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Climate Change and Performance of Small Reservoirs in the Upper East Region of Ghana

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Abstract

Increasing evidence on impacts from climate change and variability, suggests that poor rural communities in semi-arid sub-Saharan Africa need to adapt in order to reduce effects on their livelihoods. In semi-arid areas characterized by high poverty, small reservoirs even though most of them are performing below average, act as important assets that support a wide range of livelihoods. However, in the face of climate change and variability it is not clear how and to what extent the performance of small reservoir systems is affected.

A lot of studies have been done on the issues of climate change and performance of small reservoirs. However, this literature has not strongly linked the two issues making it difficult to understand how climate change and variability affects performance of these water systems. In addition, there is also limited literature documenting what water management strategies communities using small reservoir have adopted to enhance their adaptive capacity to climate change and variability.

This study attempts to answer these questions using a multiple-case study of two contrasting small reservoirs involving a well and poorly performing reservoir in the Upper East Region of Ghana. The study revealed that the unprecedented levels of benefits associated with small reservoirs in rural areas are greatly threatened by increasing climate change events such as floods, droughts and increasing temperatures.

Climate change and variability was found to affect the multiple uses of the reservoirs, with irrigation being the most affected and threatened. Although the communities showed an array of adaptation measures to the harsh environment; water management strategies that should help enhance the communities adaptive capacity to climate change and variability are inadequate and ineffective.

Therefore, reducing the effects of climate change and variability on the performance of small reservoirs and increasing the adaptation in communities, calls for adaptive water management strategies and integrated approaches in the management of small reservoirs. These strategies should focus on strengthening enforcement of institutional arrangements for using small reservoirs; effective resource mobilization and maintenance of reservoir infrastructure; and efficient and more improved water and land management.

Keywords: Climate change, Small reservoirs, Performance, Adaptation, Upper East Region of Ghana

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To all of you I wish you God's Blessings!

Table of Contents

List of Figures

List of Tables

List of Abbreviations and Acronyms

AEA	Agriculture Extension Agent
AWM	Agriculture and Water Management
BOR	Bureau of Reclamation
CEEPA	Centre for Environmental. Economics and Policy in Africa
CLISS	Comité permanent Inter-Etats de Lutte contre la Sécheresse dans le Sahel
DA	District Assembly
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organisation
FGD	Focus Discussion Group
GCM	Global Circulation Model
GDP	Gross Domestic Product
GIDA	Ghana Irrigation Authority
ICOLD	International Commission on Large Dams
IFAD	International Fund for Agricultural Development
IPCC	Inter-governmental Panel on Climate Change
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
LUMID	Lund University Master Programme in International Development and Management
MoFA	Ministry of Food and Agriculture
NADMO	National Disaster Management Organization
PNAS	Proceedings of the National Academy of Sciences
PRA	Participatory Rural Appraisal
SSA	Sub Sahara Africa
UER	Upper East Region
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States of America Agency for International Development
WUA	Water Users Association

INTRODUCTION

In semi-arid environments characterized by high poverty levels, small reservoirs act as important assets that support a wide range of livelihoods. Apart from supporting multiple uses such as irrigation, livestock watering, fishing, construction and domestic water needs, small reservoirs store water, buffer the effects of variable rainfall (Turner 1994). The Bureau of Reclamation (BOR) (1987) and the International Commission on Large Dams (ICOLD) (1998) define small reservoirs as water storage structures less than 15 meters high and with an embankment volume generally less than 0.75 million cubic meters.

However, many reservoirs are currently functioning at sub-optimal levels and/or are falling apart (Small and Svendsen 1992 cited in Kuscu et al. 2008: 125). This is due to several factors, which include physical, climatic; social, economic; political, governance and management factors. Physical, ecological and climate change factors (storm events) are serious factors that affect performance of small reservoirs especially in developing countries (Keller et al. 2000: 7; Abernethy and Sally 2000). Major climate factors associated with climate change include frequent and severe floods and droughts (Center for Environmental Policy in Africa - CEEPA, 2006: 1). These events have devastating impacts on physical infrastructure including small reservoirs, natural resources and the general livelihoods of people and in severe cases may lead to loss of human life (Fraiture 2007: 4). At the same time the International Water Management Institute (IWMI) (2009: 1) state that the multipurpose infrastructure such as small reservoirs can play an important role in ensuring food security and building resilience for adapting to climate change.

In the UER of Ghana there are numerous small reservoirs. The IWMI Inventory indicates a total of 243 small reservoirs in this region. Most of them were installed by the Government through a series of donor-funded projects to support various social and economic benefits associated with dams (and notably the scope they offer for irrigation development). However, these water systems and livelihoods that depend on them are threatened by climate change. The Inter-governmental Panel on Climate Change (IPCC) (1997) state that apart from the current floods and drought situations common in the UER region of Ghana, future scenarios for the country indicate increases in temperatures and reductions in rainfall. According to Vordzogbe Von and Kranjac-Berisavljevic cited in EPA (2008: 168) accelerating land degradation and climate variability in Ghana are trending towards aridity. This may cause reductions in groundwater recharge of between five (5) and twenty two (22) percent by the year 2020 and between 30 and 40 percent by 2050 (EPA 2008: 167). Domestic use and industrial water demand may not be affected by climate change, but irrigation water demand could be affected considerably (*Ibid*). A region like UER with the highest number of dams and dug outs in the country coupled with an increasing population, this could significantly affect livelihoods of a large population that depends on these structures for various livelihoods (Vordzogbe Von and Kranjac-Berisavljevic cited in EPA 2008: 167).

Although there is limited documentation of the impacts of climate change on small reservoirs and how communities using these water systems have adapted, the study by Vordzogbe Von and Kranjac-Berisavljevic cited in EPA (2008: 168) suggest that in Ghana, farmers are trying to adapt to the changing climate in different ways but it is not clear how effective their adaptive strategies are in terms of biophysical status and human livelihoods. Therefore in understanding what water management and institutional strategies that communities using small reservoirs in the UER of Ghana have adopted as adaptation and coping measures to climate change, this study first sought to understand how communities perceive climate change and performance of small reservoirs; and how climate change and to what extent it affects performance of small reservoirs.

1.2 Aim of Study

The aim of the study is to identify promising water management strategies that would enhance the adaptive capacity of local communities in dealing with the impacts of climate change on small reservoir systems. The findings will contribute to the on-going ‘Small Reservoirs Component’ of the Agriculture Water Management (AWM) Solutions Project led by IWMI, which aims at identifying factors that influence successful adoption and up-scaling of promising small-scale AWM interventions such as small reservoirs for the benefit of the rural poor.

1.3 Research Questions

In order to contribute to this aim the study I seek to answer the following questions:

i. How do communities' perceive climate change and performance of small reservoirs?

ii. How and to what extent does climate change affect performance of small reservoirs?

iii. What are the community-level water management strategies for adapting to climate change in order to maintain performance of small reservoirs? and how effective are they?

1.4 Research Frontier and Justification

Previous studies have contributed a great deal to an extensive body of literature on various aspects of small reservoirs and climate change world over. However, this literature does not document the linkage of performance of small reservoirs and climate change in detail.

Literature reviewed on small reservoirs in Ghana and other parts of the world at basin, sub-basin and reservoir levels cover various aspects of performance of these water systems ranging from hydrological, water management and productivity (Faulkner 2006; Sally 2002; Mamba 2007); design and technological aspects (Plusquellec 2002); governance, social and institutional aspects of small reservoir systems (Vermillion et al. 2004; Meinzen-Dick 2007; Poolman 2005; Kinderen 2006) and determinants of collective action (Gyasi, 2005; Sally 2002); pollution and environmental aspects (Masona 2007; Keller et al. 2000); livelihoods and socio-economic aspects (Balazs 2006).

Literature reviewed on climate change in Africa and Ghana focus on impacts of climate change on various natural resources and processes that includes water availability (Neuman et al. 2007; Jung and Kunstmann 2007; Thornton et al. 2006; EPA 2008); and impacts on the temporal and spatial distribution of climate variables (Jung and Kunstmann 2005; Hulme et al. 2001; Vordzogbe and Kranjac-Berisavljevic 2008; Nicholson 2001; Nicholson 1993); hydrological variability (Oguntunde et al. 2006); climate change and anthropogenic influence on land cover (Wittig et al. 2007) and impacts of climate change on irrigation water use (Asante 2009). These studies focused on different time periods within the current and previous century. Other studies include Fraiture et al. (2007) that explored water management options to build resilience of farmers vulnerable to changes in rainfall and water supply in Sub-Sahara Africa. Keller et al.

(2000) and Von Vordzogbe and Kranjac-Berisavljevic cited in EPA (2008) also explored climate change and adaptation strategies for water resources.

Therefore this study attempts to link the two issues by understanding the impacts of climate change on performance of small reservoir systems as important livelihood support systems at community level especially in rural poor and semi-arid environments in the UER of Ghana. Secondly, these studies focused on understanding performance of small reservoirs for irrigation purposes not multiple uses supported by these water system, which this study attempts to explore. Further, there is little understanding of water management and institutional strategies that farmers using small reservoir systems employ and how effective they are in increasing their adaptive capacity to climate change, which this study attempts to address. Understanding the implications of the changing environmental context on the performance of small reservoir systems is necessary to inform responsible institutions on the required responses and/or adaptation mechanisms through appropriate water management and institutional strategies in order to reduce vulnerability.

This report is organized into six chapters with the first chapter providing an introduction and background to the research. The second chapter elaborates the methodology and methods used in the research including limitations. The third chapter provides a theoretical framework for the study, while the fourth chapter provides a description of the study sites. Chapter five presents and discusses the findings of the research. The last chapter is a conclusion that also provides recommendations for increased adaption of rural communities using small reservoirs to climate change in order to maintain performance of these important water systems.

METHODOLOGY

This is a qualitative study using both qualitative and quantitative methods. The study approach involved understanding of long-term trends in climate variables (rainfall and temperatures), followed by understanding individuals and communities' perceptions on climate change and performance of small reservoirs. Lastly, the study explored water management strategies that communities use to adapt to climate change and variability and assessed their effectiveness in enhancing their adaptive capacity.

I used a multiple-case study approach involving two contrasting cases (a well-performing and poorly-performing reservoir). This approach was designed to expand the external validity and generalizability of findings, which a single-case study may not achieve (Yin 2003: 53-54). However, the use of a two-case study does not completely rule out the limitations of generalizability of cases studies to the wider population. This is because the two cases selected do not necessarily provide a representative sample since small reservoirs operate in different contexts and their performance is affected by a combination of different factors. However, the strength of case study approaches lies in their contribution to the expansion and generalization of theories (*Ibid*: 10).

I assessed performance of small reservoirs based on the perceptions of users against set objectives or intended multi-purposes of small reservoirs. Assessing performance of multiple-user systems from the perspective of users is important because performance of such systems is often dependent on the perspectives of different users- irrigation may be seen as beneficial by irrigators, possibly less so by other users such as fishermen or livestock farmers (Bos et al. 2005: 11). Participatory Rural Appraisal (PRA) methods used provided a detailed understanding of the people's perception and experiences on climate change trends and performance of small reservoirs. PRA approaches offers effective approaches which enable local people to share, enhance and analyze their knowledge of life and conditions and to plan and act (Chambers 1994). However, the limitation of PRA methods is their heavy reliance on the skills of researchers, which can introduce research bias. In addition to PRA methods, quantitative methods were used to support the study on some aspects, particularly on the trends of climate change events in the study area and factors affecting small reservoirs in the greater UER. The methods used are described below.

2.2 Type of Data, Sources and Methods Used

Data collection in the field was done jointly with my LUMID colleague Juste Rakstyte since we had a common research interest on small reservoirs though my colleague focused on equity issues involved in the management of small reservoirs.

Primary and secondary data was collected from different sources. I used a mixed approach involving qualitative and quantitative data collection methods. These are described below. A mixed approach is useful in triangulating and increasing reliability (Bryman 2008: 611).

2.2.1 Focus Group Discussions

A total of eleven (11) FGDs of five to six respondents for various water uses and socio-economic groups were conducted. Separate FGDs for men and women irrigators were conducted in each study site. However, one FDG was done for fishermen, livestock farmers, the poor people and the youths except for domestic water use and construction because these uses cut across all the other water-user groups.

In order to enrich the FGDs PRA tools that included the 'Now and Before' Matrix were used to generate perceptions in trends of climate change events by comparing two points in time. The Ranking Matrix was also used in the assessment of performance of the reservoirs. Other tools used included the Seasonality Analysis to generate information on the temporal distribution of different uses of the reservoirs in a single season/ or year. Visuals, which included Flip Charts and Marker pens, were used in addition to local material such as stones, tree twigs and so on in the application of PRA tools.

2.2.2 Individual Interviews

A total of thirty six (36) interviews with selected individuals for each respective water user-group (4-5 interviews per user-group) were conducted except for the youth group due to limited time. Semi structured interview guides were used with translation support from local translators.

2.2.3 Key Informant Interviews

Interviews with Key Informants involved a few community members who are knowledgeable about a certain matter (Nichols 1991: 13). USAID (1996: 2) emphasizes the inclusion of all major stakeholders so that divergent interests and perceptions can be captured. Key Informants interviewed included Agriculture Extension Agents (AEAs), traditional Chiefs, the Chairpersons for the Water Users Associations (WUAs), the *Tindanas* (traditional spiritual leaders), Cooperative Officers; the District Directors of Agriculture and the Chief Executive Officers for the District Assembly (DA) and the Assembly Men. Through semi-structured interviews the Key Informants provided useful information on the services and support they provide to the reservoirs and their management committees (the WUAs) including their perceptions on climate change and performance of small reservoirs.

The Historical Profile - a PRA tool was also used to generate historical data of the reservoirs paying particular interest to major historical events that took place in the communities that would have affected performance of small reservoirs. This tool was used to collect data from Key Informants who were identified to possess historical knowledge about the community, which included the AEAs, Members of the WUAs and the *Tindinas*.

2.2.4 Participant Observation

According to Nichols (1991: 12), participant observation is effective when conducting an in-depth research in small communities like Kajelo and Baare. This is because in such small areas it is easy to collect data on naturally occurring behaviors of people in their usual contexts (Mack et al. 2005: 2). This method involved a transect walk (which is also a PRA Tool) in the community and around the reservoirs while observing, discussing and conducting informal interviews with Key Informants, particularly the AEAs and local farmers and/or executive members of the WUAs. Field observations provided useful insights on the status of the reservoirs' infrastructure and maintenance works; catchment area protection and soil erosion control measures; irrigation methods and farming practices used by farmers.

2.2.5 Records Review

Records review was conducted throughout the period of the study. The IWMI Inventory on Small Reservoirs in Ghana, academic reports, research articles, books and internet sources provided useful records for literature review and secondary data. Since this research was concerned with long-term rainfall and temperature patterns over the past three decades, time-series data (30-years record) on these variables was obtained from the Meteorological Department at a fee. Data from the climate change scenarios based on the GCMs for the Guinea Agro-ecological zone was also used to understand future projections in these climate variables.

2.3 Selection and Sampling Procedures

The entry point of this research was the reservoir, and then narrowed down to the communities served by the reservoir to focus on individuals using the reservoirs. Selection of these two reservoirs was based on prior knowledge of their performance levels based on the Qualitative Assessment by AEAs that was conducted by IWMI in building its Inventory on Small Reservoirs. Since there were several dams that formed the sampling population in the inventory, selecting the two contrasting cases was achieved by using a minimum criteria that included the following: reservoirs designed for multi-purposes; used for multi-purposes; and built more than 15 – 30 years ago for purposes of capturing climate trends.

Identification and selection of multiple user-groups using the reservoirs was done with the help of AEAs. The identified user-groups formed the basis for a non-proportionate quota sampling of a total of ten (10) individuals who fitted in the respective quotas (user-groups). These individuals were selected using availability sampling procedure. From the total of 10 selected individuals five – six participated in FGDs, while the 4 - 5 individuals participated in individual interviews. According to Bryman (2004: 102) quota sampling aims at producing a sample that reflects a population in terms of the relative proportions of people in different categories such as gender, ethnicity, age-group, socio-economic groups, and region of residence, in combinations of these categories.

2.4 Data Analysis and Presentation

Since this research made use of PRA methods, the tools used served two purposes: to collect data and to analyse (initial analysis) it at the same time in a participatory manner.

Further analyses of primary data collected from both FGDs and individual interviews was done using qualitative methods that included logical analysis, which makes use of generalized causation or logical reasoning processes (Ratcliff n.d: 2). This method was used in analysing factors affecting performance and how climate change and variability affects performance of small reservoirs. Results are presented in an illustrative figure. Narrative and discourse analysis methods were used in analysing how individuals and communities perceive climate change and performance of small reservoirs. Results are presented in boxes, written descriptions and tables where appropriate. Both qualitative and quantitative methods were used to analyze secondary data, depending on its nature. Analyzed quantitative data is presented in tabular, descriptive statistics and graphical formats. Findings from secondary data sources and literature review are also presented in chapter five where they have been discussed together with research findings.

2.5 Ethical Considerations

The main ethical considerations in this study included explaining the research purpose to participants, obtaining informed consent and researcher debriefing. Before each interview and FGD was conducted participants were informed about the purpose of the research and where given an opportunity to ask questions for clarification before proceeding. Informed Consent of respondents was respected by giving them sufficient information about the research in order for them to make an informed decision whether or not to participate in the study. Preliminary findings and recommendations arising from the research were presented to Directors of Agriculture was done in the study sites.

2.6 Problems and challenges Encountered

Most of the problems and challenges faced were related to selection of reservoirs and respondents and actual data collection in the field.

These included the process of selecting two contrasting cases that would provide interesting results was complicated and time consuming. It was not always possible to have respondents from all the sections using the reservoirs despite attempts to balance representation of respondents in the interviews due to their availability. However, this did not seem to have introduced serious bias since no significant contradictions in the respondents given by each user-group were found. We also faced difficulties in finding respondents who were exclusive to each user-group or quota. This was not possible as many respondents overlapped across two or more user-groups especially for rain-fed farming. Obtaining elaborate responses from the open-ended questions in the FGDs was quite a challenge without providing a clue. There were several cases when the interpreters were not asking the question but giving the answer themselves. It was also happening unintentionally, as interpreters were trying to adjust the answers of respondents and give us the "right" ones. FGDs in some cases were dominated by a few vocal individuals. However, attempts were made to prompt other participants to make contributions. Lastly, identifying poor people in the community was also challenging due to high expectations and stigma. The AEAs and community leaders helped in this.

THEORY

This study made use of the theory on climate change, which provides an insight on the climate change phenomenon. A theory on adaptation has also been used as an important option for reducing vulnerability of communities and water systems to climate change and variability. A further theoretical elaboration has been done to appreciate challenges faced in adapting to extreme events associated with climate change. This part also gives examples of some of the adaptation strategies to extreme and severe climate change events and what approaches exist to integrate them in existing natural resources and sustainable development programmes and strategies for purposes of ensuring successful adoption and implementation.

3.1 The Concept of Climate Change

The Inter-governmental Panel for Climate Change (IPPC 2007: 30) defines climate change as any change in climate over time, whether due to natural variability or as a result of human activity. The theory behind climate change describes it as a global phenomenon caused by land use changes and emission of Green House Gases (GHGs) from anthropogenic processes, which alters the atmospheric concentrations of gases, which consequently interfere with the energy balance of the global climate system causing changes in climate patterns (IPCC 2007: 36). Climate change has existed throughout the history of the Earth, associated with Ice Ages and relatively warm periods in temperate regions, while in Africa it has been associated with intermitted wet periods and dry periods (Kemp 1994: 40 cited in Van der Geest 2002: 2). The changes in the global climate patterns experienced in the recent years include increasing surface temperatures, frequent and severe climate events such as floods and droughts (CEEPA, 2006: 1).

However, the impacts of climate change will vary from one region to the other (IPCC 2007: 36). The poor rural households engaged in subsistence and smallholder agriculture are expected to be the most affected. Their vulnerability is because their livelihoods are heavily dependent on natural resources; they have limited adaptive capacity due to high poverty; weak financial and institutional capacities, and lack of safety nets (IPCC 2007: 36). Thornton et al. (2006: 95) states that climate change in the Sub-Sahara Africa (SSA) affects the livelihoods of people through increased vulnerability of agriculture production by increasing water constraints; causing crop failure; increasing prices of agriculture commodities; loss and/or increased variability of livestock production; increased human migration; destruction of infrastructure; health and droughts. Therefore, the long-term impact of climate change is increased vulnerability of the poor, which entails reduced capacity to prepare; reduced capacity to cope; reduced capacity to recover from climatic shocks and stresses (*Ibid*: 4).

3.2 The Theory of Adaptation in dealing with Climate Change

The complexity and high uncertainties posed by climate change impacts can be addressed using two main strategies that include mitigation and adaptation (Perrings in PNAS 2007: 15180). However, this study is more concerned with adaptation. The study uses the IPCC definitions of adaptation and adaptive capacity, which state that *adaptation is adjustment in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts,* while *adaptive capacity* is defined as the *potential or ability of a system, region, or community to adapt to the effects or impacts of climate change* (IPCC 2001: 881).

The IPCC (2001: 883 – 885) makes further distinctions of adaptations, which include *Anticipatory Adaptations* that take place before impacts of climate change are observed; *Autonomous* - strategies that do not constitute a conscious response to climatic stimuli but are triggered by ecological changes and by market/ welfare changes; *Planned Adaptations* which result from a deliberate policy decision, based on an awareness that conditions have changed or are about to change and there is need to do something about it; while adaptations by individuals, households or private companies are termed as *Private*; those initiated and implemented by government are termed as *Public Adaptations***.** Lastly, *Reactive Adaptations* are those that take place after impacts of climate change have been observed.

Although adaptation strategies are not a panacea to climate change they are critical in reducing risk and vulnerability by enhancing resilience of communities and their livelihood systems (Nelson and Agbey 2008: 199; Fraiture *et al*. 2007: 1). The importance of adaptation in dealing with climate change is in two ways: firstly, adaptation enables assessment of impacts and vulnerabilities, and development and evaluation of response options (Nelson and Agbey 2008: 199). Planned, anticipatory adaptations are considered to have the potential to reduce vulnerability, with minimal costs and can avoid residual damages compared to autonomous adaptations (IPCC 2001: 902). Vulnerability of ecosystems or livelihoods to climate change impacts depends on the degree of exposure to the stimuli and on the ability of impacted systems to adapt (*ibid*: 881). The capacity to adapt depends on several factors that includes improved access to resources; poverty level; improved infrastructure; financial capacity; insurance mechanisms; adequate information and skills; existing early warning and protection from natural hazards.

In addition, adaption also depends on how people perceive climate change. There is a lot of evidence that links people's perception, adaption and responses to climate change (Diggs 1991: 114). Maddison (2007: 37) found that adaptation is something undertaken only by those who perceive climate change. However, even though farmers perceive climate change through experience, what determines whether or not they adapt to it is education (*ibid*: 36). Lane (2005: 5) defines perceptions as the process by which people become aware of objects and events in the external world. In this study perceptions also include experiences and views of people about climate change events.

Adaptation also depends on other factors that include availability of traditional knowledge, indigenous technology and new technology (Stigter 2002?: 1). Adding new technology, which is based on traditional knowledge, also reduces adaptation costs (*ibid*). Local institutions also play a significant role in adapting communal systems to climate change. O'Riordan and Jordan (1999) describe the role of institutions "as a means for holding society together, giving it sense and purpose and enabling it to adapt."

Therefore, in developing future adaptations strategies and policies, factors that constrain farmers to adapt to changing climate need to be considered (IPCC 2001: 888).

3.3 Adapting to Extreme Climate Events

Floods and droughts are normal climate occurrences within the natural climate system. Floods can be described in simple terms as water inundations over a large area caused by extremely intense or extremely long rainfall events. There are many definitions of drought however; this study uses the definition given by Krysanova et al. (2008: 4) that they are long periods of abnormally low rainfall, resulting in water shortages for human activities or natural systems.

In the context of climate change these climate events may become more frequent and extreme (Krysanova et al. 2008: 1). Adaptation to climate events in many semi-arid environments has been going on for a long time. However, it is adaptation to the increased uncertainty, frequency and extremes outside the normal range that is problematic. The IPCC (2001: 903) state that communities are more vulnerable and less adaptable to changes in the frequency and/or magnitude of conditions other than average, especially extremes. For example, in Ghana the increasing unpredictability of rainfall has made farmers to gradually lose their skills to predict major and minor rainy seasons (Nelson and Agbey 2008: 169).

There are various strategies that are used to adapt to extreme climate events, many of them are the same ones that are used to reduce vulnerability to normal climate variability and hazards (El Shaer *et al*., 1996; Rayner and Malone, 1998 cited in IPCC 2001: 889). What should change now is the pace of adaptation by becoming more urgent and effective than before (Stigter 2001?: 1). Examples of adaptation strategies to floods include structural and non-structural flood protection measures. Structural strategies involve measures that make use of physical infrastructure such as dykes, dams and reservoirs etc. Non-structural includes social measures and watershed/ catchment measures (Krysanova et al. 2008: 2). Strategies for dealing with droughts range from management of water supplies to demand management of scarce freshwater resources (*ibid*).

Specific examples of adaptation measures to frequent floods include mobilizing financial resources to repair/ strengthen reservoir infrastructure (Sally 2002: 8); including water harvesting technologies in order to minimize impacts on infrastructure and crops or for use during the dry season or drought periods (Stigter 2002?; Fraiture et al. 2007 and Keller et al. 2000).

Strategies for adapting to drought events may include conservation of groundwater supplies; water harvesting and storage in reservoirs; increasing water productivity; land and water conservation techniques; use of drought tolerant crops; improving water use efficiency of crops in drylands,; crop diversification; reducing irrigation activities in the dry season; integrating livestock and fisheries; and diversify rural income sources (Keller et al. 2000; Droogers and Aerts 2005; Castillo et al. 2007; Molden et al. 2007; Gaur et al. 2007 cited Fraiture et al. 2007; Kinderen 2006: 55)

Drought and flood early warning systems including targeted safety nets for farmers with limited adaptive capacity and insurance against catastrophic losses of productive resources are also useful strategies (*Ibid*: 13).

Adaptations to temperature changes include agronomical measures such as adjusting the time of planting, using different varieties or switching to different crops (Stigter 2001?: 4; Droogers and Aerts 2005 cited in Fraiture et al. 2007)**.**

Experiences of ineffectiveness and inadequacies in using unilateral approaches have prompted the shift to integrated approaches. Therefore new approaches integrate different strategies in adapting to climate change events (Kundzewicz and Takeuchi 1999 cited in Krysanova et al. 2008: 3; Hitz and Smith 2004 cited in Chaponniere and Smakhtin 2006).

3.4 Integrating Adaptation Strategies in Water Management Systems

Planned adaptation strategies can only be effectively implemented if they are integrated as components or as modifications to existing natural resources and sustainable development programs and strategies at community, regional or national levels including integration with adaptations that address non-climatic stimuli (Campos *et al*., 1996; Magalhães, 1996; Theu *et al*., 1996; Mimura, 1999a; Apuuli *et al*., 2000; Munasinghe, 2000; Osokova *et al*., 2000) cited in (IPCC 2001: 895). Two complementary approaches that are used to integrate different strategies in the management of water resources include the Integrated Water Resources Management (IWRM) and the Adaptive Water Management (AWM).

3.4.1 Integrated Water Resources Management (IWRM) and Climate Change

The key principle of IWMI is to ensure sustainable use of water resources. This is premised on the fact that water is a natural resource that is multifunctional and multidimensional in nature; a source of conflicts; and that its quantity and quality is threatened by increasing demand for water and climate change factors (Global Water Partnership, 2000). The IWRM approach ensures sustainable use of water resources by stressing the importance of broad stakeholder's participation in decision-making to ensure consideration of all interests (interests of various user-groups) relative to water conservation and use and also requires that decisions or strategies made take into account all major political, economic, environmental, social aspects (*Ibid*). Without an IWRM approach it is very difficult to achieve high performance levels and sustainable management of multipurpose small reservoir systems.

3.4.2 Adaptive Water Management and Climate Change

Due to its ability to respond to uncertainty, adaptive water management is expected to be better able to deal with the uncertainties associated with climate change (Van der Brugge and van Raak2007: 1; Pahl-Wostl et al. 2007: 2).

Adaptive Water Management is defined as systematic strategies for improving management policies and practices by learning from the outcomes of previous management actions (Pahl-Wostl (2008: 1). It aims to increase the adaptive capacity of the water system by putting in place both learning processes and the conditions needed for learning processes to take place. This includes social learning as it is important in initiating change in, to build, and to sustain the adaptive capacity of water management systems. This approach could be useful in increasing the adaptive capacity of communities in managing small reservoirs in the context of climate change. However, its implementation has challenges, which in many developing countries include the need for profound structural changes; limited management capacity; political instability and the absence of reliable administration; inadequate knowledge base and monitoring capacity by implementing institutions (*ibid*).

DESCRIPTION OF THE STUDY SITES

This study was undertaken in two sites namely Baare and Kajelo. The two sites are located in the Upper East Region (UER) of Ghana. The region has the highest concentration of small reservoirs in Ghana. Most of them were developed under the government's irrigation policy to reduce the high risks associated with rain-fed agriculture (Edig et al. 2002 in Gyasi 2005: 4).

Kajelo is one of the largest multi-purpose reservoirs in Kasena Nakana West (Paga) District. The reservoir was built in the 1950s. Kajelo underwent major rehabilitation from 2004 – 2006 by MoFA under the IFAD phase II project. Management of the reservoir is by a WUA introduced in 2006. The dam serves a population of approximately 650 households. The community is composed of one ethnic group called *Kasenas*. The reservoir serves multiple communities in the area. Other sources of water in the community include wells, hand dug wells and boreholes.

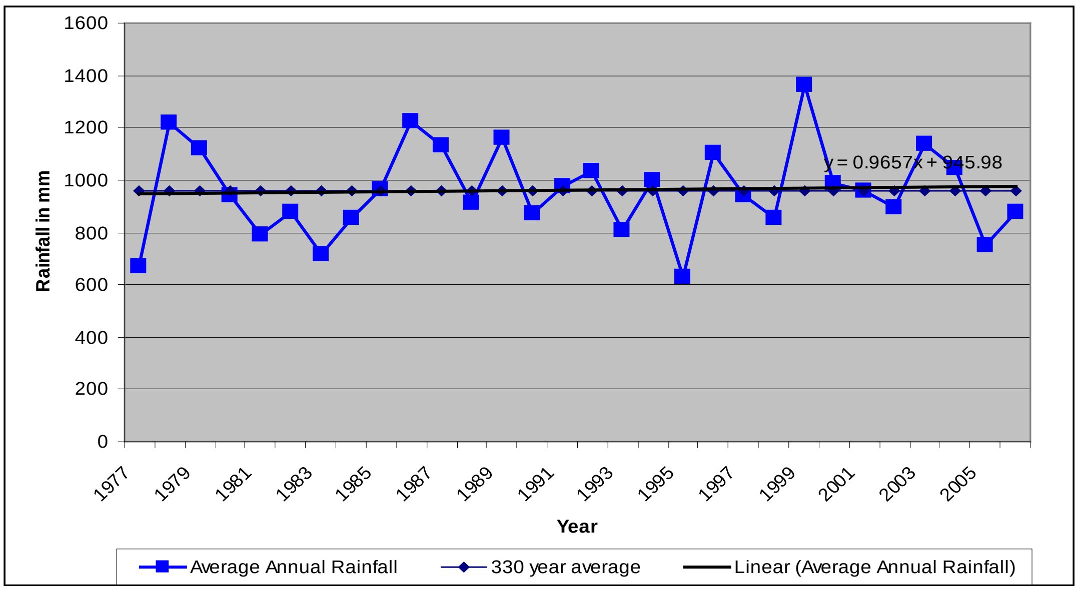
Baare is one of the largest multiple-purpose reservoirs in Talensi-Nabdam District. It was constructed in 1987. The dam serves about 400 households. The community is composed of one ethnic group. The first major rehabilitation was done in 2006 funded by the Africa Development Bank. The dam is managed by the WUA that was introduced in 1998.

The UER region is one of the poorest regions of Ghana and is predominantly rural with more than 90% of the population engaged in livestock and crop farming. The region is characterized by a high population density; erratic rainfall (average rainfall of 1000mm); high day temperatures; high evapo-transpiration rate (exceeding annual precipitation); wide-spread droughts; floods and soil erosion; infertile soils; low ground water and annual food shortages. The greater region falls under the guinea savannah ecological zone (Gyasi 2005: 4; Bruce et al. 1999, Abatania and Albert 1993 in Gyasi 2005: 8; EPA 2008: 166). Generally, farming in the north shows considerable adaptation to these spatially and temporal variable ecological conditions (EPA 2008: 166).

ANALYSIS AND DISCUSSION

5.1 Long-term Trends in Rainfall and Temperatures

Results from the analysis of the 30-year rainfall and temperature series data indicate positive trends in both Kajelo and Baare (see figure 1 below). The trend analysis for Baare is in Appendix 1. Details of the rainfall data used in the analyses are in appendix 2 & 5. The rainfall pattern in the graph below indicates high inter-annual variability of sharp troughs and peaks.



Source: Data from the Meteorological Department of Ghana

Figure 1 30-year Rainfall Trend at Navrongo Station

Notable troughs (below average rainfall) occurred in 1980, 1981, 1984, 1990, 1995, 1997 and 2004. Figure 1 above also indicate rainfall peaks associated with floods in 1979, 1988, 1991, 1996, 1999, 2001 and 2007. These results correspond with most respondents and official reports that indicated the occurrence of droughts and floods in these years (also see official reports in table 1). Put et al. (2004: 28) also found an increasing drought risk between 1960s and years thereafter for almost all the rain stations in West Africa. The most considerable drought risk was observed between 1965 and 1985 and after 1985.

Studies at regional level by Nicholson (2001) observed considerable multi-decadal variability in rainfall over time. He found drying in the recent years and a striking decrease in annual rainfall in the Sahel Region after 1968, with a decrease of around 20 to 40% from 1931–1960 to the period 1968–1997. According to Nicholson (1993), the 1980s were the driest period of the 20th century in West Africa. Hulme et al. (2001) also found a decrease in precipitation exceeding 25% within the last century over some western and eastern parts of the Sahel.

Similarly, different studies at basin level by Wittig *et al*. (2007); Oguntunde et al. (2006); Neumann et al. (2007); and Kunstmann (2005) found positive and stable trends in temperatures; gradual increase in dryness at a rate of 15 % of mean in aridity index; decrease in precipitation of 6 mm/yr for the period 1970–2002; significant increases in runoff at the rate of 23 mm/yr; shortened total period of the rainy season; increases in evapo-transpiration due to the possible increases in temperature and/or net radiation. These studies attributed these changes to the possibility of climate change and land cover change.

Ghana has climate change scenarios developed for 2020, 2050 and 2080 for all agro-ecological zones using the 1961 – 1990 base period, which provide an important basis for taking policy actions on climate change for the country (Minia 2008: 6). These scenarios are based on the General Circulation Models (GCMs), which are mathematical formulations that simulate expected future climate under various projections of anthropogenic green house gas emission profiles (*Ibid*: 2).

Projected future rainfall based on the GCMs indicate decreasing trends in mean total annual rainfall by 2%, 8% and 11% in the year 2020, 2050 and 2080, respectively. See future rainfall scenarios for the Guinea Savannah Ecological Zone in Appendix 10. This is not far from the IPCC (1997) projection of 10% reduction in rainfall by 2050 for Ghana.

The positive rainfall trends that I observed in figure 1 are therefore not consistent with the different studies cited above including projected climate Change Scenarios for the region. The observed positive trend in rainfall though very minimal, for both Kajelo and Baare do not necessarily mean a positive trend or increases in rainfall in the future. This is because the rainfall trends performed are based on linear analysis, which does not take into account other environmental variables like GCMs. This could explain the difference in the observed trend in rainfall in this study and the expected future rainfall based on the GCMs scenarios. However, climate scenarios based on GCMs also have limitations which include low spatial resolution; therefore many smaller-scale elements of climate are not properly represented. Precipitation in particular, is poorly represented both spatially and temporally in GCMs (Asante 2009: 63).

A similar long-term (1980 – 2009) trend analysis for mean minimum and maximum monthly temperature for Zuaraungu station, which is the closest meteorological station to Baare indicate a positive trend (see figure 2 below). Temperature data is appended in 3 & 4 for Baare and 6 & 7 for Kajelo (using Navrongo station). In addition, the graphical analysis of mean maximum and minimum monthly for Baare is in Appendix 8.

The observed positive trend in temperature in this study is consistent with the future climate change scenario for the mean annual temperatures for the Guinea Savannah Agro-ecological zone, which also indicate a positive trend. See figure 3 below.

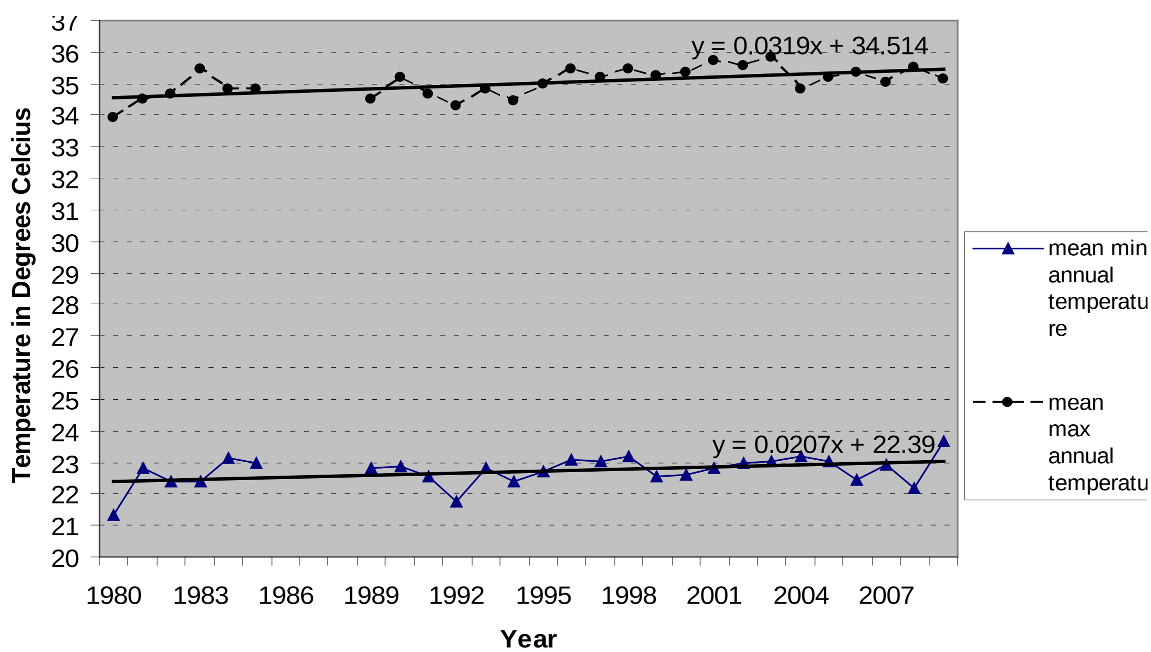
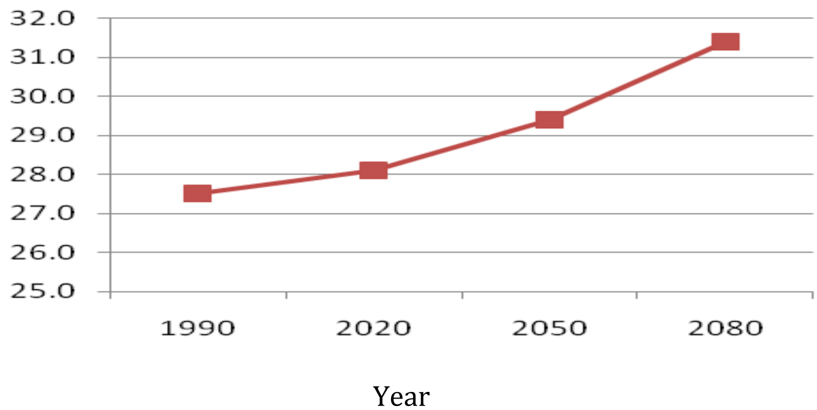


Figure 2 30-year Trends in Mean Max and Mean Min. Temperature at Zuarungu Station

In the trend analysis of climate change scenarios for temperatures in the Guineas Savannah Zone in figure 3 below, I found future temperature increases of 0.6^{o}C, 2.0^{o}C and 4.0^{o}C in the year 2020, 2050 and 2080, respectively. Temperature scenario data is in Appendix 9. These projections fall within the range of expected temperature increases of 1.4^{o}C - 1.6^{o}C by 2050 projected by IPCC (1997).



Source: Data compiled from EPA 2008: 335

Figure 3 Mean Annual Tempt. Projections in ^{o}C for the Guinea Savannah

The Ghana Initial Communication to the UNFCC (EPA 2000 in EPA 2008: 237) state that although future climate change scenarios indicate increased temperatures in all the agro ecological regions in Ghana, increases in the Sudan Savannah Region where temperature is already high are much higher than the other regions.

5.2 Climate Change: Perceptions of Communities and Key Informants

Although most farmers were not able to remember the exact dates of occurrence of drought and flood events, they perceived that the climate situation has changed in the recent years compared to more than 30 years ago. Despite some contrasting perceptions on the occurrence of climate change events in some cases, they at least indicated that in the last five years there has been more than one drought and flood occurrence in their areas. Similarly, some Key Informants also perceive that climate in the areas has changed. The Director for Agriculture in Kajelo indicated that droughts and floods have become more frequent nowadays. He mentioned that in 2007, 2008 and 2009 the area experienced droughts as well as floods. “We now experience droughts around late May to July and floods from August to September”, said the Director.

According to the World Bank (2009: 8), Ghana experienced more than six major floods between 1991 and 2008. Ghana also experienced droughts in 1970, 1975, 1977 and 1983 (EPA 2008: 159). Table 5 below shows drought and flood events experienced in the UER and Kajelo over the last five years as compiled from FGDs and official sources (the World Bank 2009: 8 and MoFA District Director, respectively.

Table 1 Drought and Flood Events in the UER and Kajelo in the Last Five Years

Category	2005		2006		2007		2008		2009	
	drought	flood	drought	flood	Drought	Flood	drought	flood	drought	Flood
Fishermen	**XX**	**XX**		**XX**					**XX**	
Men	**XX**	**XX**	**XX**						**XX**	
Women					**XX**	**XX**	**XX**		**XX**	
Livestock					**XX**					
Poor						**XX**				
Official Reports*					**XX**	**XX**	**XX**	**XX**	**XX**	**XX**

Source: compiled from FGDs and Official reports from the MoFA District Director and the World Bank (2009: 8)

Although there are some notable differences, the conclusion from Table 1 is that different people perceive that droughts and floods occur nearly every year. Nearly all the respondents mentioned the flood that occurred in 2007 partly because it was a serious one. Perceptions from Key Informants were that the rainfall pattern has changed over the years. The MoFA Director indicated that the pattern of rain has become more unpredictable and that the rainy season has shortened. “The rainfall used to be from April to November but now it is from June to October”, said the MoFA Director in Kajelo. In addition, droughts and floods are more frequent occurring nearly every year characterized by droughts around late May to July followed by floods from August to September. The Director of MoFA in Baare also had similar perceptions. See box 1 below:

Box 1 Climate Change Perceptions by the Director of MoFA in Baare

'There is a change in the peak of floods. For the past 3 years, there is a flood every year, which causes loss of livestock and crops. This year (2009) the peak of floods came in September. This is a change in the peak of rainfall compared to the previous years - the normal pattern was broken. The time we expected the rain it never came. The normal time of rain is May – June. The floods are taking place every other year, which was not the case in the past.'

In the FGDs farmers also indicated the high rainfall variability and intermittent occurrence of droughts and floods within a single growing season as a common feature nowadays.

A PRA tool 'Now and Before Matrix' was used to generate the communities' perceptions on the occurrence of climate events (droughts and floods) in terms of frequency and severity of impacts on their livelihoods. This tool compared perceptions of the Baare community before the dam was constructed about 30 years ago and the present situation (see figure 4 below). Though this tool has a limitation since it only weighs two points in time 'before' and 'now' without capturing trends in between, it is a useful tool in generating people's perceptions of improvements or deterioration in one or more issues at hand. Using this tool I found contrasting views among user-groups of the reservoir on the occurrence and impacts of climate change events in Baare and Kajelo. In Baare, the differences were notable between livestock farmers and irrigators.

ISSUE	Men 30 yrs ago	Women 30 yrs ago	Livestock farmers 30 yrs ago	Men NOW	Women NOW	Livestock farmers NOW
Floods	–	–	+	+	+	–
Droughts	–	–	–	+	+	+
Impact of Floods & Droughts	+	+	–	–	–	+

(–) indicates a negative trend (+) indicates a positive trend

Source: Field Data

Figure 4 Trend Analysis of communities' perceptions of climate change events in Baare

However, I found that the same pattern of perceptions between men and women irrigators for all the climate events including the levels of impacts. The irrigators perceived that before the small reservoir was constructed about 30 years ago the frequency of occurrence of floods and droughts was low compared to nowadays, while the livestock farmers had a contrasting perception. Similarly in Kajelo differences in perceptions were noted among different user-groups including results from individual interviews.

The reasons for the differences can be attributed to the varying degrees of impacts affecting respective user-groups of small reservoirs. In addition, the impacts of climate events among individuals also vary depending on the main livelihood of an individual and coping/ adaptation strategy adopted. However, despite contrasting perceptions, there was a general perception or consensus across the different user-groups in both study areas concerning the role the small reservoirs have played in reducing the communities' vulnerability to climate events, particularly droughts. This is because the reservoirs provide additional livelihood opportunities such as dry-season farming, fishing and livestock watering in drought years, which was not the case before they were constructed.

The contrasting perceptions made it difficult to rely on the results from the 'Now and Before' trend analyses alone in understanding trends of climate change events in the study sites without the support of climate data from the meteorological department. The use of two methods helped to provide a clear picture in these trends.

5.3 Performance Levels of Small Reservoirs in the UER

Analysis of data from the IWMI Inventory on Small Reservoirs in the UER of Ghana as assessment by the Agriculture Extension Agents responsible for the small reservoirs in the respective areas showed that the majority of small reservoirs (59%) are performing below average, while 17% are performing at average level and 25% are performing above average (assessed as high and very high performing). See Table 2 below.

Table 2 Performance Levels of Small Reservoirs in the UER of Ghana

Performance Level	Frequency	Percentage
Very Poor	77	32
Poor	65	27
Average	40	17
High	44	18
Very High	16	7
Total	**242**	**100**

Source: Data from the IWMI Inventory on Small Reservoirs (2010)

5.4 Factors Affecting Performance of Small Reservoirs in the UER

Analysis of data from the IWMI Inventory of Small Reservoirs indicated the following factors in table 3 below as affecting performance of small reservoirs in the UER of Ghana. In the table it is clear that the major factors affecting performance are physical and infrastructural factors related to the effect of climate factors.

Siltation of reservoirs constituted the most common factor (more than 41%); followed by broken dam walls (more than 27%); lack of irrigation infrastructure (more than 18%) and low water availability (more than 12%). Isolating the factors highlighted above to determine the key ones affecting performance is difficult without understanding the inter-relationships between them.

Table 3 Factors Responsible for low Performance of Small Reservoirs in the UER

Main Reasons for low Performance	Total	%
Siltation	41	30
Broken dam wall	27	20
No irrigation infrastructures	18	13
Low water availability	12	9
Broken dam wall, Siltation	7	5
Broken canals	4	3
Siltation, poor dam wall	4	3
Design problems	3	2
Seepage	3	2
Siltation, seepage	3	2
Siltation, broken canals	2	1
Siltation, no irrigation infrastructures	2	1
Broken canals, Siltation	1	1
Broken dam wall, no valve	1	1
Broken spillway	1	1
Broken spillway, leaking valve	1	1
Disrepair	1	1
Eroded dam wall	1	1
Low dam wall	1	1
Reservoir not in use	1	1
Not rehabilitated	1	1
Siltation, no cooperative group (WUA)	1	1
Work not completed	1	1
Grand Total	**137**	**100**

Source: IWMI Inventory of Small Reservoirs (2010)

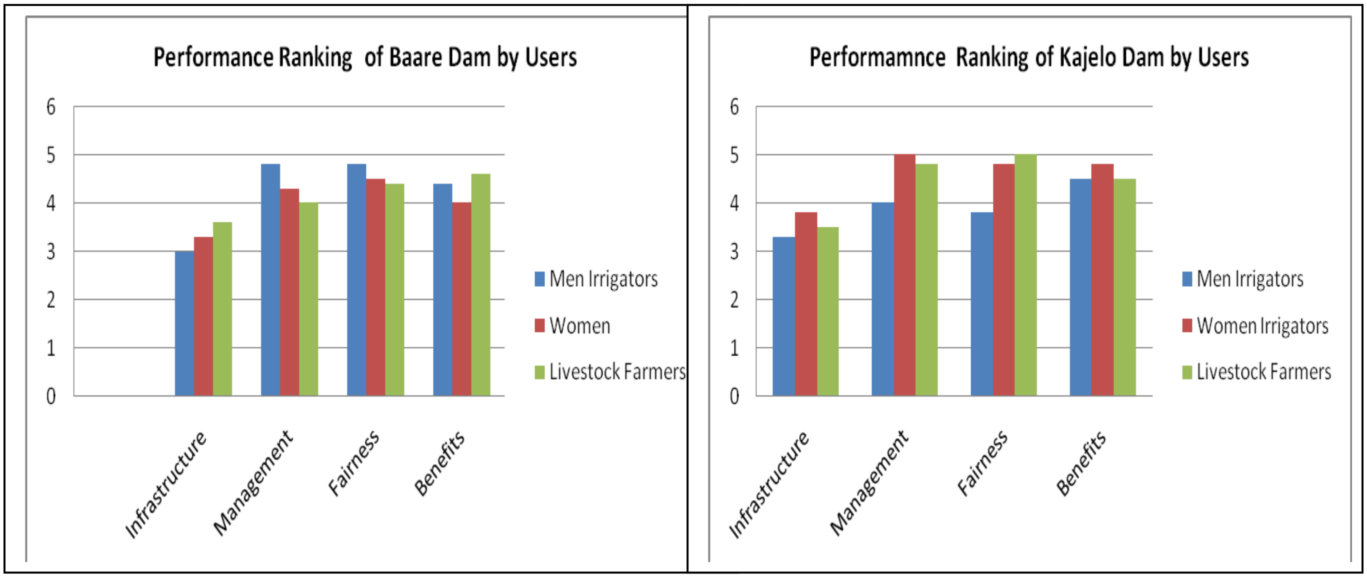
According to Bos et al. (2005) understanding the interrelationships and linkages of factors affecting performance helps to determine the cause and effect. In analyzing this interrelationship, I found that siltation is not only strongly linked to storm events, surface runoff; and land-use change, but it is also a product of soil erosion control and catchment management. The problem of siltation was found to reduce the quantity and quality of water available for different uses hence limiting benefits from the reservoirs.

The interrelationship among these factors also link broken dam walls to the effect of climate factors (floods) and management failure to control the damaging actions of crocodiles living in the reservoirs. Key Informants indicated that breaching of most dam walls in the UER is caused by crocodiles that live in the small reservoirs. In the UER crocodiles are considered as sacred animals therefore they are protected by the local people. This has created a large population of crocodiles in the reservoirs. These reptiles make holes in the dam walls where they lay eggs. It is these holes that weaken the dam walls from the effect of floods. The effect of floods are also due to the large catchment areas which are associated with high surface runoff that exceeds the storage capacities of small reservoirs leading to spillage and breaching of dam walls (Keller et al. (2000:7). In addition, the dam walls of many small reservoirs easily collapse from the effect of floods partly because they are constructed from weak earth material as the case in both Kajelo and Baare.

Another factor that I found to affect performance was low water availability. Using the same logical reasoning this problem can be attributed to low rainfall and/or drought effect as well as inadequate design of the reservoirs. The respondents from FGDs also attributed the problem of low water availability in both Kajelo and Baare to low rainfall and limited storage capacities of the reservoirs. They mentioned that the limited storage capacity of the reservoirs was a design problem that is worsened by siltation. In Kajelo the farmers also attributed the low water availability in their reservoir due to the low rainfall received in 2009. However, studies by Faulkner and Sally found that performance of small reservoirs was inversely related to water availability. The study by Faulkner's involving two small reservoirs in the UER of Ghana found that a reservoir system with relatively less water available performed better than the one with relatively more water due to a well-structured management and more efficient irrigation system in the former system (Faulkner 2006: 31-32). Similarly, the study by Sally in Burkina Faso found that irrigation schemes with relatively low water availability tend to make more productive use of water (Sally 2002: 8). These findings are context specific, therefore cannot be generalized.

5.5 Performance of Small Reservoirs: Communities' Perceptions

In terms of performance, water users were asked to rank their perceptions on the performance of their reservoirs based on four qualitative indicators: design, condition and functioning of infrastructure; management arrangements of the reservoir; benefits accruing from the use of the reservoirs and fairness of resource distribution. The ranking was based on a scale from 1 to 5 with one (1) indicating very poor; two (2) indicating poor; three (3) indicating average; four (4) indicating good; and five (5) indicating very good. Results from three user–groups (Men and Women Irrigators and livestock farmers) are summarized in figure 5 below. The actual rankings are provided in Appendix 11.



Source: Field Data compiled from individual interviews

Figure 5 Users Perceptions of Performance of Small Reservoirs

The users' rankings of performance of small reservoirs in figure 5 above indicate infrastructure design, status and functioning as the lowest (with average overall rank of 3.4) in all the three categories of water users in both Kajelo and Baare. The major reasons advanced for the low ranking of infrastructure included: poor state of canals which lead to high water losses due to leakages; inadequate water and storage capacity of the reservoir due to limited storage capacity of small reservoirs and the effect of siltation. Some farmers also attributed low performance to the canal failure to deliver water to the plots located at the tail end.

However, the other three qualitative indicators (management, socio-economic benefits and fairness in institutional arrangements), were ranked as good to very good (the overall rank for these indicators was 4.5). The farmers mentioned improved water availability for livestock watering as one major benefit from the reservoirs. The farmers in Baare stated that before the reservoir was constructed they used to cover long distances of more than 10miles to water their livestock, which is no longer the case. Other benefits mentioned included increased income from sales of irrigated cash crops; water for domestic use, construction material, general increase in food during the dry season; improved health and nutrition from eating green vegetables.

On the contrary, the Director of MoFA indicated that the problems associated with the Kajelo Dam were mainly because of bad management; however most of the community members do not see any shortcomings with the management of the reservoir only a few men-irrigators in Kajelo highlighted flaws in management by the WUA such as wastage of irrigation water; poor attendance of WUA meetings by farmers; poor turn-out for maintenance work; and that WUA meetings are not held regularly. However, perceptions on the overall performance of the reservoirs across the three categories of users indicate a ranking of 4.2, which indicates good performance.

The results above indicate differences in the users' and key Informants' perceptions on the performance of small reservoir in Kajelo. This could have arisen from the differences in the scope and indicators used in the assessment; and the perspective or from whose view-point the assessments were conducted (Bos et al. 2005). The performance assessment by the AEA in Kajelo was based on the status of the irrigation infrastructure alone; and that of the Director was based on management indictors, while the assessment by the users were based on the overall picture in terms of benefits they derive from the reservoirs.

However, based on the multi-purpose approach of measuring performance of small reservoirs with reference to their intended purposes, the results indicate that both Kajelo and Baare small reservoirs are performing well for all the other water uses apart from irrigation. The poor performance of irrigation compared to the other water uses can be largely explained by the problems, constraints, high input and infrastructural investments required associated with irrigation. Most of the factors that were found to negatively affect performance of small reservoirs such as floods, droughts, the poor state of irrigation infrastructure, inadequate availability of water, and agricultural constraints (inputs, storage, markets and plant diseases) affect irrigation more than any other water use.

5.6 How Climate Change Affects Performance of Small Reservoirs

I found that climate change affects performance of small reservoirs both directly and indirectly. See Appendix 12 showing the illustrative figure for the logical analysis of the cause and effect of climate events on the performance of small reservoirs. The figure shows that the direct impacts of climate change on the performance of small reservoirs include damage on reservoir infrastructure; deterioration of the quality of water and reduction in the quantity of water available for various uses.

I also found indirect impacts of climate change events on the performance of small reservoirs. This happens by the effect of these events on other important components of the livelihood system such as rain-fed farming, livestock and housing. This is because these livelihoods are strongly linked to irrigation and the use of the reservoir. The relationships among these livelihoods are mutually supportive of each other. Many respondents indicated that the success in one livelihood positively benefits the other. For example, most farmers indicated that they sell some rain-fed crops following a successful harvest to raise capital for purchasing inputs required for dry-season farming and vice versa.

5.6.1 Impacts of Floods on the Performance of Small Reservoirs

In Baare, the floods experienced in the last five years were said to have had damaging effects not only on the reservoir infrastructure (irrigation canal) but also on other livelihoods of many farmers. The farmers mentioned that floods experienced in the past in 2007 and 2008, damaged the newly constructed irrigation canal leading to increased maintenance costs of the canal, most importantly these floods led to non-irrigation for two consecutive seasons (see the historical profile of Baare in Appendix 13). This negatively affected the communities' food and income levels derived from the small reservoir in the two years. The farmers also said that the ill designed spillway easily allow water to overflow due to its low height, therefore limiting the reservoir's role of flood control. While in Kajelo most respondents indicated that floods do not have any effect on the reservoir infrastructure because when it floods the water spills. They mentioned that the reservoir is experiencing the problem of siltation, which deteriorates water quality for domestic purposes. Juracek and Ziegler (2006) also state that soil erosion and sedimentation in arid and semi-arid environments affects performance of small reservoirs by reducing water quality and availability, therefore increases financial costs for human use. Siltation was observed to be a bigger problem in Kajelo compared to Baare. The problem of siltation in Kajelo was observed to be partly due to the sand extraction from the edges of the reservoir for construction purposes. The community members stated that the WUA encourages them to extract building sand/ clay from the edges of the reservoir in the dry season in order to help deepen the reservoir so that it collects more water. The impact of deteriorated water quality for domestic use is felt more by individuals who do not have alternative water sources such as boreholes.

I also found indirect impacts of climate events on performance of small reservoirs by affecting other vital livelihoods that are linked to small reservoirs such as livestock farming, rain-fed farming, housing, alternative water sources and even lives of people, particularly women and children. Table 4 below indicates the extent of damage and impacts of floods in the northern part of Ghana as assessed by the National Disaster Management Organization (NADMO).

Table 4 Summary of the extent of damage due to flooding in Northern Ghana in 2009/2010

	No. Affected Entities	**Total Affected**
1	No. of Districts	26
2	No. of Communities	924
3	Farms Destroyed (acres)	28,264.5
4	No. of Collapsed Houses	5,104
5	Schools Destroyed	13
6	No. of Affected Persons:	
	Children	31,521
	Pregnant Women	170
	Other women	17,934
	physically challenged	1
	Dead	8
	Total No. of Affected Persons	**121,044**

Source: CILSS 2009: 21

It was estimated that about 26 districts, 11,536 ha of farms, 5,104 collapsed houses and 121,000 people were affected by the floods (CLISS 2009: 21). Many housing structures that get damaged are those built close to the reservoirs in low laying areas and those made out of weak mud/ clay material.

The IFRCRCS (2007: 2) highlighted malaria and diarrhoea as serious diseases linked to high morbidity and mortality rates in the UER, caused by the effect of flood water, which increases breeding of mosquitoes and contaminates domestic water sources such as wells and boreholes. Floods also cause loss of crops by farmers; damages food storage sites, all which increases farmers' vulnerability to food insecurity. Floods also cause death of human beings. In 2007 about 30 people were reported to have been killed by floods in the northern part of Ghana.

In both Baare and Kajelo, the farmers stated that floods also lead to livestock losses by causing livestock diseases and in many cases livestock is lost by being washed away by flood water. It was found that the women, children and people living very close to the reservoirs and in low-lying valley areas, are the mostly affected by floods.

5.7 Impacts of Droughts on the Performance of Small Reservoirs

The common perception of communities in Kajelo and Baare is that the impacts of droughts have reduced to some extent in the recent years compared to more than 20-30 years ago due to the existence of small reservoirs as they provide an opportunity for dry-season food production.

The respondents through FGDs and individual interviews perceive that droughts experienced now are not as severe as the one experienced in 1983. In both Baare and Kajelo the respondents clearly remembered the impacts of the 1983 drought since it was a national disaster. However, they could not remember all the event years mainly because they were relatively less severe.

Direct effects of droughts on the performance of small reservoirs include inducement of water shortage that reduces productivity of small reservoirs for various purposes, particularly irrigation. Droughts also deteriorate water quality for domestic use. In Kajelo, the low water level during the 2009/2010 season significantly affected the agricultural productivity of the reservoir. According to the WUA secretary, about half the number of gardeners did not irrigate in that season due to inadequate water in the reservoir. The impacts of droughts are more for farmers who begin to irrigate late as the water in the reservoirs drops drastically during such times of water stress.

Similarly, drought has indirect affects on the performance of small reservoirs by causing crop failure in rain-fed fields and also affects the health of livestock.

5.8 Impacts of Increased Temperatures

High temperatures currently experienced in the UER coupled with erratic rainfall triggers high evapo-transpiration. According to Asante (2009) this affects irrigation water demand for crops. The effect on each crop differs depending on its water requirement and how much it is cultivated. All the major cash crops grown under irrigation in both Kajelo and Baare are high water consuming crops. The study by Asante found that irrigation requirements for these major cash crops grown in the UER of Ghana ranged from 457.4 mm/period to 905.5 mm/period for onion and rice, respectively while irrigation requirements for tomato and pepper fell within this range (*Ibid*: 39). He also found that the expected future increases in temperatures and reduction in rainfall in the UER will further increase evapo-transpiration that will trigger increases in the irrigation water requirements of these crops in the range of 0.6 – 9.0 percent from the base year of 1990.

Since tomato is not currently irrigated at Baare and Kajelo due to the various constraints affecting its production, which include the nematode plant disease in Baare and poor storage and marketing in Kajelo, expected temperature increases will not affect performance of these reservoirs for tomato production. However, okra and pepper production are likely to be negatively affected as these are the major cash crops currently being irrigated at Baare and Kajelo, respectively.

6.5 Water Management Strategies for Adapting to Climate Change

Despite this study focusing on water management strategies, a wide range of adaptation strategies covering other major livelihoods of communities, which includes livestock and rain-fed farming were also documented. This is because the use of small reservoirs is strongly linked to the other livelihoods in a mutually supportive relationship. This linkage provides both opportunities and constraints that explain how communities respond to climate change and variability. The other reason is that farmers prefer mixed strategies to maximize diversity of production in order to spread risks (Vincent 1994: 312).

I summarized results in table 5 below according to the main adaptation types as defined by the IPCC (2001: 887), which includes anticipatory, reactive, private and public adaptation strategies. Table 5 below shows that there are various adaptation strategies that communities use in adapting to climate change and variability at both individual and community level. In the table below it is clear that structural and non- structural strategies are integrated in responding to flood events, while adaptations for responding to droughts involve both management of water supplies to managing demand of scarce freshwater in the reservoirs.

These strategies are described below, particularly water management strategies including a brief assessment of their effectiveness in contributing to the enhancement of communities' adaptive capacity to climate change and variability based on a criteria that includes cost, benefits, equity, efficiency and implementability, which is commonly used in evaluating the effectives of adaptation strategies (IPCC 2001: 885).

Table 5 Water Management & other strategies for adapting to climate change and variability in Kajelo & Baare

	Anticipatory	Reactive
Private	<u>Dry season farming</u> • Adjusting planting dates • No irrigation • Use of soil moisture in valleys <u>Rainfed-faming</u> • Stone bonding • Contour ploughing • Planting vertivar grass around rain-fed field • Intercropping • crop diversification • Use of drought tolerant cops • Use of early maturing crop varieties • Switching/ changing crop varieties • Adjusting planting dates • Increasing land productivity/ yields <u>Others strategies</u> • Diversifying income sources • Mixed farming • Integrating livestock and fisheries • Drought early warning by the tindanas	<u>Dry Season farming</u> • No irrigation <u>Rainfed-faming</u> • Replanting after failed crops <u>Others strategies</u> • Collecting firewood & shear nuts for sell • Migrating to the southern part of the country
Public	• Institutional arrangements for water use (large water vessels/tankers not allowed, the *Fulani* animals not allowed; use of pumps to irrigate not allowed; free movement of livestock at irrigable not allowed; use of bathing soap not allowed in reservoir) • Minor maintenance of small reservoirs by the WUAs (re-planting of vertivar grass) • Soil erosion control and catchment protection • Water harvesting (deepening reservoir to store more water) • Group fishing in Kajelo done once in a week • Fishing in Baare is only done by MoFA	• Change in water allocation or reducing irrigation activities • Major rehabilitation of small reservoirs by the D.A • Minor maintenance by the WUAs (mending holes in the canals) • Flood control (opening water valve of the reservoir when flood water is in excess)

Source: Compilation from field data

6.5.1 Maintenance of Small Reservoir Infrastructure

Since small reservoirs are communal resources their maintenance is a responsibility of the WUAs and the District Assemblies (DA) depending on the nature or scale of maintenance required. The WUAs are responsible for minor maintenance work while the DAs are responsible for major maintenance. Major maintenance usually involve huge capital and financial investments, while minor maintenance are simple periodic works such as mending holes or cracks in the canals. I found minor maintenance of the reservoirs to be a public (community-level) adaptation strategy, which is both anticipatory and reactive depending on its timing and purpose. It is usually done after the rainy season in order to repair damages caused by flood events and prepare for dry season farming. However, minor maintenance that is done during the rainy season such as re-planting vertivar grass on the reservoir embankment, which is occasionally done, is meant to lessen soil erosion, this action is therefore anticipatory.

Most of the resources for minor maintenance are mobilized locally. This includes labour and finances from water charges collected from irrigators and individual financial contributions by farmers. Unlike financial contributions; labour is usually provided by all water users not only irrigators depending on the infrastructure component involved. In Kajelo non-irrigators stated that they do not get involved in any maintenance of canals but other components of the reservoir. The social capital in form of strong unity and social cohesion makes it easy for the two communities to effectively mobilize the local resources for minor maintenance. The communities in both areas expressed satisfaction with minor maintenance work which they do to the reservoirs.

However, this strategy has not been effectively implemented in both Kajelo and Baare mainly due to weak institutional arrangements and financial capacity to ensure effective and more sustainable management of the reservoirs. The weak institutional arrangements include inadequate control of livestock watering as this causes damages to irrigation infrastructure particularly canals. The weak financial capacity is largely due to the ineffective revenue collection mechanism involving water-use charges - less than 38% (see table below 6) of registered irrigators paid from 2008-2010 despite many farmers indicating that the charges are reasonable. The narrow revenue base, which is currently restricted to water charges for irrigation excluding other water users and revenue from other sources such as penalties as stipulated in the WUA constitution and bye-laws, also contribute to the weak financial capacity.

Table 6 Kajelo Dam II – Paid and Unpaid up Members (Irrigators) of the WUA

	Irrigation Season					
	2008/2009*			**2009/2010****		
Irrigator	**Paid**	**Unpaid**	**Total**	**Paid**	**Unpaid**	**Total**
Male	54	58	**112**	22	41	**63**
Female	15	95	**110**	22	33	**55**
Total	**69**	**153**	**222**	**44**	**74**	**118**

*Paid at the end of irrigation season (2008/2009). **Paid at the beginning of the season (2009/2010)

Source: Compiled from the Kajelo WUA payment register

The general argument why other water uses such as livestock do not attract a water-use levy is that practicality regulating livestock is difficult because it comes from different communities, which makes it difficult to identify the owners. The other reason they gave was that livestock watering uses less water compared to irrigation. Nevertheless, at the time of the study, finances available in the Management Fund (Bank Account) for Baare and Kajelo stood at US $414 and US$483, respectively. Sally (2002: 8) also found inadequate financial capacity by many local farmer organizations to make substantial repairs to reservoirs such as renewal of facilities and repairs of damages caused by floods despite their financial contributions for minor maintenance. The inability of many irrigation farmers in Kajelo and Baare to pay water charges is linked to many factors such as poverty; poor harvests from rain-fed farming; and the flexible payment system that allows farmers to pay at the end of the irrigation season.

Major maintenance of small reservoirs only takes place when there is urgent need. It is usually done as a reactive strategy to repair damages caused by floods and siltation. In some cases it is done to reduce water losses by constructing concrete irrigation canals as in the case of Baare Dam. Water users also participate in major maintenance by providing the required labour. Similarly, major maintenance faces financial constraints on the part of the responsible authorities (the District Assemblies). This is despite adequate national policy frameworks that support irrigation development and management of small reservoirs in Ghana. The DA has limited financial capacity to assist communities in major maintenance because it also heavily depends on financial support from the central treasury and donors such as the International Fund for Agriculture Development (IFAD). The other constraint facing this adaptation strategy is the poor quality of material used including the poor output by contractors who are engaged to work on the small reservoirs. Communities in Baare and Kajelo expressed dissatisfaction with major maintenance works by contractors, which they said was of poor quality. The lack of an effective procurement and quality control system involving major maintenance of small reservoirs exacerbates the situation.

The poor minor and major maintenance of small reservoirs observed increases labour demands and financial costs on the part of users due to repeated maintenance required. This makes maintenance a very costly venture. The use of cheap and weak material in the maintenance of small reservoirs increases the exposure of communities to risks associated with storms. The issues raised here have serious implications on the productivity and performance of small reservoirs, which affect the adaptive capacity of communities in responding to climate change and variability.

6.5.2 Flood Control, Soil Erosion Control and Catchment Protection

Flood control, soil erosion control and catchment protection help to reduce sediment load or siltation of reservoirs and damages to infrastructure. In both Baare and Kajelo soil erosion control was found to be an important institutional strategy for water management in the face of heavy storms and floods. Apart from structural measures (maintenance of infrastructure) and the use of vertivar grass mentioned above, the other common adaptation measures to floods include non-structural measures such as catchment protection. This is an important anticipatory adaptation strategy for the management of small reservoirs because it helps to reduce soil erosion and siltation of reservoirs by limiting land use activities such as cultivation and grazing in the catchment area. Contour ploughing and planting vertivar grass around rain-fed fields were other commonly used strategies for soil erosion control involving rain-fed farming.

However, these strategies were found to be ineffective in reducing soil erosion and siltation in both Baare and Kajelo. This is mainly due to weak enforcement of institutional arrangements for managing the reservoirs. The WUA does not strictly enforce soil erosion control measures. Field observations in Baare showed incomplete coverage of the embankment with vertivar grass. About 40% of the surface area of the embankment was not covered, this part of the embankment showed signs of soil erosion. The sign included riles and small gullies which had begun forming (see plate 1 below).

Soil erosion taking place on the embankment part not covered by vertivar grass

Poorly constructed irrigation canal requires patching up leaking areas

Plate 1 Pictures showing signs of soil erosion and a poorly constructed irrigation canal in Baare

The community said that it will complete planting the grass once the rain season begins. Similarly, weak enforcement of soil erosion measures was observed in the catchment. Although cultivation in the catchment area is prohibited, livestock grazing is not. Farmers in Kajelo argued that grazing does not subject the soils to erosion. They said no amount of ground cover can arrest soil erosion in the catchment area due to the rapid storm runoff, which they experience in the area. Even at an individual level few practice soil erosion control measures despite many of them being aware of these practices. The traditional chief in Kajelo attributed this to the fragmented nature of the cropping fields and the tedious work involved in applying soil erosion and conservation measures. There this seems to be a problem of perception and attitude towards soil erosion and control measures rather than the awareness and costs associated with adoption.

However, a few farmers suggested the following as possible adaptation measures to reduce soil erosion and minimize impacts of climate change and variability: planting more trees; avoiding cutting down of trees; avoiding burning grass and bushes in the catchment area; encouraging farmers to use stone bonding and terracing as soil erosion and catchment area protection measures.

Poor design of infrastructure in Baare was also mentioned to contribute to ineffective flood control of the reservoir. The community mentioned that the spillway is not properly designed therefore easily allows water to spill over during flood events. Farmers in Kajelo also mentioned that the poor positioning of the spillway before it was corrected in 2006 was associated with flooding in the area.

At individual level, both structural and non-structural flood control measures were found. These include stone-bonding, avoiding cultivation and settling in low laying/valley or down-stream places. Stone-bonding is commonly applied in Baare to protect rain-fed crop fields from flooding. Individuals who were said to be better-off in terms of poverty manage to construct their houses using cement material. Most community members said they cannot afford to buy cement to use for constructing more durable housing infrastructure that could withstand floods. Therefore they rely on locally available clay even though it cannot withstand floods.

6.5.4 Non-Irrigation/Reducing Irrigation Activities

Reducing cropping activities or non-cropping under irrigation was found to be a reactive adaptation strategy to drought events. Farmers mentioned that they only use this strategy in the event of less water in the reservoir therefore by reducing irrigation activity water is conserved for other less water-consuming purposes. In Kajelo, this strategy was used in the 2009/2010 in which about 50% of the irrigable area was used for irrigation as a response to low water availability in the dam due to low rainfall received in that season. Some individual farmers indicated that in times of drought or low water availability they resort to non-cropping in the dry season. In Kajelo and Baare it was found that during drought years many young men and women migrate to the south in search of employment to earn some income. Women also said they resort to collecting and selling firewood and sheer nuts, during such harsh environmental situations as alternative income sources.

Although this strategy is effective in conserving water and its implementation is easy during droughts, it may have serious implications on income and food security of individuals who are highly dependent on irrigation.

6.5.5 Re-allocation of Water to priority uses

In Baare, the community mentioned that during drought or low water availability in the reservoir, livestock watering was given preference to the other water uses. This is a public reactive strategy that re-allocates scarce water from one less prioritized use to a high priority use. In this case, water available in the reservoir is re-allocated from irrigation to livestock watering. This strategy is premised on many farmers' perception that irrigation uses more water than other water uses and also that the primary purpose of the reservoir is for livestock watering not irrigation. This strategy is also premised on the communities' argument that the need for water was more critical for livestock than irrigated crops because animals' health and survival depends on the availability of water while it is relatively easy to find alternative food crops even without irrigating.

Allocating water to more productivity or economically valuable uses such as livestock is a good strategy. However, it is not very clear to what extent this economic value of livestock influences this strategy or decision in times of less water availability or drought given the reasons above. Mamba used this concept as an IWRM tool to quantify multiple uses of water from reservoirs in Mzingwane catchment in Zimbabwe for purposes of allocating scarce water resources to local uses that have potential of bringing maximum benefits to the user communities. He found that water use for livestock watering (donkey and cattle) and brick making to have a higher monetary water productivity value compared to crops (maize and wheat) and domestic use (Mamba 2007: 3, 12).

This concept could be used in solving future water allocation challenges in view of the increasing demand for irrigation by community members, which currently far exceeds its water supply. At the moment Baare and Kajelo reservoirs accommodate less than a quarter of households in their respective communities for irrigation. Their current capacities stand at about 107 and 230 farmers, respectively. However, for Kajelo the number of farmers supported by the reservoir was said to vary depending on water availability. The WUA Secretary mentioned that during the seasons of less water availability the dam accommodates half the normal capacity.

6.5.6 Efficient Water Use and Conservation

Efficient water use and conservation through the application of appropriate techniques helps maintain water quantity and performance of irrigation systems. In the case of Kajelo and Baare, water management was found to be very poor or not in existence at all. The poor water management arises from the use of open and leaking channel systems to convey water from the reservoir into the main canal through tertiary canal and dug trenches to the fields. See plate 2 below.

Plate 2 Pictures showing water wastage due to lack of water conservation at Kajelo Dam

Asante also found poorly constructed furrows at Vea and Tono small reservoirs in the UER as contributing to wastage of water (Asante 2009: 60). In addition, the farmers apply water to their crops using a flooding system in channels created in between the soil ridges where crops are grown. The water is usually left to flood the field for 2-3 days before the next water allocation. This is a common irrigation practice in both Kajelo and Baare for pepper and okra. Though this is a cost-effective way of irrigating, it is wasteful due to significant water losses through evaporation and percolation therefore reducing the quantity of water available for irrigation. The absence of strict institutional rules for conserving or regulating water usage by individual irrigators contributes to water wastage.

However, application of irrigation water at field level involving leafy vegetables mostly grown by women was found to be conservative. This is because women use calabashes and other useful containers to apply water to their crops as opposed to flooding the fields. Nevertheless, this practice by women is not done as a planned adaption strategy to drought or water conservation strategy. The reason why they use calabashes is because they are less labour intensive on smaller portions of land where leafy vegetables are usually grown compared to the labour associated with irrigating cash crop such as okra and pepper.

It was interesting to find that despite the farmers complaining about the inadequate water for irrigation, simple soil and water conservation measures such as mulching were lacking. Instead the common strategy which farmers expressed as a way of addressing the problem of limited water for irrigation was the expansion and deepening of the reservoirs to store more water. However, the study by Asante found the practice of mulching and cultivation of short-duration leafy vegetables at the Vea and Tono reservoirs in the UER as a means of withstanding drought years (Asante 2009: 59).

The study also found some institutional rules that help conserve water quantity and quality for various purposes to some extent. Notable ones included informal rules that prohibit using detergent soap when bathing or washing clothes at the reservoir as this contaminates the water. The major challenges to preserving water quality for domestic use include siltation and the uncontrolled livestock watering. Use of large water tankers to fetch water from the reservoir is also not allowed without permission. In Kajelo cattle belonging to the *Fulani* people – nomadic pastoralists are not allowed to water from the reservoir. This is a local arrangement to conserve water in the reservoir because the *Fulani* animals are large both in body and herd size therefore they require large quantities of water, which the reservoir cannot manage support.

Asante recommended provision of extension information on proper construction of furrows and how to determine irrigation field capacity in order to avoid water wastage (*Ibid*: 60). He also recommended the use of efficient irrigation systems such as drip, micro-spray techniques and water harvesting (runoff or rainwater harvesting) during the wet season as adaptation strategies to drought and limited water availability for irrigation. He stated that drip irrigation was being piloted at Tono small reservoir. Though drip irrigation systems make efficient use of water for irrigation, they are costly to install and manage. The current land tenure arrangements involving temporal usufruct rights for irrigation during the dry-season observed in both Kajelo and Bare pose further challenges on the application of drip systems.

6.5.7 Increasing Land Productivity and Crop Yields

Fraiture et al. (2007: 10) highlighted deriving more value from water through higher yields as an effective strategy for climate change adaptation. This strategy was also found in both Baare and Kajelo largely as a response to the general poor soil fertility in the UER. This is achieved through the use of pesticides and chemical fertilizers. This strategy falls under individual anticipatory strategies since it is meant to maximize benefits by individuals from expected environmental constraints. Apart from water availability, the use of fertilizer and pesticides was mentioned to be a key factor that determines a successful harvest from gardening. Some farmers use cow dug manure to fertilize their irrigated and rain-fed crops. A few farmers, particularly old and poor farmers mentioned that they do not use artificial fertilizer but instead use locally made herbal concoctions mixed with goat droppings as a pesticide, which they apply to irrigated crops.

However, even though the use of artificial fertilizers is effective in producing high yields under irrigation, it raises questions of cost-effectiveness and environmental sustainability. This is because most gardeners expressed that they face financial constraints to afford the use of chemical fertilizers. In Kajelo, about 25% was estimated as the number of very poor irrigators who cannot afford to buy fertilizer by the FGD of Men Irrigators. The level of harvest by poor farmers who do not apply fertilizer and pesticides was estimated at about 10% of what better-off gardeners who use fertilizer and pesticides produce. The use of organic manure is more sustainable since is it locally found, cost-effective and is more environmentally friendly.

Artificial fertilizer and pesticides were found to be a major constraint to women irrigators than men because they do not own livestock, which they can use to buy these inputs. The women stated that they resort to collecting and selling firewood to raise capital for irrigation inputs. Young and single women are constrained by inadequate labour and finances to engage in irrigation. The strategy of obtaining inputs on credit, which is common among this social group including other poor farmers, is more costly in the long-term than purchasing on cash basis.

The use of agro-forestry practices is also more sustainable in maintaining soil fertility, improving soil moisture retention and in contributing to increased carbon sequestration. This was also recommended by Asante (2009: 69). Since agro-forestry is an adaptation strategy that require long-term investment on a piece of land. There is a need to further investigate the effectiveness of this strategy under the current land tenure arrangement for irrigation, where farmers only have temporal usufruct rights for dry-season farming.

6.5.8 Switching/Changing Crop Varieties

Using different varieties or switching to different crops is also effective in adapting to climate change (Droogers and Aerts 2005 cited in Fraiture et al. 2007). The Director for Agriculture in Kajelo stated that many farmers have begun to study the changing climate situation in order to shift from traditional crops to new varieties. See box 2 below.

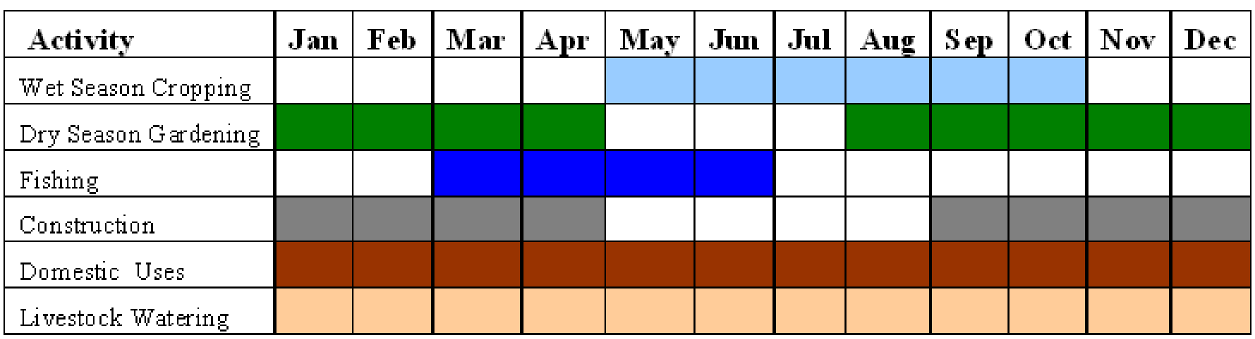
Box 2 Perception of climate change and adaption by the Director of MoFA in Kajelo

> "*In areas where they were planting sorghum (in low areas) they are now changing. They are now using early maturing sorghum variety. They are now producing more maize in areas where they were planting traditional crops. Those who planted maize in 2008 and 2009 their yields were very good despite floods. They now plant in May. The maize is able to withstand high moisture. Millet is failing because it cannot with stand a lot of moisture. Rice variety being grown matures early. The early maturing rice variety introduced is called kapala. These responses farmers are doing do not know that they are adaptation strategies to changing climate but they do it unconsciously.*"

However, the study did not find changes in cropping patterns in response to droughts that were applicable to irrigation. In view of future increases in temperature coupled with reductions in rainfall, Asante recommended changing crop patterns to more suitable varieties that can withstand expected harsh environmental conditions (Asante 2009: 66).

6.5.9 Adjusting Planting Dates

In Baare farmers mentioned that they change/ adjust planting dates depending on drainage conditions. This is an important reactive adaptation strategy at community level in Baare, while in Kajelo it is an individual level strategy. In Baare, irrigation can only begin after the WUA makes an announcement, while in Kajelo it is an individual's decision. In Baare farmers stated that they normally begin irrigation activities around November or December. In a year of floods they begin late after Christmas time, while in drought years they begin early in November. In Kajelo most farmers begin dry-season activities early by August while a few begin in October up to April. See seasonality calendar in figure 6 below. They stated that apart from drainage conditions that are determined by floods and droughts, usage of irrigable land during the wet season determines the start date of irrigation in the following season. Usage of irrigable land for rain-fed farming delays the start date of dry season farming and vice-versa.



Source: compiled from field Data

Figure 6 Seasonality Calendar of Water Use from Small Reservoirs

The MoFA Director in Kajelo mentioned that the area now experiences droughts around late May to July and floods from August to September. Therefore, those who plant late when rains come in mid April, their crops get destroyed.

6.5.10 Use of Soil Moisture in River Valleys and Wetlands

Some individual farmers stated that during drought years they make use of valley bottoms and river beds to cultivate as these areas retain sufficient soil moisture for the growth of crops. This reactive strategy can help reduce demand for irrigation water from the reservoirs hence conserving it for other purposes. This strategy can be used in growing less water consuming crops, which mature early such as leafy vegetables in drought situations. One major constraint that could hinder the wide application of this strategy is availability of land and tenure arrangements.

6.5.11 Mixed-Farming

Due to the strong linkage of irrigation and rain-fed farming, many respondents indicated that they sell some rain-fed crops following a successful year to raise their capital base required for dry-season farming, while in years of poor yields they consume all of their produce. The commonly practised mixed-farming involving crops and livestock re-enforces the adaptive capacity of the farmers in both Kajelo and Baare to some extent. Most of them mentioned that they own different types of livestock such as goats, cattle, sheep, pigs and guinea fowl not only for social benefits and raising money for school fees but also as a coping strategy for maintaining livelihoods in poor cropping seasons. In addition, livestock plays a supportive role to both rain-fed farming and dry season gardening by providing manure and income for purchasing inputs, respectively.

This anticipatory strategy will be effective in dealing with the demand side of water particularly in drought situations. If many community members are involved in mixed farming it would reduce dependency on irrigation to some extent.

6.5.12 Other Adaptation Strategies

Some farmers mentioned that they rely on the spiritual powers of the *tindana* (a traditional spiritual leader) for early-warning on the occurrence of drought events; re-planting failed crop after experiencing droughts at the beginning of the wet season was one strategy some individual farmers use to cope. Others include diversifying income sources; crop diversification and intercropping of drought tolerant principal crops with other crops. Most of these are applied under rain-fed farming.

6.6 Promising Water Management and Adaptation Strategies

The water management and adaptation strategies presented in the previous section indicate that the communities in the UER of Ghana have adapted to a harsh environment for a long time. This is both at community and individual level where a mix of reactive and anticipatory strategies is practiced. Most of the adaptation strategies found are more applicable to rain-fed farming than to livelihoods based on small reservoirs, particularly dry-season farming. However, I agree with other researchers who state that most of these strategies have remained the same for a long time (Kinderen 2006: 56; Stigter 2002?: 1). The clear perceptions of people about changing climate should translate to more urgent measures to adapt, which is not the case at the moment.

The several constraints identified that communities and individuals face to effectively adapt to climate change and variability need to be considered in adopting promising water management and adaptation strategies for the management of small reservoirs. These include high poverty levels, land tenure constraints; limited knowledge of the application of efficient and conservative irrigation methods; lack of access to new technologies; weak financial capacity to undertake effective and more sustainable maintenance of small reservoir infrastructure; weak enforcement of institutional rules for the effective management of small reservoirs; and lack of access to reliable drought and flood early warning systems.

Promising water management strategies should focus on strengthening some of the current strategies such as flood control, soil erosion and catchment protection; water re-allocative and distribution strategies; and increasing water productivity from high yields. In order to reduce costs and effectiveness of adaptation, future strategies should also be based on existing traditional knowledge and technologies (e.g. the use of goat droppings mixed with herbs used as pesticides); strong social capital and openness of the communities to new ideas. Cost-effective soil and water management technologies such as agro-forestry could also be introduced as public (community-level) adaptation strategies for dry-season farming considering the land tenure constraints if they have to be adopted at individual level. However, for the identified promising water management strategies to be more effective they need to be well- planned and integrated using approaches such as the IWRM and AWM.

CONCLUSION

Although Kajelo and Baare represented a poorly performing and a well performing reservoir, respectively as assessed by AEAs, the two reservoirs were found to have brought about unprecedented levels of improvements in the welfare of many users and have increased the communities' adaptive capacity to climate change and variability to some extent, particularly droughts through increased availability of water for livestock watering, domestic uses and dry-season farming that has improved food, nutrition and income levels.

However, improving and sustaining these benefits is a growing challenge due to the increasing threats of climate change and variability associated with frequent and more severe floods, droughts and high temperatures, which affect performance of these water systems. I found that climate change and variability affect performance of small reservoirs both directly by damaging reservoir infrastructure, quantity and quality of water available for different uses and indirectly by affecting other important livelihoods connected to the use of small reservoirs. Performance of small reservoirs for irrigation purposes was found to be the most affected. Further increases in temperatures as climate change scenarios project will have significant effects on okra and pepper production as major cash crops under irrigation at Baare and Kajelo, respectively.

However, when compared to livelihoods based on small reservoirs, livelihoods based on rain-fed farming indicate a wide-range of adaptation strategies to the harsh environmental situation. Despite communities' perceptions indicating awareness on the changing environmental context in which they live, the study did not find any evidence pointing to an increasing sense of urgency on the part of communities in responding to the current and future expected impacts of climate change. This is evident in the traditional adaptation and coping strategies that have remained unchanged for a long time. This can be attributed to several constraints that communities using small reservoirs face to effectively adapt to climate change and variability. The major ones include high poverty levels, land tenure constraints; limited knowledge of the application of efficient and conservative irrigation methods; lack of access to new technologies; weak financial capacity to undertake effective and more sustainable maintenance of small reservoir infrastructure; and weak enforcement of institutional rules for the effective management of small reservoirs. The common perception by many community members that droughts and floods are natural events, which they do not have control over including the lack of access to effective disaster management and early warning systems further, puts the communities in a more vulnerable position to the impacts of climate change.

The observed effects of climate change and variability on the performance of small reservoirs, which are expected to increase in future, and the demonstrated inadequate adaptive capacity of communities, call for more urgent measures than what has been traditionally done. Since the extent of effects on the performance of small reservoirs largely depends on the quality and status of infrastructure; management practices and adaptation strategies that are put in place, there is need to strengthen these areas. This should include strengthening enforcement of institutional rules for managing small reservoirs; strengthening local resource mobilization for effective maintenance of infrastructure; application of new technologies for better use and management of small reservoirs; improved catchment protection and soil erosion control measures and introduction of efficient water-use and soil conservation measures. However, there is need for research to investigate how communities can effectively adapt to climate change and variability under the current land tenure arrangements of small reservoirs, which do not seem to provide incentives for investing in soil and water management for dry season farming.

Furthermore, these strategies need to be integrated using integrated approaches to water resources management such as the IWRM and AWM, as these approaches require active participation of all key stakeholders not only irrigators and help to strengthen learning processes on which future adaptation strategies should be based.

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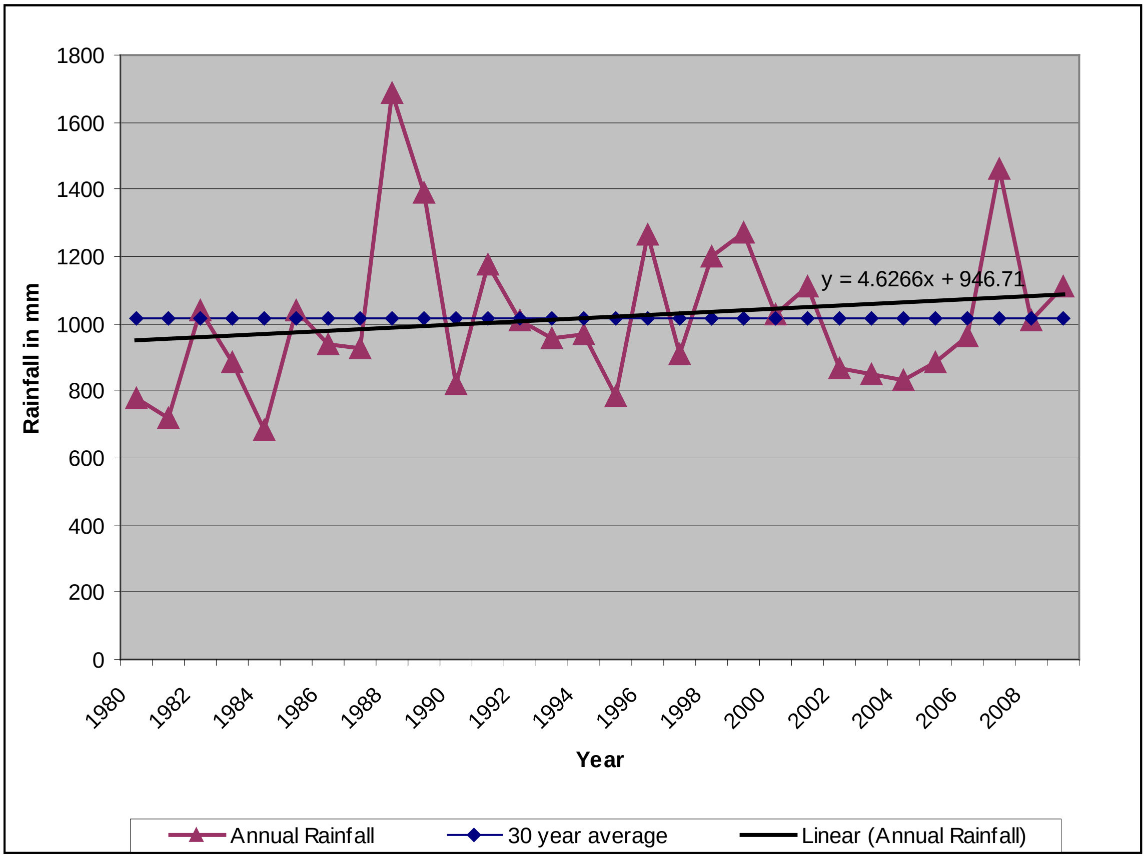
APPENDICES

Appendix 1 30-Year Rainfall Trend at Zuarungu Station (1980-2009)



Source: Data from the Meteorological Department of Ghana

Appendix 2 Monthly Mean Rainfall Figures in mm at Zuarungu Station from 1980 -2009

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	000.0	000.0	000.0	039.1	058.2	064.0	108.0	273.1	133.0	102.7	000.0	000.0
1981	000.0	000.0	000.5	059.1	037.9	131.5	140.2	217.1	058.8	073.1	000.0	000.0
1982	000.0	005.1	012.7	063.5	174.2	209.8	190.6	182.3	154.0	020.4	024.4	000.0
1983	000.0	000.0	000.0	000.0	024.1	060.1	087.8	155.0	345.4	212.7	000.0	000.0
1984	000.0	000.0	008.7	035.4	092.7	097.1	114.0	158.5	135.1	026.5	016.6	000.0
1985	000.0	000.0	000.0	008.6	065.5	152.1	262.6	268.5	220.0	042.8	020.3	000.0
1986	000.0	000.0	000.0	032.8	064.0	091.3	299.6	166.6	224.0	042.8	020.3	000.0
1987	000.0	000.0	036.8	009.1	032.6	121.1	199.4	328.5	160.1	036.2	000.0	000.0
1988	000.0	000.0	003.6	045.7	092.2	132.4	888.2	203.9	259.9	012.7	046.5	000.0
1989	000.0	000.0	031.5	002.8	064.2	224.8	178.9	441.0	322.4	077.8	000.0	044.6
1990	000.0	000.0	000.0	009.8	110.8	036.8	242.0	235.9	115.3	039.0	002.4	025.6
1991	000.0	005.0	047.0	086.7	132.6	177.0	209.4	349.1	109.5	058.5	000.0	000.0
1992	000.0	000.0	000.0	015.8	141.2	115.5	160.0	262.0	257.6	054.7	002.8	000.0
1993	000.0	000.0	000.0	037.9	049.4	144.8	214.2	305.5	165.0	036.7	000.4	000.0
1994	000.0	000.0	012.2	007.6	086.2	067.2	102.9	336.9	161.4	196.1	000.0	000.0
1995	000.0	000.0	000.0	000.0	071.3	123.6	125.0	315.9	023.8	122.8	000.0	001.2
1996	000.0	000.0	002.6	062.1	063.8	115.2	074.8	577.6	297.9	069.4	000.0	000.0
1997	000.0	000.0	005.4	063.7	101.4	230.5	075.6	152.5	225.4	055.6	000.0	000.0
1998	000.0	019.1	000.0	050.5	199.8	168.3	135.3	336.6	261.2	029.2	000.0	000.0
1999	000.0	008.2	009.4	035.8	109.1	111.7	212.5	419.6	298.5	065.3	000.0	000.0
2000	001.2	000.0	000.0	005.2	198.8	275.5	153.6	207.7	114.1	072.9	000.0	000.0
2001	000.0	000.0	054.0	000.0	063.7	086.9	268.1	327.8	293.8	016.1	000.0	000.0
2002	000.0	000.0	000.0	094.3	092.3	078.9	189.3	192.4	095.8	118.6	006.4	000.0
2003	000.0	001.5	003.8	014.8	062.1	160.0	195.6	193.1	160.8	047.4	013.3	000.0
2004	000.0	000.0	028.5	122.5	069.5	088.4	172.5	219.1	097.9	023.4	007.2	000.0
2005	000.0	003.5	002.4	048.3	101.7	172.7	143.1	194.3	159.7	057.0	000.0	000.0
2006	000.0	000.0	009.7	042.9	138.0	165.3	169.1	130.1	238.5	071.7	000.0	000.0
2007	000.0	000.0	004.9	176.5	169.0	098.9	226.2	601.3	178.8	007.7	000.6	000.0
2008	000.0	000.0	032.6	020.5	072.5	103.2	217.3	321.9	165.3	074.2	000.0	000.0
2009	000.0	023.1	000.0	024.5	097.9	212.3	121.6	277.4	220.6	112.5	019.3	-

Source: Meteorological Department of Ghana

Appendix 3 Mean Monthly Minimum Tempt. in ^{o}C at Zuarungu Station from 1980 - 2009

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	-	-	-	-	-	-	-	-	22.6	22.4	21.7	18.7
1981	18.5	23.0	25.9	26.6	25.0	24.1	22.7	22.5	22.6	22.9	20.9	18.8
1982	18.6	22.5	25.8	25.6	24.4	22.9	22.7	22.3	22.6	22.7	19.8	18.6
1983	17.4	22.3	25.2	26.4	25.3	23.1	22.5	22.2	21.9	22.3	21.8	18.6
1984	18.7	22.2	26.5	27.4	25.0	23.9	23.8	23.0	23.2	23.0	22.1	18.5
1985	20.3	21.8	25.7	27.5	25.7	24.4	22.0	22.6	22.1	23.4	21.7	18.6
1986	-	-	-	-	-	-	-	-	-	-	-	-
1987	-	-	-	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-	-	-	-	-
1989	19.2	21.1	24.3	26	25.8	23.0	22.5	21.6	22.6	22.0	20.3	25.1
1990	19.7	20.4	24.9	25.1	25.5	23.3	22.2	22.2	22.8	24.1	23.3	20.8
1991	19.2	22.9	25.8	25.5	22.5	24.4	22.7	22.2	22.8	23.1	21	18.6
1992	17.5	20.8	24.0	21.5	24.7	23.6	22.6	22.2	22.4	23.2	20.2	18.2
1993	18.6	22.8	25.0	26.9	24.6	23.8	22.2	22.0	22.6	24.1	22.9	18.5
1994	18.3	21.9	26.0	26.8	24.5	23.2	22.9	22.8	22.6	22.4	19.5	18.1
1995	17.6	20.9	26.0	27.5	25.0	24.3	22.9	22.3	22.7	22.7	20.2	20.3
1996	20.7	23.8	26.2	25.9	25.4	23.7	23.1	22.5	22.8	23.0	21.8	18.0
1997	20.5	21.0	25.2	26.1	25.2	23.4	23.2	23.1	23.3	23.8	22.1	19.2
1998	19.2	23.2	24.9	27.5	26.3	24.2	23.4	22.4	22.4	23.3	21.6	19.8
1999	19.8	21.6	25.9	26.0	25.3	24.2	23.0	22.2	22.4	22.6	20.6	17.3
2000	21.1	19.4	24.7	27.1	25.3	23.4	22.9	22.6	22.6	22.7	21.0	18.4
2001	18.3	20.3	25.7	27.2	25.8	24.2	23.4	22.6	22.5	23.1	21.6	19.0
2002	19.3	21.7	26.9	27.2	24.9	23.3	23.4	22.6	23.0	22.8	21.4	19.3
2003	19.4	23.4	25.2	25.7	26.1	23.2	23.6	22.5	22.6	23.8	22.0	19.0
2004	21.1	23.3	25.7	26.2	25.4	-	22.5	22.6	22.1	23.1	21.9	21.1
2005	19.3	-	28.1	27.2	24.6	22.9	21.8	22.9	23.1	22.7	21.3	19.6
2006	21.5	23.4	26.4	26.8	24.3	23.0	22.3	22.0	21.2	22.1	18.7	17.7
2007	17.3	20.5	26.2	26.1	24.9	24.4	23.2	22.2	23.0	23.4	22.7	20.9
2008	17.6	21.8	25.4	26.4	23.6	22.7	22.2	22.4	22.2	19.2	20.5	-
2009	19.3	24.0	27.1	26.6	26.0	24.1	23.0	23.1	22.7	23.0	21.7	-

Source: Meteorological Department of Ghana

Appendix 4 Mean Monthly Maximum Tempt. in ^{o}C at Zuarungu Station from 1980 -2009

Year	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980	-	-	-	-	-	-	-	-	32.0	34.4	35.6	33.7
1981	34.6	38.3	38.9	38.3	35.2	33.3	30.1	30.0	28.5	35.5	36,4	36.7
1982	34.9	37.2	38.6	37.9	35.1	32.3	31.3	30.1	31.8	33.3	36.1	37.3
1983	34.1	38.5	39.2	40.0	36.6	33.7	31.6	30.4	34.0	35.4	36.0	35.7
1984	34.5	36.1	38.2	38.1	35.9	33.5	32.7	32.0	31.6	33.5	35.9	35.6
1985	35.9	35.9	38.9	40.3	37.6	33.4	30.1	30.1	31.8	33.8	34.8	35.5
1986	-	-	-	-	-	-	-	-	-	-	-	-
1987	-	-	-	-	-	-	-	-	-	-	-	-
1988	-	-	-	-	-	-	-	-	-	-	-	-
1989	33.3	35.0	37.6	39.1	35.6	35.0	30.9	29.9	31.4	33.4	37.1	35.5
1990	34.1	37.0	38.3	38.4	36.3	35.0	31.7	30.1	31.3	35.0	37.2	37.8
1991	35.2	39.2	39.2	39.3	33.0	33.5	31.2	29.9	32.3	33.6	35.0	34.5
1992	32.8	36.6	39.0	39.4	35.0	33.3	31.0	30.5	30.9	33.8	34.2	35.3
1993	32.7	37.3	39.0	39.6	36.0	35.0	30.4	30.8	30.7	34.7	36.9	34.6
1994	34.0	37.3	40.0	39.7	36.3	32.8	30.9	29.7	30.9	32.3	35.3	34.0
1995	32.2	36.9	40.1	39.7	36.5	33.5	31.6	30.5	32.0	33.3	37.1	36.6
1996	37.5	39.0	39.7	38.2	37.3	33.3	31.3	30.2	30.7	34.2	37.0	37.3
1997	37.2	36.4	38.2	37.8	36.2	32.1	31.6	31.5	32.6	34.5	37.2	37.1
1998	36.5	39.1	40.2	39.9	36.3	32.8	31.3	30.7	30.5	33.9	37.4	36.7
1999	36.7	36.5	41.2	39.4	37.3	34.1	30.6	29.6	30.6	33.6	37.4	36.0
2000	37.3	36.1	39.9	40.7	37.6	32.6	31.1	30.6	31.0	33.9	37.6	36.0
2001	36.5	37.4	40.8	39.5	37.6	33.9	31.2	29.9	31.1	35.5	37.9	37.4
2002	34.7	38.5	41.0	39.6	36.6	33.3	33.1	30.6	32.1	33.5	37.2	36.7
2003	36.5	39.3	40.4	39.7	38.1	32.5	32.0	30.9	31.7	34.9	37.3	36.8
2004	36.4	37.9	38.3	37.6	34.7	-	30.7	30.6	31.3	33.6	36.4	35.9
2005	33.7	-	40.9	39.9	36.9	32.8	31.3	30.6	31.8	34.5	37.5	37.0
2006	37.2	38.8	40.4	39.9	34.6	33.5	32.1	30.8	31.0	33.6	36.4	35.9
2007	34.6	38.8	40.0	37.4	34.1	32.4	31.7	30.0	32.6	35.3	37.4	36.3
2008	33.7	37.7	38.7	39.2	36.3	33.3	31.2	36.1	31.8	33.9	37.5	36.7
2009	35.2	39.1	40.1	38.7	36.6	33.8	31.6	30.9	31.7	33.6	35.2	-

Source: Meteorological Department of Ghana

Appendix 5 Monthly Rainfall in mm for Navrongo Station from 1977 - 2006

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1977	000.0	000.0	038.7	013.4	057.1	041.9	204.3	176.0	090.1	049.0	000.0	000.0
1978	000.0	000.0	036.9	089.3	231.2	090.2	182.4	344.4	131.7	111.5	000.0	000.0
1979	000.0	000.0	000.0	114.8	168.3	139.4	261.8	211.7	164.2	056.2	004.6	000.0
1980	000.0	000.0	000.3	074.5	095.9	064.7	176.9	307.3	150.8	069.2	000.0	000.3
1981	000.0	000.0	002.0	042.7	062.7	198.1	166.5	232.7	084.4	003.9	000.0	000.0
1982	000.0	000.0	079.6	036.5	016.1	081.5	130.7	243.2	236.2	051.5	001.0	000.0
1983	000.0	000.0	000.0	020.5	098.2	139.7	119.9	261.1	078.6	001.0	000.0	000.0
1984	000.0	000.0	008.7	097.5	188.2	084.5	098.0	222.0	116.2	036.7	000.5	000.0
1985	000.0	000.0	000.0	002.6	064.4	164.6	231.0	306.0	181.9	014.0	000.0	000.0
1986	000.0	000.0	009.4	037.8	113.1	179.2	248.8	142.4	447.7	041.0	005.8	000.0
1987	000.0	000.0	085.5	009.3	031.8	274.3	176.6	413.0	095.3	046.1	000.0	000.0
1988	000.0	000.0	026.6	130.2	031.9	141.6	123.2	246.9	187.4	000.7	026.0	000.0
1989	000.0	000.0	011.2	032.3	041.3	162.1	184.1	354.0	297.8	047.2	000.0	031.8
1990	000.0	000.0	000.0	019.7	136.1	048.9	233.0	249.7	126.1	009.9	013.7	033.6
1991	000.0	000.0	034.0	043.1	148.0	064.7	164.7	357.4	083.5	081.1	000.0	000.0
1992	000.0	000.0	000.0	058.8	153.4	152.7	243.7	211.5	154.1	058.6	000.0	000.0
1993	000.0	000.0	000.0	046.5	075.2	157.1	172.5	170.4	173.5	012.5	001.6	000.0
1994	000.0	000.0	032.3	012.7	115.8	062.4	164.3	428.2	100.8	084.7	000.0	000.0
1995	000.0	000.0	005.7	041.6	044.6	141.5	094.0	231.1	55.7.0	072.5	000.0	000.0
1996	000.0	000.0	001.1	047.4	194.6	207.2	108.2	300.5	206.6	038.4	000.0	000.0
1997	000.0	000.0	007.5	034.8	155.5	204.0	091.3	194.7	178.9	073.3	000.0	000.0
1998	000.0	019.7	000.0	020.8	134.8	077.0	127.5	281.9	146.0	047.9	000.0	000.0
1999	000.0	004.1	001.5	029.6	117.9	108.1	312.6	455.5	258.1	077.9	000.0	000.0
2000	001.0	000.0	000.0	002.8	053.7	228.7	237.9	282.2	158.2	022.6	000.0	000.0
2001	000.0	000.0	000.0	030.3	125.1	131.1	176.9	336.2	155.9	004.2	000.0	000.0
2002	000.0	000.0	000.0	065.1	105.3	094.0	192.9	211.2	122.2	085.3	020.2	000.0
2003	000.0	001.8	000.9	022.3	095.8	207.2	182.8	284.4	238.6	100.1	006.1	000.0
2004	000.0	000.0	028.0	176.6	074.3	139.8	259.9	210.4	118.5	034.7	002.2	000.0
2005	000.0	004.5	000.0	020.7	013.7	226.1	179.0	189.3	088.3	028.7	000.0	000.0
2006	000.0	003.8	004.0	082.4	055.6	117.8	193.6	183.4	153.1	083.2	000.0	000.0

Source: Meteorological Department of Ghana

Appendix 6 Mean Monthly Maximum Tempt. in ^{o}C for Navrongo Station from 1977 - 2006

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
1977	36.0	32.0	38.1	38.8	36.2	33.5	31.5	30.2	31.3	34.1	36.9	34.8
1978	36.2	38.9	38.1	34.4	34.4	33.2	30.2	31.2	31.8	34.3	36.3	36.4
1979	37.0	38.1	39.5	39.7	34.9	31.5	30.6	30.8	31.3	34.1	36.2	34.3
1980	36.9	38.0	39.9	39.4	36.1	33.6	31.9	30.6	32.3	34.2	36.2	33.9
1981	34.7	38.3	39.3	38.9	35.7	34.1	30.8	30.7	31.0	36.3	37.1	36.9
1982	34.7	36.9	37.6	37.5	35.2	33.2	32.4	30.4	32.2	34.0	35.6	34.8
1983	32.1	38.2	39.6	40.6	36.1	32.5	32.0	31.3	32.2	36.6	37.3	35.7
1984	34.8	36.9	39.3	37.8	34.8	32.8	32.3	32.1	31.5	34.6	37.1	34.1
1985	36.3	36.4	39.4	38.9	37.4	33.5	30.8	30.2	30.7	35.2	37.4	33.6
1986	34.8	38.6	39.0	39.5	36.7	33.4	30.5	30.7	31.0	34.0	35.5	34.2
1987	36.5	39.2	38.5	40.2	39.0	33.1	31.8	31.3	32.1	34.3	37.6	35.5
1988	34.8	38.3	40.1	38.2	37.6	32.8	30.4	30.1	31.2	35.7	36.9	33.8
1989	33.8	35.9	38.3	39.7	38.8	33.7	31.1	30.2	31.6	33.9	37.3	35.1
1990	34.7	36.9	39.6	38.7	36.4	33.7	31.2	31.5	31.9	36.1	38.1	36.2
1991	36.1	36.4	39.4	37.9	33.0	32.9	31.2	30.4	32.6	33.5	36.6	34.8
1992	33.4	37.5	39.6	38.2	34.3	32.2	30.4	30.0	31.9	34.7	35.5	36.2
1993	33.9	37.8	39.2	39.2	38.4	35.4	30.9	31.0	31.2	34.8	37.7	35.6
1994	33.9	37.8	39.8	39.6	36.1	32.6	31.8	30.0	31.2	32.7	35.6	34.5
1995	34.0	36.8	40.1	39.1	37.1	34.3	31.7	30.0	32.2	34.4	37.4	36.7
1996	37.8	39.1	40.0	39.1	36.7	32.0	31.5	30.8	31.0	33.3	36.4	36.8
1997	37.0	33.9	38.4	37.8	35.6	31.8	31.6	31.7	32.6	34.5	37.2	36.3
1998	35.7	38.9	39.9	40.0	36.7	33.4	32.0	30.6	30.7	34.1	37.5	36.1
1999	36.4	36.7	40.7	39.2	37.1	34.1	31.4	30.2	30.9	33.6	37.4	35.6
2000	36.7	35.6	39.5	40.3	37.1	33.2	31.2	31.0	32.0	34.6	37.9	35.7
2001	36.1	36.9	40.4	39.8	36.7	33.4	31.9	30.8	31.8	36.6	38.2	37.9
2002	34.8	37.8	40.9	39.4	37.3	33.9	32.6	30.7	32.2	34.0	37.0	36.1
2003	36.1	39.2	40.0	39.4	37.6	32.3	31.3	31.0	31.9	34.9	37.3	36.3
2004	36.4	38.0	38.5	37.0	34.2	35.4	30.9	30.9	31.6	36.1	37.1	38.1
2005	34.5	39.7	41.1	40.3	37.6	33.0	31.1	30.8	32.2	35.0	38.1	37.2
2006	37.1	38.7	40.7	39.8	36.0	34.4	31.5	30.8	31.0	33.3	36.4	36.8

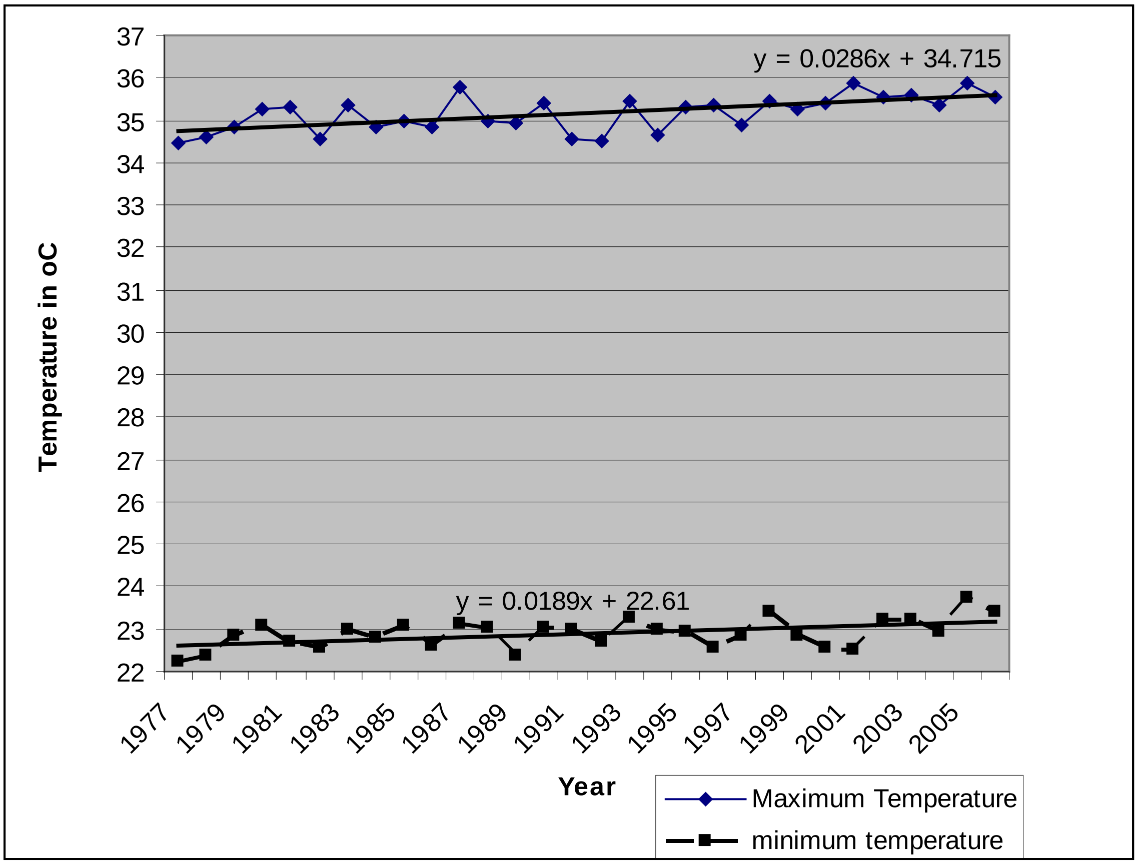
Source: Meteorological Department of Ghana

Appendix 7 Monthly mean minimum tempt. in ^{o}C for Navrongo Station from 1977 - 2006

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1977	20.6	17.7	24.3	27.1	25.5	23.9	23.0	22.3	22.3	21.8	19.5	18.8
1978	20.0	22.7	25.2	24.5	24.2	-	22.3	22.4	22.1	22.6	20.6	19.5
1979	20.6	21.4	26.3	27.0	24.8	23.2	22.4	22.7	22.3	22.8	21.0	19.8
1980	21.1	23.5	25.0	26.5	25.7	24.1	23.5	22.6	22.7	23.0	21.1	18.3
1981	19.3	22.8	25.6	26.7	25.2	24.0	22.9	22.6	22.0	22.4	20.2	18.6
1982	19.0	23.0	24.9	26.3	24.8	23.5	22.9	22.4	22.7	22.5	19.6	19.1
1983	19.5	23.8	26.1	27.7	25.4	23.5	22.9	22.9	22.5	21.7	19.9	20.2
1984	20.3	22.0	25.8	26.6	24.6	23.5	23.2	22.7	22.1	22.5	21.4	19.1
1985	21.4	22.5	27.3	27.1	26.3	24.1	22.1	22.6	22.4	21.9	20.3	18.8
1986	18.9	23.4	25.3	27.1	25.9	23.7	22.4	22.4	22.0	22.3	19.4	18.3
1987	20.4	22.5	24.6	26.9	27.3	24.1	23.2	22.7	22.9	23.0	20.1	19.8
1988	20.6	22.5	26.8	26.9	26.2	23.6	22.8	22.7	22.6	22.2	20.3	19.3
1989	18.9	21.5	23.7	26.7	26.1	23.2	22.9	22.5	22.1	21.7	19.8	19.6
1990	20.8	21.7	24.5	26.5	25.2	23.9	22.8	22.4	22.1	22.7	22.5	21.1
1991	21.4	22.7	26.0	26.2	24.4	24.3	23.1	22.9	23.2	22.2	20.0	19.6
1992	19.8	22.8	26.3	26.3	24.7	23.2	22.5	22.5	22.1	22.5	20.8	19.2
1993	19.1	23.1	25.5	26.9	26.0	24.7	22.7	22.8	22.3	22.8	22.9	20.5
1994	20.6	22.7	25.7	27.2	25.3	23.7	23.1	22.9	23.1	22.7	19.2	19.5
1995	18.6	21.1	26.2	27.0	25.9	24.5	23.2	22.5	23.0	22.7	20.5	20.1
1996	19.9	23.6	26.1	26.6	25.7	23.1	22.8	22.6	22.5	22.1	17.6	18.1
1997	20.2	20.7	25.6	25.8	25.1	23.6	23.1	23.0	23.3	23.3	21.1	19.3
1998	20.1	23.4	25.4	28.1	26.5	24.5	23.6	23.1	22.9	23.1	20.5	19.9
1999	21.4	21.8	25.9	26.1	25.3	23.9	23.0	22.7	22.3	22.4	20.5	18.7
2000	21.8	21.0	24.4	27.2	25.5	23.5	22.5	22.4	21.9	22.3	19.6	18.4
2001	18.6	21.3	24.4	26.0	25.7	23.4	23.0	22.4	22.4	22.5	20.6	20.1
2002	20.9	22.1	26.5	27.4	26.1	24.2	23.7	22.9	22.5	22.4	20.3	19.6
2003	20.8	23.6	24.9	26.6	26.2	23.6	23.2	23.0	22.7	23.6	21.3	19.1
2004	20.7	22.6	24.2	25.6	24.2	24.5	22.7	22.8	22.7	23.0	21.7	20.7
2005	20.4	25.7	27.5	28.3	26.1	24.1	22.9	22.8	23.1	22.4	20.9	20.7
2006	21.9	23.6	26.0	26.9	25.2	24.5	23.1	23.0	23.3	23.3	21.1	19.3

Source: Meteorological Department of Ghana

Appendix 8 30-years trend in mean monthly tempt. at Kajelo from 1977-2006



Source: Data from the Meteorological Department of Ghana

Appendix 9 Climate Change Scenarios for temperature for the Guinea Savannah Zone

Baseline Mean Temp.			**Mean Temp. Change**			**Climate Scenarios**		
T- max	**T- min**	**T- mean**	**2020**	**2050**	**2080**	**2020**	**2050**	**2080**
35.2	19.5	27.3	0.6	2.5	4.0	27.9	29.8	31.3
37.6	22.0	29.8	0.7	2.1	4.1	30.5	31.9	33.9
38.9	25.0	32.0	0.7	2.1	4.2	32.7	34.1	36.2
38.2	26.1	32.1	0.8	2.6	5.0	32.9	24.7	37.1
36.0	25.1	30.5	0.8	2.2	5.2	31.3	32.7	35.7
33.0	23.3	28.2	0.6	1.9	4.0	28.8	30.1	32.2
31.2	22.6	26.9	0.5	1.8	3.4	27.4	28.7	30.3
30.4	22.3	26.3	0.5	1.7	3.4	26.8	28.0	29.7
31.2	22.1	26.6	0.5	1.6	3.6	27.1	28.2	30.2
34.2	22.2	28.2	0.5	1.6	3.3	28.7	29.8	31.5
36.2	20.1	28.1	0.6	2.0	4.2	28.7	30.1	32.3
35.1	19.0	27.0	0.6	2.0	4.0	27.6	29.0	31.0
34.8	22.4	28.6	0.6	2.0	4.0	29.2	29.8	32.6

Source: EPA (2008: 335)

Appendix 10 Climate Change Scenarios for rainfall for the Guinea Savannah |Zone

Baseline Means			**Mean Change in Rainfall**			**Scenarios: Mean Rainfall Amt.**		
mean total	**mean rain**	**mean rain/day**		**percent**			**mm**	
mm	**days**	**mm/day**	**2020**	**2050**	**2080**	**2020**	**2050**	**2080**
001.0	001.0	001.4	-04.8	-12.8	-31.0	001.0	000.9	000.7
003.7	001.0	004.6	-09.0	-29.7	-58.4	003.3	002.6	001.5
018.3	002.0	010.0	-07.3	-23.8	-47.2	017.0	014.0	009.7
057.4	005.0	012.2	-07.2	-23.8	-36.8	053.3	043.8	036.3
095.7	008.0	012.5	-04.6	-14.8	-18.0	091.3	081.5	078.5
125.2	010.0	012.5	-01.6	-12.8	-17.4	123.2	109.2	103.4
193.9	014.0	014.2	00.2	-04.6	-04.9	194.3	185.0	184.4
266.7	018.0	015.0	00.6	-00.5	-08.4	268.3	265.3	244.3
173.4	014.0	012.4	-00.6	-03.8	-10.8	172.4	166.8	154.7
048.4	007.0	007.2	00.0	-00.1	-09.9	048.4	048.3	043.6
004.8	001.0	007.2	-01.4	-04.8	-12.7	004.7	004.6	004.2
003.4	001.0	004.4	-00.6	-01.6	-03.6	003.4	003.3	003.3
991.9	082.0	012.1	-01.1	-06.7	-12.8	980.6		

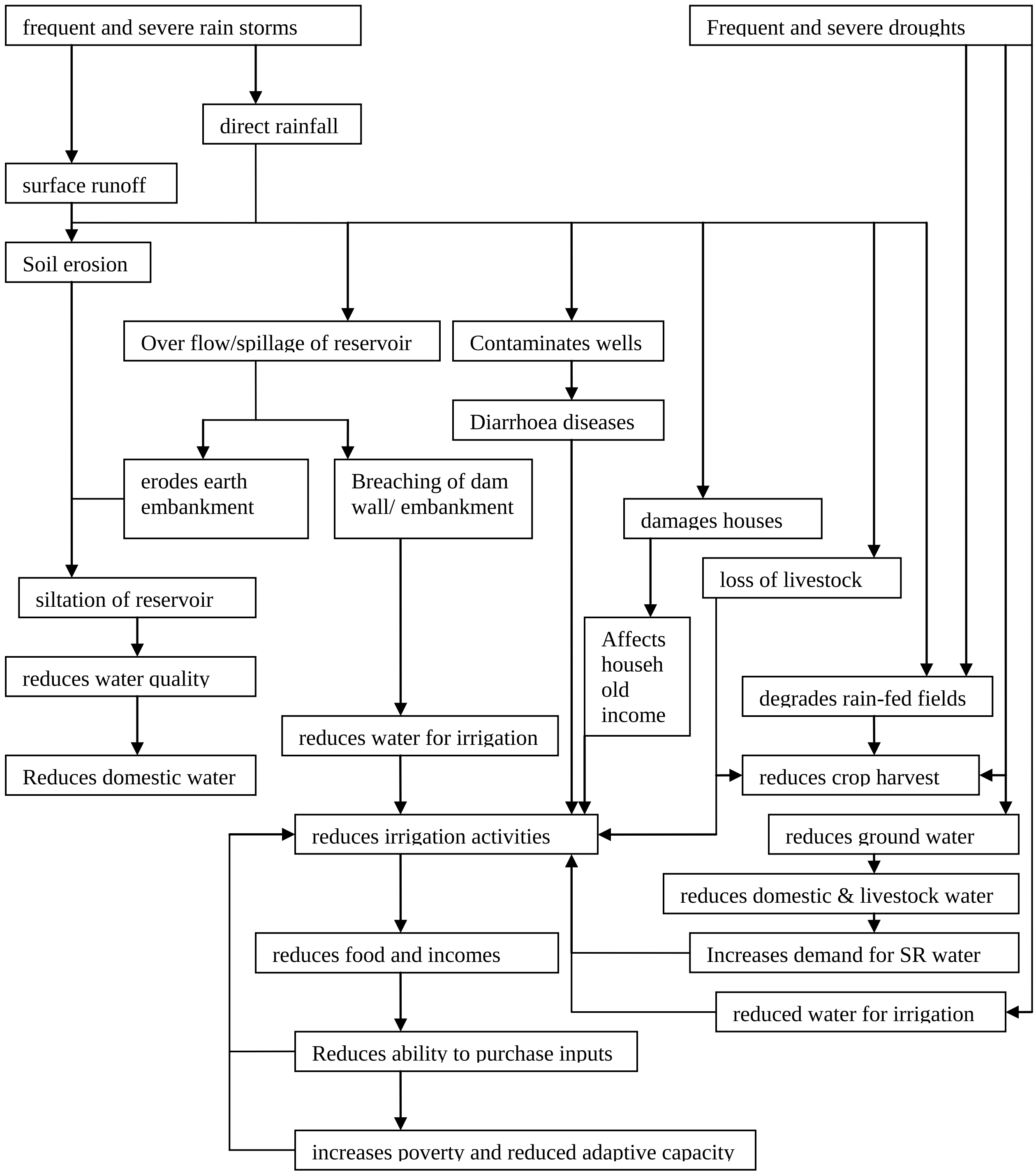
EPA (2008: 332)

Appendix 11 Average rankings indicating perceptions of different water users on the performance of Kajelo and Baare dam

	Baare			**Kajelo**			**Overall**
Category	Men Irrigators	Women Irrigators	Livestock Farmers	Men Irrigators	Women Irrigators	Livestock Farmers	
Infrastructure	3.0	3.3	3.6	3.3	3.8	3.5	3.4
Management	4.8	4.3	4.0	4.0	5.0	4.8	4.5
Fairness	4.8	4.5	4.4	3.8	4.8	5.0	4.5
Benefits	4.4	4.0	4.6	4.5	4.8	4.5	4.5
Overall Performance	4.3	4.0	4.2	3.9	4.6	4.4	4.2

Source: Field Data

Appendix 12 Illustrative figure for the logical analyzing of the cause and affect of climate events (floods and droughts) on the performance of small reservoirs



Appendix 13 Historical Profile of Baare Small Reservoir

Year	1987	1998	1999	2001	2002	2003	2004	2005	2006	2007	2008	2009
Livestock use												
Domestic use												
Construction												
Fishing												
WUA				created						new committee		
Irrigation										no cropping	no cropping	
Irrigated Crops		okra/leafy veg.	Tomato					Onion				
Problems						nematodes				brocken canal	brocken canal	
Climate events										floods	floods	
Maintenance			minor						minor			
Rehabilitation									LACOSREP		LACOSREP	
Training		irrigation						Onion				

Drawn by the Extension Agent, Field Supervisor, a local farmer and member of WUA