able to access some farm inputs and training. Farm labour is now required year round and this has impacted positively on the farmers thus increasing their earnings from the farming activity. However, the water becomes very turbid during the month of March because it gets to its lowest level and in April it sometime dries out.

5.6 Stone Bunds

The intervention used by the people of Tindongo is stone bund (Plate 5.6). The community members initiated this intervention several years ago. The intervention came about as a result of destruction of farm lands by erosion. The intervention is been practiced during raining season.

There are specific implications of the intervention on both men and women. The intervention has enabled some men in the community to buy bicycles, educate their children to the tertiary level, marry more wives and register for the National Health Insurance Scheme. It has also helped women to provide food for home consumption.

Plate 5.6: Stone Bunds at Tindogo.

5.6.1 Adoption of Stone Bunds

It was not easy for the farmers to adopt the intervention because of the work load it entails. The farmers did not modify their cropping system before the use of the intervention. The materials required for the start of the intervention is readily available. The community members are the owners of the intervention. With the exception of this intervention, farmers have not invested in any AWM intervention before but would be very willing to do so if the opportunity comes because their livelihood would be improved if they have an intervention that would enable them to farm during the dry season.

5.6.2 Water Use and Water Management

The community members use first come first serve system in accessing water. They usually access water from rainfall and ground water during the cropping season however these water sources are not reliable. Sometimes they meet rocks or hard pans when digging the wells and these make it very difficult for them to use water from this source. The water obtained from these water sources are used for irrigation, watering livestock and for domestic purposes. The water is used on a daily basis but not enough for crops and livestock. The farmers normally use bucket and ropes and sometimes basins to transport water to their fields.

5.6.3 Operation and Maintenance

Man power is required to utilize the intervention successfully. Men provide this labour in the community. The investment cost for the intervention is GH¢100.00 per acre and the maintenance cost is GH¢60.00 per acre in a year.

5.6.4 Impacts on Crop and Livestock Production

Crop production in the community has improved as a result of the intervention. For example, cereals like maize, sorghum and millet have increased in yield. Farmers can produce about 8-10bags/acre however for legumes like groundnuts, cowpea etc. they can produce about 7-8bags/acre. Using organic manure as farm input has contributed to the improvement of crop production in the community. The technology has however not improved the livestock production in the community because there are no grazing lands.

5.6.5 Enabling Environment

The farmers normally sell their produce at Tindongo market. They usually use bicycle, donkey/cart to transport their produce to the market and in most cases, the women carry the produce on their heads to the market. On average, farmers sell 30% of their produce. The farmers sell their livestock at Bolga market. Apart from selling the livestock, they also use them for sacrifices, funerals, payment of dowries etc.

5.7 Shallow Well

The intervention used by the Doba community is shallow well (Plate 5.7). The intervention was initiated according to the people by their great grandfathers. They used to fetch water by scooping the sand at the river bed during dry season. Due to inadequate water in the Doba reservoirs, increased population and competition for farming in the irrigable area, some of the farmers sort to the shallow wells and the river bed dugout in the Anayare River for dry season farming.

During the raining season, according to MOFA officers, the river overflows its banks flooding most of the lands especially the ones close to the river which are fertile and for that matter farmers have the chance of cultivating during the dry season. The river dries up early during the dry season and shallow wells are the only ways to get water for cropping. The farmers were bound by bylaw and rules regarding river protection.

The intervention is noted to work in areas where the water table is high, mostly along or about 50m to 100m close to water body. Farmers use buckets and ropes for the shallow well and water pumps for river bed dugouts. The wells/ dugouts are filled back with the excavated soil before the raining season.

Plate 5.7: A-Shallow well within the cropping area and B-A temporary shallow well at Doba.

5.7.1Adoption of the Shallow Well Interventions

According to the Agric Extension Agent (AEA), 2000 farmers are involved in the dry season farming using this intervention, and there are 800 men, 1000 women and 200 children involved. Some of the extension services given to them by the MOFA AEAs are on fertilizer and pesticide application, and other farm management. They also formed groups with the help of MOFA, which enable them to get loans to practice the intervention successfully.

Lands along the Anayare River are owned by the community and families. Farmers get land through Tindanas, landowners and family head to farm only during the dry season. The required materials and equipment such as hoe, pick axe and shovel needed to aid up-scaling are available and so it is possible to out-scale if they so desire.

5.7.2Water Use and Water Management

The wells are managed by individual farmers. There is no barrier to the use of the intervention. The shallow wells are quite reliable. The water from the shallow wells is used for crop irrigation whilst the mechanised borehole is used for watering livestock and for domestic use. The sunken beds also help the soil to conserve and increase moisture. Farmers cultivate according to the available water in the well.

5.7.3 Cost of Shallow Well Construction

Due to the temporary nature of the intervention, it costs about 50 to 70 Ghana Cedis per farmer every. When an unlined wall of the well collapses, it sometimes costs farmers about 30 Ghana Cedis for maintenance.

5.7.4 Impacts on Crops and Livestock Production

The intervention has improved cropping in Doba and other communities. Some of the crops grown are green pepper, tomatoes and onion in small quantities. Most of the farmers grow to sell. Generally, about 85% of the produce is sold out and 15% consumed.

5.7.5 Enabling Environment

Farmers sometimes travel about 5km to Navrongo, during market days to sell their produce either on bicycle, motor bike, donkey/chart, bus or walking. They sometimes get buyers from the south but due to increase in price of produce as a result of input cost, buyers now go as far as Burkina Faso to buy.

Farmers think the road from Bolgatanga to Navrongo has contributed to the success of the intervention in that their produce would have delayed and gone rotten (Plate 5.8).

Plate 5.8: Women selling produce along the Bolga-Navrongo road at Doba.

Source: Author's field survey, 2012

5.7.6 Conflict Management

There has not been any conflict among them or their livelihood strategies. They work individually. In spite of that, the community has a standing committee in charge of settling conflict.

5.7.7 Environmental and Human Impact

Since the inception of the intervention, the lives of the people have improved. The men are able to cater for their families' needs. The women also buy their own cloths as well as their children's. They also support their husbands in the payment of their children's school fees. They also buy what they want and need without having to ask their husbands for help. The children's support earns them food, and cloths from their parents and pocket money for school. It has created job opportunities for many people and that help in the reduction of rural-urban migration in the community.

5.8 GIS and Remote Sensing Component

5.8.1 Land use/cover Suitability Mapping

One of the criteria for identifying potential areas for AWM was land use/land cover (LULC) type. Not all land cover types are suitable for AWM. Since AWMI have the potential to increase the productivity of arable and grazing land by increasing the yields and by reducing the risk of crop failure, the croplands are considered as the optimal. The identified land use/cover types were cropland (18.82%), cropland with open woody vegetation (29.67%), deciduous shrubland (25.31%), deciduous woodland (25.97%), and water body (0.24%) as shown in Table 5.3.

From the analysis, the optimally suitable area for small reservoirs, stone bunds, and earth bunds were determined to be the cropland (>50%). Croplands with open woody vegetation were determined to be highly suitable; with deciduous shrub land being moderately suitable; and deciduous woodland not being suitable. The suitability levels of each LULC type and their corresponding areas are shown in Table.5.3. The cropland with open woody vegetation has highest of the total area, followed by deciduous woodland and shrubs and the smallest being the cropland (50%).

Table 5.3: Suitability Levels for LULC Types and Area (%)

LULC Type	Suitability Levels			Area(km^2)	Area%
	Small Reservoirs	**Stone Bund**	**Earth Bund**		
Cropland (> 50%)	OS	OS	OS	1660.27	18.82
Cropland with open woody vegetation	HS	HS	HS	2617.94	39.67
Deciduous Shrubland	MS	MaS	MS	2232.95	25.31
Deciduous woodland	NS	NS	NS	2291.66	25.97
Water body	Restricted	Restricted	Restricted	21.17	0.24
				8824	**100**

OS- Optimally Suitable; HS- Highly Suitable; MS-Moderately Suitable; MaS-Marginally Suitable; and NS- Not Suitable

5.8.2 Soil Suitability Mapping for Small Reservoirs, Stone and Earth Bunds

The suitability soil (Table 5.4) presents the soil types that are suitable for small reservoirs and stone bunds. The suitability level for small reservoirs and the earth bunds were the same. Suitability of soil texture for stone bunds in the order of optimally suitable to not suitable was sandy loam to loam, sandy to silt soil, loam, humus clay loams to clay, clay sand and clay acidic. From Table 5.4, the optimally suitable soil type for stone bunds, sandy loam to loam covers a percentage area of 16%.

The optimal suitability levels for small reservoirs were clay sand and clay acidic with a cumulative percentage area of 74%. Humus clay loams to clay with a corresponding 1% of total area were also found to be highly suitable. Marginally suitable and not suitable soil types were sandy loam to loam and sandy to silt soil, loam with corresponding percentage areas of 16% and 9% respectively. The reason for this is that for crop growth, clay sand and clay can absorb more nutrients and water holding capacity than sand or silt particles, because the clay particles provide a much greater surface area for adsorption.

Table 5.4: Suitability Levels for Soil Types and Area (%)

Soil Texture	Suitability Levels		Area Km^2	Area %
	Stone Bund	Small Reservoirs		
Sandy loam to loam	OS	MaS	1379.92	16
Sandy to silty soil, loam	HS	NS	832.87	9
Clay sandy	MaS	OS	6253.21	71
Humus clay loams to clay	MS	HS	86.65	1
Clay, acidic	NS	OS	271.35	3

OS- Optimally Suitable; HS- Highly Suitable; MS-Moderately Suitable; MaS-Marginally Suitable; and NS- Not Suitable

5.8.3 Potential Areas for Small Reservoirs, Stone Bunds and Earth Bunds

The process of identifying suitable AWMI area was done using the model builder of ArcGIS 9.3. The suitability maps of the AWMI were generated by integrating criteria maps (slope, land use/cover, runoff and soil) using MCE. The three suitability maps for small reservoirs, stone bunds and earth bunds generated each with five suitability classes i.e. Optimal, High, Moderately, Marginal and Not suitable

From the analysis, considering suitability level for small reservoirs, stone bund and earth bunds, areas classified as highly suitable was dominant compared to optimal, moderate and marginal areas. The areas corresponding to optimal, high, moderate and marginal suitability levels for small reservoirs are 2272.40km^2, 3496.86km^2, 2,924.96km^2 and 113.3km^2 respectively, while the suitable areas for stone bunds are 337.75km^2, 4072.62km^2, 3043km^2 and 1350.98km^2 respectively. On the other hand, the percentage areas with respect to the suitability levels of optimal, high and moderate for earth bunds are 27%, 42%, and 21% respectively (Table 5.5).

Almost all the optimally and highly suitable areas of small reservoirs and earth bunds have slopes less the 8%; with intensively cropland cover; clay, clay sandy and humus clay loam with fine and medium texture; and the rainfall ranges from 800 to 1100mm per year. The slope selection is in agreement with the earlier study done by Mbilinyi *et al*. (2005).

The developed suitability maps (Figures 5.7, 5.8 and 5.9) indicated that most suitable areas for AWMI are located in the eastern part of UER. This can be attributed to the rainfall distribution in the region which increases from the eastern part and decreases to the north–western part. Optimally suitable areas for AWM were found in the eastern part of UER.

Table 5.5: Percentage Suitable Areas for Small Reservoirs, Stone and Earth Bunds

	Small Reservoirs		**Stone Bunds**		**Earth Bunds**	
Suitable class	**Area (km^2)**	**Area (%)**	**Area (km^2)**	**Area (%)**	**Area (km^2)**	**Area (%)**
Restricted	19.67	0%	19.67	0%	19.67	0%
Marginal	113.13	1%	1350.98	15%	37.71	0%
Moderate	2924.94	33%	3043.00	34%	2695.40	31%
High	3493.86	40%	4072.62	46%	3669.30	42%
Optimal	2272.40	26%	337.75	4%	2401.93	27%

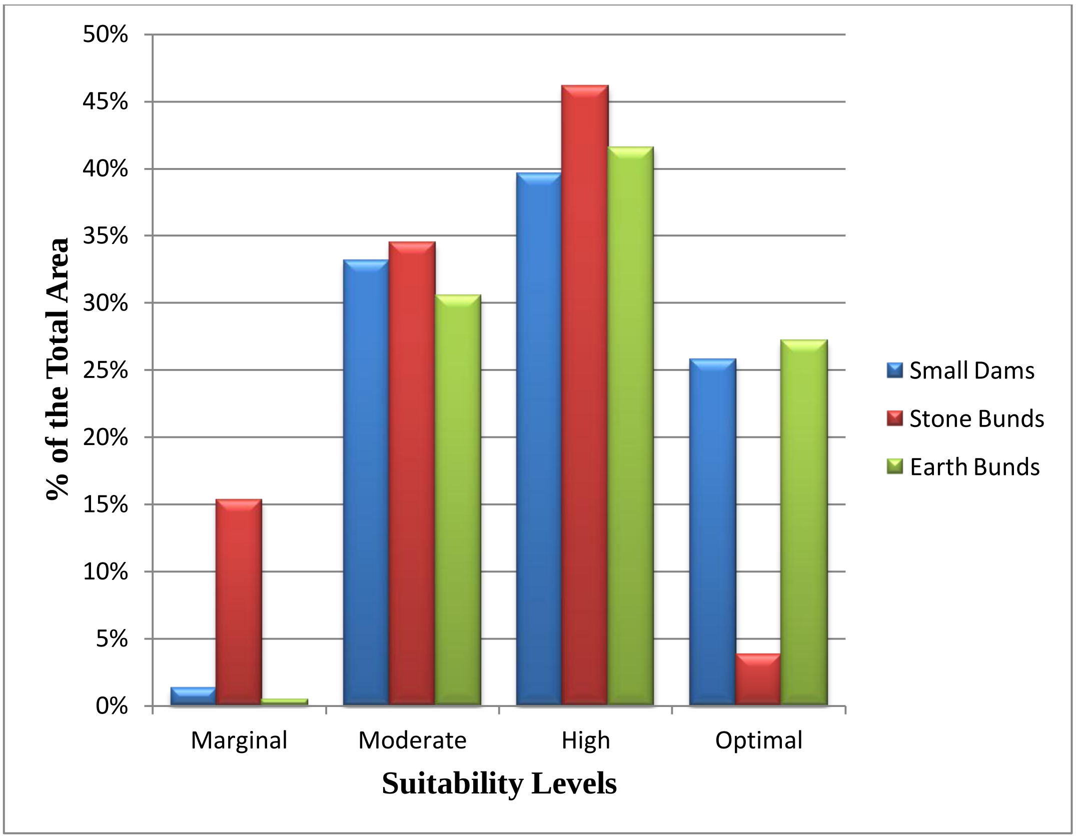

Figure 5.6: Suitability Level for the Small reservoir, Stone and Stone Bunds

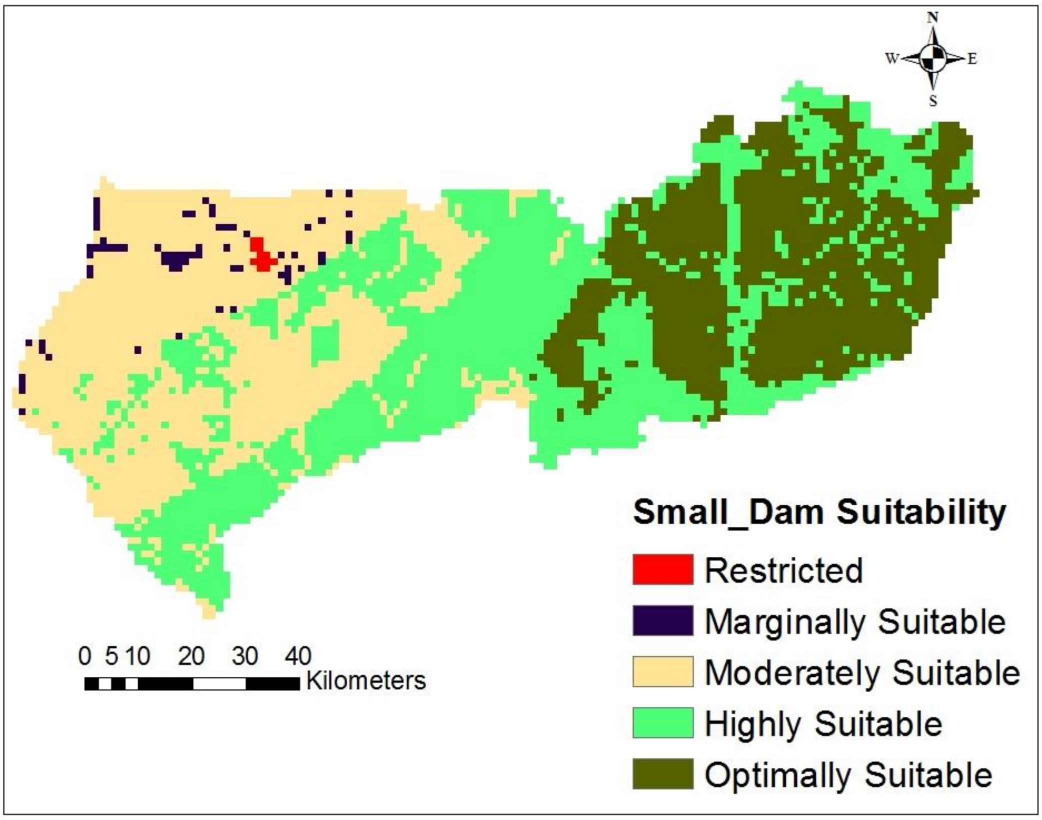

Figure 5.7: Map Showing Potential Areas for Small Reservoirs

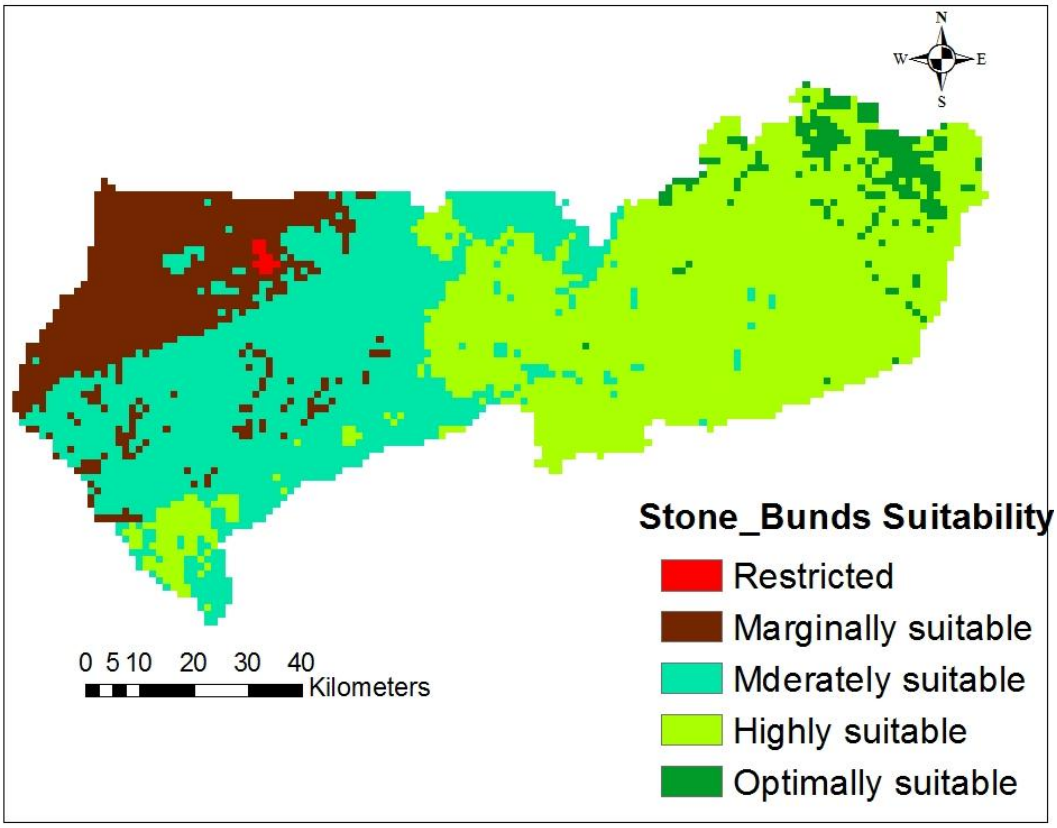

Figure 5.8: Map Showing Potential Areas for Stone Bunds

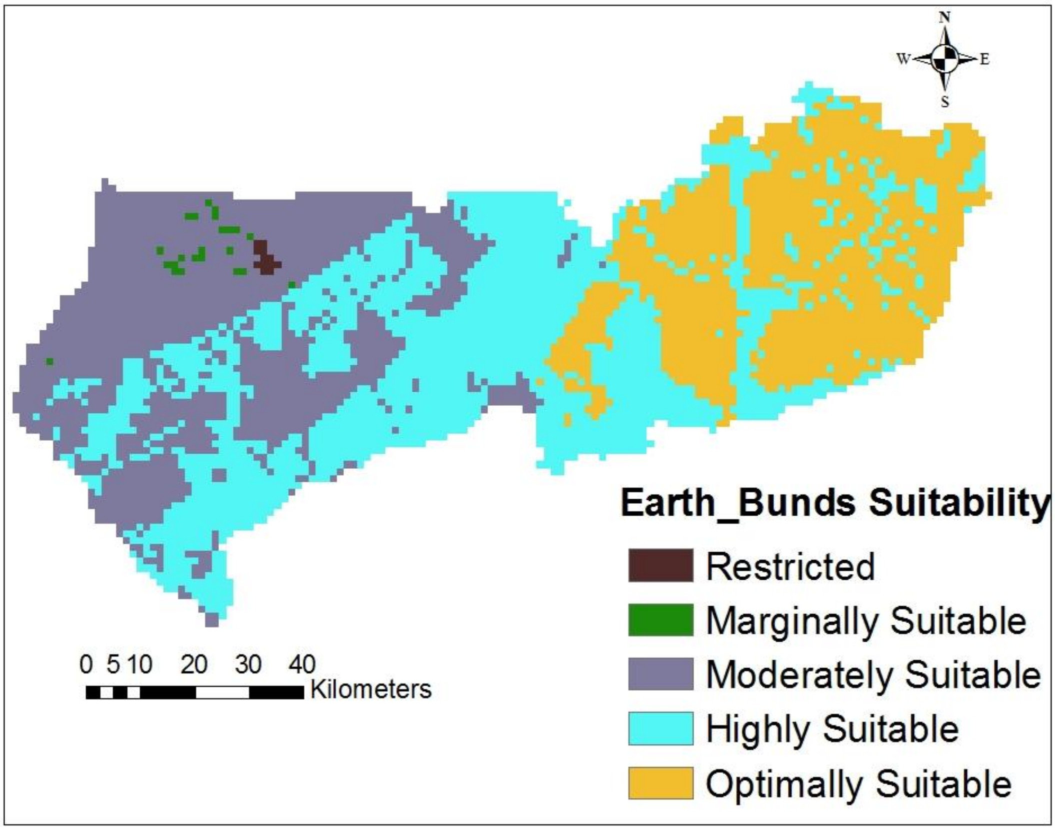

Figure 5.9: Map of Potential Areas for Earth Bunds

5.8.4 Validation of the Identified Potential Areas

The validation of the suitability maps for AWMI was carried out by assessing the number of AWMI per each suitability area. This was achieved by overlaying the existing AWMI collected from the survey on the generated potential maps. The results (Figure 5.10) revealed that eighty one (81) out of the 255 small reservoirs in the region were located at optimally suitable areas. Ninety six (96) small reservoirs were found in highly suitable areas. This indicates that the suitability map generated, matches the existing small reservoirs. The remaining 78 small reservoirs were found in the moderately and marginally suitable areas and quite close to each other. This is attributed to the fact that the small reservoirs were sited based on political or community demand and not necessarily on bio-physical factors.

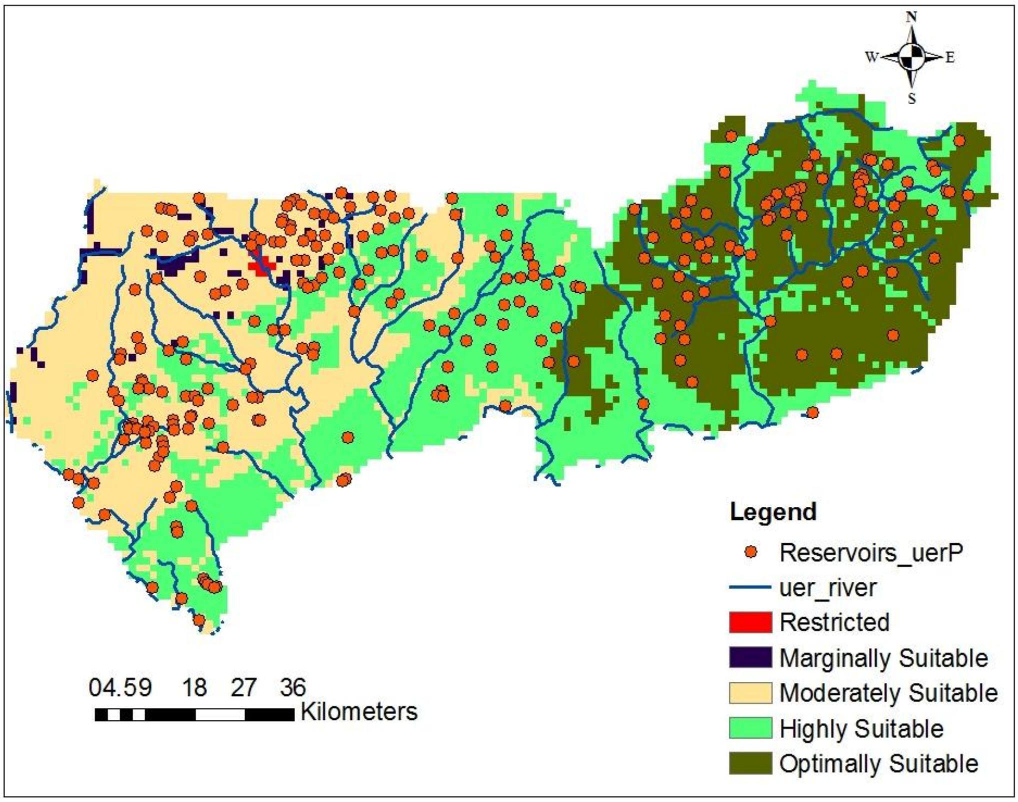

Figure 5.10: Map showing the exiting Small reservoirs' layer on the Suitability Map.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1Conclusions

The results of the research showed that, several interventions including small reservoirs, stone bunds, earth bunds, shallow well, treadle and motorized pumps were identified to be in use as means of reducing the seasonal water shortage problem. The success of these interventions were not only linked to biophysical factors but other factors such as fertilizer, access to market, transportation and agronomic practices.

The adoption of the interventions in numerous ways has tremendously impacted positively on the livelihood of the indigenes. With the inception of the interventions, the indigenes have had improved crop yields (e.g. to about 300% increase of rice yield at Beo), increased income and crop diversity, and reduced migration of their youth to the urban areas.

The developed suitability maps indicated that optimally/highly suitable areas for small reservoirs, stone bunds and earth bunds are located in the eastern part of UER as 5766km^2 (66%), 4410km^2 (50%) and 6071km^2 (69%) of the total area respectively. This shows that, UER has a large potential for AWMI Implementation which could be tapped.

6.2 Recommendations

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

- Access to credit, particularly informal systems, will continue to be important to ensure that irrigation equipment and inputs are sufficiently affordable and accessible to farmers.
- A close examination of the other factors determining AWMI success, such as socio-cultural environment, the possibility of adapting the population to agricultural innovations, the development policy objective of the country are important for consideration.
- National and local NGOs are more likely to reflect local needs for irrigation than government and so there is a need to link more strongly the activities of NGOs with the development programmes of government and aid donors for the benefit of all.
- National institutional arrangements (GIDA) should be made to co-ordinate the design and implementation of various AWM projects and to build a database to record the experience. There is need to systematically collect and collate data on soil, natural vegetation and land use, cropping pattern, rainfall amount and distribution, water resources and crop and water requirements as a national inventory of the potential of AWM.
- From developed suitability maps, 66% of the area will be suitable for up scaling of small reservoirs.

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APPENDICES

APPENDIX A: Questionnaire for High Level Stakeholders in the White Volta Basin - Ghana

Name(s) of respondent: ………………………………………………………

Organization: …………………………………………………………………

Position in Organization: ……………………………………………………..

Phone number: ……………………… Interview Date: …………………………..

1 Characteristic Of Project

Tick the Agricultural Water Management Intervention available in your district/ communities

1.1 Fill in the Project that brought the AWM Interventions, the location and the start & end years for the project.

Project	AWM Intervention	Yes	Location	Start/End Year
	Shallow Wells			
	Permanent Wells			
	Mechanized Wells			
	Water Pumps			
	Treadle Pumps			
	Earth Bunds			
	Stone Bunds			
	Grass Bunds			
	Tied Ridges			
	Small Reservoirs			

1.2. Fill in the number of households that started the interventions, the number that are still using the interventions and organizations that the project worked with.

Agricultural Water Management Intervention	No. of HH Intervention started with	No. of HH still using Intervention	Organizations
Shallow Wells			
Permanent Wells			
Mechanized Wells			
Water Pumps			
Treadle Pumps			
Earth Bunds			
Stone Bunds			
Grass Bunds			
Tied Ridges			
Small Reservoirs			

2 Design and Implications of the Intervention

Name of AWM Intervention: ………………………………………………..

Location: ……………………………………………………………………............

2.1 Were communities involved in the introduction and selection of interventions?
Yes [ ] No [ ]
2.2 If yes, give reasons ………………………………………………………..........
……………………………………………………………………………………
2.3 If no, give reasons ……………………………………………………………………
....
2.4 Were communities involved in the designing of interventions?

a. Yes [ ] b. No [ ]

2.5 If yes, at what stage and how was it done?

Stage: ……………………………………………………………………...............

How: …...

2.6 Was there existing knowledge of the project intervention already present in the participating communities?………...

2.7 Were there considerations for specific implications of the interventions for men and women?

b. Yes [ ] b. No [ ]

2.7. 1 If yes state implications on men:……...

2.7.2 State implications on women:………..

2.8 For the intervention to be out scaled – was all the required equipment available to the local communities?

a. Yes [ ] b. No [ ]

2.8.1 Could they out scale the intervention/intervention if they wanted to?

a. Yes [ ] b. No [ ]

2.8.2 If no, were there barriers?………………………………………

3 Adoption and Adaptation

3.1 How did the project get communities or people involved in the use of the intervention?

a. Incentives [ ]
b. Meetings [ ]
c. Loans [ ]
d. Training [ ]
e. Other specify..

3.1.1 What worked and what didn't?………………………………………………

How easy was it for communities or people to adopt the intervention?

a. Very easy [ ]

b. Quite easy [ ]

c. Not easy [ ]

d. Not very easy [ ]

e. Not easy at all [ ]

3.3 Did they have to modify/change their farming/cropping system?

a. Yes [ ] b. No [ ]

3.3.1 If no, could it work in their existing approach?

a. Yes [ ] b. No [ ]

3.3.2 If yes, what modifications/changes were made?...

3.2 Did the community or people involved in the intervention modify or adapt the intervention to local conditions/preferences?

a. Yes [ ] b. No [ ]

3.3.1 If yes, how was it done?..

3.3 How did you ensure ownership of the intervention by the community or people?

....

3.4 What were the main challenges for adoption?.....................................

3.5 How did the project overcome these challenges?..

4 Technological Requirements

4.1 Soil types

4.1.1 On what soils did the intervention work? ➲If possible mark the appropriate and inappropriate soils on the first acetate.

a. Loamy [ ]
b. Sandy [ ]
c. Clayey [ ]
d. Other, specify ……………………………………………………………

4.1.2 Where did it not work?➲If possible mark the appropriate and inappropriate soils on the first acetate.………………………………

4.2 Soil erosion

4.2.1Is the intervention affected soil erosion?

a. Yes [ ] b. No [ ]

4.2.2 If so where?➲If possible mark the soil erosion issues on the first acetate.

....

4.3 Slope

4.3.1 On what slopes did the intervention work?

a. flat- (0-2 %) [ ]

b. gentle (2-5%) [ ]

c. moderate (5-8%) [ ]

d. rolling (8-16%) [ ]

e. hilly (16-30%) [ ]

f. steep (30-60%) [ ]

g. very steep (>60%) [ ]

4.3.2 Where did it not work? ➲If possible mark the suitable areas first acetate.

……………………………………………………………………………………………

4.4 Water Table

4.4.1Where does the intervention work in terms of the depth of the water table?

………………………………………………………………………………………

4.5 Surface Water

4.5.1 How far away from the watercourse do you think the intervention could work?

………………………………………………………………………………………

4.6 Water Quality

4.6.1 Is water quality a problem?

a. Yes [ ]   b. No [ ]

4.6.2 If so, which water quality problems exist in the communities?

a. Sediment load [ ]
b. Salt [ ]
c. Heavy metal [ ]
d. Faecal matter [ ]
e. None [ ]
f. Other, specify ………………………………………………………

4.7 Resilience of the Intervention

4.7.1Has the intervention been reservoirsaged by livestock/wild life?

a. Yes [ ]   b. No [ ]

!! Make sure the legend is clear on the acetate !!

4.7.2 If yes, where and how is the problem resolved?
………………………………………………………………………………………
………...

Switch to the SECOND acetate. Add ground control points (for example: the corners of the map, a crossing of a river and a road, or you can draw a few features of the topographic map unto the acetate)

5 Land Use Classification

5.1 Where are the following land use ➲Mark the different land uses on the second acetate

a. Crop fields

b. Crops types

c. Vegetable gardens

d. Grazing land
e. Other specify …………………………………………………

5.2 What are the institutional arrangements for managing each land use?

…………………………………………………………………………………………

5.3 Where are the other resources the communities access for their livelihoods:

5.3.1Forest resources including: Fuel wood, Building materials, Wild foods

Medicinal plants ➲Mark the different resources on the second acetate

5.4 What are the institutional arrangements for managing these other resources?

…………………………………………………………………………………………

…………………………………………………………………………………………

5.5 Has the use and demand of these resources changed since the intervention?

a. Yes [ ] b. No [ ]

5.6 Livelihood Mix

5.6.1What is the mixture of livelihood strategies in the communities in the project area?

a. Farmers utilising the irrigation intervention [ ]
b. Traditional rain-fed farmers [ ]
c. Livestock keepers [ ]
d. Small businessmen [ ]
e. Other specify...

5.6.2 What proportion of the community practice these different strategies?

Community livelihood	**Number /Percentage**
1. Farmers utilising the irrigation intervention	
2. Traditional rain-fed farmers	
3. livestock keepers	
4. Small businessmen	
5. Hunting	
6. Fishing	
Other	

!! Make sure the legend is clear on the acetate !!

6 Water Use and Water Management

6.1What are the institutional arrangements for water use?

…………………………………………………………………………………………

………………………………………………………………………………………

6.2 Where do farmers access water from during the cropping season?

a. Rain [ ]

b. Surface [ ]

c. Ground water [ ]

d. Other specify...

➲If possible mark these locations on the second acetate.

6.3 How accessible are the water sources?

a. Easily accessible [ ]

b. Quite accessible [ ]

c. Not accessible [ ]

d. Other specify...

6.3.1 Are there any barriers to use?

a. Yes [ ] b. No [ ]

6.3.1a.If yes, comments...

6.4 How reliable are these water sources?

Water source	**Very reliable**	**Quite reliable**	**Not reliable**	**Other, specify**
Rain				
Reservoir				
River/stream				
Temporal Shallow well				
Permanent Shallow well				
Permanent deep well				
Mechanized well				
Other				

6.5 How is the water used?

a. Crop irrigation [ ]

b. Watering livestock [ ]

c. Household/domestic use [ ]

d. Other specify...

6.6 How frequently is it used?

a. Daily [ ]

b. Two time a week [ ]

c. Three time a week [ ]

d. Four time a week [ ]

e. Other, specify………………………………………………………………………

6.7 Is there enough water available for crops and livestock?

a. Yes [ ] b. No [ ]

6.8 If no, comments ……………………………………………………………......

6.9 Are there any water quality issues affecting their use?

a. Yes [ ] b. No [ ]

6.9a. If yes, give reason...

6.10How do people transport water to their fields/livestock (focus on additional delivery systems used in conjunction with the intervention/intervention)?

…………………………………………………………………………………………

…………………………………………………………………………………………

6.11 How did the years of the project run in terms of water availability?

a. Good [ ]

b. Normal [ ]

c. Bad [ ]

6.12 Comment …………………………………………………………

…………………………………………………………………………………………

7 Details of the AWM Intervention/Intervention

7.1How is the intervention powered?

a. Electricity [ ]
b. Diesel [ ]
c. Human [ ]
d. Animal [ ]
e. Solar [ ]
f. Other, specify...

7.2 How reliable is this power source?

a. Very reliable [ ]

b. Quite reliable [ ]

c. Unreliable [ ]

d. Other, specify...

7.3 Are there any problems with accessing power reliably?

a. Yes [ ]   b. No [ ]

7.3.1 If yes, what problems are encountered?………………………………

7.4 What labour inputs are required to utilise the intervention/intervention successfully?………………

7.5Who provides this labour in the project communities (gender balance, labourers etc)?……………………………………

7.6 Has the required amount of farm labour changed since the intervention/intervention was introduced?

a. Yes [ ]   b. No [ ]

7.6.1 Comment on any chosen answer……………………………………………

……………………………………………………………………………………

7.7 Has the change been positive or negative (eg. farmers can now achieve an additional harvest, but this requires that they work in the fields throughout the year)………………………………………………………..…

7.8 Did the project team provide training to the community?

a. Yes [ ]   b. No [ ]

7.9 If yes what kind(s) of training?

a. Intervention/intervention [ ]

b. Maintenance [ ]

c. Farm management [ ]

d. Other, specify……………………………..

7.10 In general, what level of support did the project team and partner organisations provide to the communities to help ensure the successful implementation of the intervention?…………………………………………………………………

7.11What support in terms of funds, grants, subsidies, access to loans etc did the project provide to help fund the investment in the intervention/intervention for farmers?…………………………………………………

7.12 What is the financial cost for farmers to adopt intervention (investment, maintenance)?……………………………………………………………….....

7.13 Were farmers willing and able (financially) to make investments in AWM intervention/interventions improvements?

a. Very willing [ ]

b. Quite willing [ ]

c. Not willing [ ]

d. Other, specify…………………………………………………………………………..

Comment(s)……………………………………………………………………………

8 Impacts – Crop Production

Only answer these questions if the AWM intervention is focussed on crop production.

8.1 Overall has the intervention resulted in any improvement in cropping?

a. Yes [ ] b. No [ ]

8.2 If yes, is this due to change in number of **harvests** and/or changes in average **yields** for each crop? ➲Mark the locations of these improvements in relation to the landuse/crop fields mapped on the acetate for Land Use Classification.

	Number of Harvests		**Average Yield**	
Crop	***Before***	***After***	***Before***	***After***

8.3Did the introduction of the intervention result in changes in water management?

a. Yes [ ] b. No [ ]

8.4. If yes/no, give reason(s)

…………………………………………………………………………………………

8.5 What crop growing stage is now most critical to water availability?

a. Nursing [ ]

b. Transplanting [ ]

c. Maturing [ ]

d. Other, specify ……………………………………………………………………

8.6 Was this different before the AWM intervention(s) was introduced?

a. Yes [ ] b. No [ ]

8.7 If yes, comment ………………………………………………………………

8.8Were these improvements also linked to changes in other farm inputs

Farm input	Yes	No
Fertilisers		
Pesticides		
Machinery		
Other		

8.9 In what year, after farmers got the intervention, did improvements happen?

……………………………………………………………………………………..

8.10 Overall has the project increased sustainability of crop production?

…………………………………………………………………………………………

9 Impacts – Livestock Production

Only answer these questions if the AWM intervention is focussed on livestock production.

9.1 Did the AWM intervention/intervention result in a change in the quality of grazing land? ➲Mark these locations these improvements in relation to the landuse/grazing areas mapped on the acetate for Land Use Classification

a. Yes [ ]   b. No [ ]

9.2 Comment on answer …………………………………………………………

9.3 How has the intervention improved livestock management and/or yields (meat, milk, quality of livestock) and if so by how much?

…………………………………………………………………………………………

9.4 Did the introduction of the intervention result in changes in water management?

a. Yes [ ]   b. No [ ]

9.4 If yes/no, give reason ……………………………

9.5 In what year, after farmers got the intervention/intervention, did any improvements in livestock production occur?...

9.6 Overall has the project increased sustainability of livestock keeping?

…………………………………………………………………………………………

10 Infrastructure – Crop Production

Only answer these questions if the AWM intervention is focussed on crop production.

10.1Where are the markets farmers sell their produce at?➲<u>Where possible mark the locations on the acetate - else just record the place names</u>

…………………………………………………………………………………………

10.2 How do the farmers transport their produce to market?

a. Bicycle [ ]
b. Motorbike [ ]
c. Lorry/bus [ ]
d. Donkey/ cart [ ]
e. Walking [ ]
f. Other, specify ....

10.3 On average how much of their crop is sold (this can be the % of the crop sold)? Has this percentage changed since intervention?

	Amount Sold (GH)		**Amount Sold (%)**	
Crop	***Before***	***After***	***Before***	***After***

10.3 Which other changes in infrastructure in the project communities could have helped achieve the successful implementation of the AWM intervention?

a. New/improved roads [ ]
b. Schools [ ]
c. Change in government policies [ ]
d. Subsidies [ ]
e. Health Centres [ ]

f. Other, specify ……………………………………………………

➲<u>Where possible mark the locations of these changes on the second acetate</u>

11 Infrastructure – Livestock Production

Only answer these questions if the AWM intervention is focussed on livestock production.

11.1 Where are the markets farmers sell their livestock at?➲<u>Where possible mark the locations on the acetate - or else just record the place names</u>

…………………………………………………………………………………………

11.2On average what (financial) income do farmers get from their livestock? Has this changed since the project intervention?

	Income	
Livestock	***Before***	***After***

11.2.1 Are there any other non-financial benefits of owning livestock? Have these changed since the project intervention?

	Non-Financial Benefits	
Livestock	***Before***	***After***

11.3 Were there any other changes in infrastructure in the project communities that could have helped achieve the successful implementation of the AWM intervention?

a. New/improved roads [ ]
b. Schools [ ]
c. Change in government policies [ ]
d. Subsidies [ ]
b. Health Centres [ ]
c. Other, specify …………
➲Where possible mark the locations of these changes on the second acetate

12 Conflict Management

12.1 Have there been changes in the nature or severity of conflicts between different livelihood strategies or communities resulting from the introduction of the intervention/intervention?

a. Yes [ ] b. No [ ]

12.2 If yes/no, give reason(s) ……....................................

....…..........

12.3 Have there been changes in conflicts related to water between different livelihood strategies or communities resulting from the introduction of the intervention/intervention?

a. Yes [ ] b. No [ ]

12 If yes, comment..

12.4Did the project manage/address these conflicts?

a. Yes [ ]　　　　b. No [ ]

12.5 If so how?……………………………………

13 Wider Impacts of the AWM Intervention

A. Environmental Impacts

13.1Have there been wider environmental impacts resulting from the introduction of the AWM intervention?

		Environmental Impacts		
		Positive	***Negative***	***Mixture***
1.Water availability	Upstream			
	Downstream			
	Between different livelihoods			
2.Water quality	Upstream			
	Downstream			
	Between different livelihoods			
3.Salinity	Upstream			
	Downstream			
	Between different livelihoods			
4.Biodiversity				
5. Pests				
6. Other				

13.2In case of negative ones – how have these been managed (by the community and/or project)?

Negative ones	**Community**	**Project**

B. Human Impacts

13.3 Were there any health related issues resulting from the introduction of the AWM intervention? (These could be positive – or negative – or a mixture).

....

…………………………………………………………………………………………

13.4 Did the introduction of the AWM intervention/intervention result in any new community or farmers groups being established?

a. Yes [ ]   b. No [ ]

13.5 If yes, what new communities or groups of farmers?

…………………………………………………………………………………………

…………………………………………………………………………………………

13.6 Did the introduction of the AWM intervention/intervention result in farmers collaborating or working together more than before?

a. Yes [ ]   b. No [ ]

13.7 If yes how was it done?

…………………………………………………………………………………………….

14 Key Lessons Learnt

14.1 Were there any **critical factors** that made the project a success?

……………………………………………………………………………………………..

14.2 What do they feel are the key factors for **wider uptake?**

…………………………………………………………………………………………

14.3 What **main lessons** were learned by doing this project?

…………………………………………………………………………...............

14.4 Any more critical points to share?

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