FINANCIAL VIABILITY OF GROUNDWATER USE FOR IRRIGATION BY SMALLHOLDER FARMERS IN THE USANGU PLAINS, TANZANIA

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ABSTRACT

Groundwater (GW) use for irrigation by smallholder farmers has been proposed as a solution to increasing water scarcity in the Usangu Plains, Tanzania. This study evaluated the financial viability of utilising GW for irrigation by smallholder farmers in the plains. Specifically, the study analysed the costs and benefits of using GW for small scale irrigation, examined the socio-economic factors influencing the use of GW for irigation, and assessed the financial affordability of smallholder farmers to invest in GW irrigation. Primary data were collected using a semi-structured questionnaire which was administered to a random sample of 97 households in three villages, while data from key informants were gathered using a checklist. Secondary data from various sources were used to supplement the primary data. Discounted cash flow, descriptive statistics, and logistic regression were used to analyse data. Key findings show that, investment in GW for irrigation is economically viable at a discounting rate of 12% and had a Net Present Value of TZS 38 636 794, Cost Benefit Ratio of 6.55, and Internal Rate of Return was 81%. Socio-economic factors namely household size was statistical significance ($P<0.05$) while gender, income and membership in socio networks although were not significant had a positive association with GWI. High initial investment cost relative to farmer's income level was revealed. Conclusively, investment in GWI by smallholder farmer is financially viable and household income level was found to be a constraint to GWI development. The study suggest that, government and development agencies should participate in GWI investment such as through subsidisation and tax exemption of GWI devices. Further market for agricultural goods should be improved in order to increase on farm production efficiency which presents opportunities for increasing income and hence farmers' capacity to initial investment costs.

DECLARATION

I, Doris Gama Greyson, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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LIST OF ABBREVIATIONS AND ACRONYMS

ACPC	African Climate Policy Centre
BOT	Bank of Tanzania
CBA	Cost benefit analysis
CVM	Contingent valuation method
EAC	East Africa Community
ECA	Economic Commission for Africa
FAO	Food and Agriculture Organisation of the United Nations
GW	Groundwater
GWI	Groundwater irrigation
IRR	Internal rate of return
NEPAD	The new partnership for African's development
NGOs	Non-Governmental Organisations
NPV	Net present value
SACCOs	Community saving and credit Cooperatives
SMUWC	Sustainable management of the Usangu wetland and its catchment
SPSS	Statistical package for social science
SSA	Sub-Saharan Africa
SWI	Surface water irrigation
TZS	Tanzania Shillings
UNIDO	United Nations Industrial Development Organisation
URT	United Republic of Tanzania
VICOBA	Village community banks
WB	World Bank
WWF	World wildlife fund for nature

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Africa has a population of more than 650 million people who depend on rain-fed agriculture in an environment which is already affected by water scarcity and land degradation (Hanjra and Qureshi, 2010). In particular Sub-Saharan Africa (SSA), about 16 percent of its population lives in semi-arid areas and depends on subsistence farming which is susceptible to drought and food insecurity (Frenken, 2005). As a strategy of supporting agricultural development for livelihoods enhancement and food security, in 2005 the Commission for Africa agreed on doubling their spending on infrastructure improvement, including small-scale irrigation. Similarly, NEPAD (2003) suggested for a comprehensive agricultural water management strategy, specifically the use of appropriate irrigation technologies as major instruments of economic growth and development.

Tanzania is an agricultural-based developing country whereby about 80% of her population are smallholder farmers who are engaged in a wide range of agricultural activities for their food and livelihood enhancement (URT, 2009). Like other SSA countries, agricultural development in the country is highly constrained with inadequate and unreliable water for irrigation. Surface water resources in Tanzania, as elsewhere in Sub-Saharan Africa (SSA), are under increasing pressure due to the increasing population, urbanization and land use changes to more intensive production of crops and livestock. This has resulted in an apparent decline in the performance of surface water irrigation which calls for an urgent need for the improvement of groundwater (GW) use for irrigation (WB, 2006; URT, 2008).

Groundwater is the water which is found under the Earth's surface in the soil pore spaces and in the fractures of rock formations. This water has been accessed through several technologies including open wells and shallow tube wells. Groundwater represents one of the important renewable resources that contribute significantly towards offsetting the effects of climate change through its use in smallscale irrigation. Therefore, strategic initiative which can support productive use and economic development in SSA is critical (Allaire, 2009; ACPC, 2013; Gowing *et al.*, 2016). GW has proven to be a reliable and accessible water source for irrigation, which, offers opportunities that surface water sources cannot provide. As Carter (1994), Foster *et al.*(2008) and Ngigi (2009) argue, GW is an attractive water resource for smallholders farmers that allow incremental development, autonomy and flexibility of water use in the hands of individual farmers or small farmers groups.

According to various scholars (e.g. Foster *et al.*, 2013; Vanlauwe *et al.*, 2014) groundwater is a critical resource in semi-arid and arid regions, and in the recent years, its importance has increased due to its use in irrigation as an insurance against drought in rain-fed agriculture, domestic use, livestock and also environmental services. Elsewhere, studies by Namara *et al. (*2011); ECA (2011); URT (2008); Villholth *et al.* (2013) underline the use of groundwater for irrigation as a mechanism of reducing risks associated with environmental degradation, rainfall variability and food insecurity. It is further recognized that groundwater is currently an under-utilized resource in irrigation. Its use in irrigation could minimise the effects of crop failure which are associated with surface water depletion and unpredictable rainfall events (You *et al.*, 2010; Gebrehaweri *et al.*, 2013; Pavelic, 2013). In contrast, there is inadequate empirical evidence to assess the financial viability of groundwater use for irrigation where majority of farmers are low income smallholder farmers who are practising subsistence farming. This justifies the need for more research on financial viability of groundwater use for irrigation by smallholder farmers in Tanzania (URT 2008).

1.2 Problem Statement and Justification of the Study

The Usangu Plains in Tanzania constitute an important area for agricultural production, wetlands and associated biodiversity that supplies water to downstream uses including the Ruaha National Park, and the Mtera, and Kidatu hydropower plants (Duvail *et al.*, 2014). These are areas with huge growth of human-associated activities and major land use changes that have remarkable effects on the environment. The Usangu Plains was realised in early 1990s to have a significant change in the downstream flows through the Ruaha National Park especially during the dry season that resulted in increased social conflicts (Walsh, 2012).

This trend attracts the country's attention to propose groundwater irrigation development as a means of alleviating pressure on the surface water resources (WB, 2006; WWF; 2010; Walsh, 2012). As evaluation of financial viability of any prospective actions is essential for its broad implementation, the existing literature does not offer enough information on the estimated costs and benefits associated with investing in GW irrigation by smallholder farmers as alternative to supplement surface water irrigation. Accordingly, the analysis of whether an investment is worthy or otherwise remains equally important to decisions making. A study by Villholth *et al.* (2013) addresses a number of issues on analysing the potential for and constraints to GW irrigation in Usangu Plains. Among the constraints, income of the farmers was found as a major constraint to GW development in the plains. Also benefit analysis executed by the study observed a potential profit gains for the farmers, by being able to grow a second crop in the dry season through irrigation using groundwater. However, not much attention has been paid to the financial viability associated with investing on smallscale groundwater irrigation as well as the ability of the smallholders farmers to own and manage the investment.

Therefore, the present study was carried out with the objective of evaluating whether investment in GW irrigation by smallholder farmers in the Usangu Plains is a financially viable alternative and mitigating option to water scarcity for agricultural development. Therefore, the study findings would provide a road map to policy makers and other stakeholders on the way forward in GWI development in the Usangu plains that will help them in planning, promoting and making relevant decision on GWI investment to deal with water scarcity and other associated environmental problems in the Usangu Plains.

1.3 Objectives

1.3.1 Overall objective

The overall objective of this study was to evaluate the financial viability of utilizing GW for irrigation by smallholder farmers in the Usangu Plains, Tanzania.

1.3.2 Specific objectives

The specific objectives of this study were to:

i. Analyse the costs and benefits of using groundwater in small scale irrigation;
ii. Evaluate the factors influencing smallholder farmers into using groundwater for irrigation; and
iii. Assess the affordability of smallholder farmers to invest in groundwater irrigation.

1.3.3 Research questions

This study intended to answer the following questions:

i. What are the costs and benefits of using groundwater for irrigation?

ii. What factors are likely to influence smallholder farmers into using groundwater for irrigation?

iii. Is there adequate capacity for the smallholder farmers to own and manage GWI investments?

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Definitions and Concepts

The concept of financial viability can be defined at different levels and in various contexts. It includes the ability of the investment to maintain its cash flows consistenly over time, upon various risks and its associated uncertainities while at the same time not degrading the natural resource (Kamara *et al.,* 2002). It also takes into account the ability of the investment to generate sufficient income to meet smallholder farmers' expectations, and at the same time to cover investment cost and all basic operations required to run the investment. Many authors (e.g. Carter and Howsam, 1994; Shah *et al.,* 2002) argue that physical and socio-economic factors of the smallholder farmers are the key issues in influencing financial viability of investing in GW small scale irrigation. In their study, they argue further that, financial viability of investing in smallscale irrigation (profitability and productivity) largely depends on smallholder farmer's reliance on irrigation as an income source, knowledge in farming and investment initiatives, entrepreneurial capacity and other households characteristics including age of a farmer, households size and education level.

Smallholder farmers are defined in various ways depending on the context, country and even the ecological zone. In common terms, a smallholder farmer refers to a farmer with limited resource endowment relative to other farmers in the sector. It can also be defined as those farmers who own small-based plots of land on which they grow subsistence crops and one or two cash crops and relying almost exclusively on family labour (Rockstrom *et al.,* 2003). For example, the Kenyan Government regards small tea producers as working on less than 20 hectares of land while in other contexts, such as in Indonesia, 15 hectares of land may be considered a relatively large farm (Toulmin and Gueye, 2005). Due to the heretogeneity in the defnitions of smallholder farmer, this study considers smallholder farming as "family farming" different from farming operating on commercial basis as described by Toulmin and Gueye (2005) and Shah *et al.* (2013). Several advantages of smallholder farming have been observed by many authors. For example, Allaire (2009), cited immediacy, low cost, drought resistance, farmer management, spatial equity, on-demand water availability and conveyance efficiency as the advantages of small-scale irrigation through GW. In another study, Pavelic *et al.*, (2012) on water balance approach for assessing potential for smallholder groundwater irrigation in Sub-Saharan Africa realised that smallholder farmers' move to GW development to overcome unreliable weather and idleness during the dry season as a resource in autonomy from natural and need low-cost technologies for pumps and drilling service.

2.2 Groundwater Small scale Irrigation in Sub-Saharan Africa

Groundwater is a critical underlying resource for human survival and economic development in extensive drought-prone areas across Sub-Saharan Africa (SSA) (Foster *et al.*, 2012). As Tuinhof *et al.* (2011) observe, many parts of SSA are prone to severe drought which is directly related to persistent poverty, hence there is a high demand for investment in GW for irrigation to overcome the impacts of drought. In SSA, dependence on groundwater in rural and urban water supply is undisputable, as evidenced by high presence of wells (boreholes and dug wells) for both domestic and livestock consumption. Currently, there is a growing interest in the prospect of promoting groundwater use for agricultural irrigation at both small and commercial scales with high-value crop production, drought mitigation and climate change adaptation (Foster *et al.*, 2012).

GWI has been observed as a rapidly expanding mode of irrigation for smallholder farmers in SSA (Giordano, 2006). As Ngigi (2009) observes, GWI for smallholder farmers in SSA is an important development pathway to fight against poverty, increase food security, land and labour productivity, as well as boosting rural employment and adaptation to the increasing impact of climate variability and climate change. Such a pathway, according to Abric *et al.* (2011), reflects the recognition of the benefits of small scale irrigation which is mostly practised by poor farmers. Villholth (2013) reports further that GW responds to the demand of smallholder farmers for a reliable and flexible irrigation water supply. As compared to surface water irrigation (SWI) schemes, which are often seen limited according to geographical location and which are highly capital intensive, GWI is considered to be more attractive to smallholder farmers due to its mode of access and ownership.

Many studies have indicated GWI as a preference to smallholder farmers because it is a resource, which is always available in an autonomous control and thus lowering the risk for the investments in other inputs and in turn leads to the diversification of high crop value with stable outputs, and net incomes per unit of investment (Shah *et al.,* 2013; Dittoh *et al.,* 2013). However despite these observations, only a small proportion of SSA agricultural land is reported to be equipped with irrigated cropping, and agriculture groundwater use in particular, is extremely limited (Siebert *et al.,* 2010). The use of GW for small-scale irrigation in SSA is reported in some parts of West Africa including Ghana, Niger, Nigeria, Ethiopia and Malawi through both private and public funds (Barry *et al.,* 2010; Tuinhof *et al.,* 2011; Namara *et al.,* 2013 Gebregziabher *et al.,* 2013). Studies reveal that small scale GWI is increasingly promoted by governments, donors, and NGOs.

2.3 Investment in Groundwater Irrigation

The decisions which farmers make about investing in a particular technology are based on the cost and benefits that are associated with such a technology. This is also highly influenced by the ability of the farmer to access such technology and its perceived/revealed output (Grabowski, 2011). Adegbola and Gardebroek (2007) revealed further that farmers' investment in a certain agricultural technology is influenced by the economic gain which is anticipated. Capital investment has been observed as the largest constraint facing poor farmers in SSA. As observe by Villholth (2013), access to GWI demand for well construction and other facilities for GWI conveyance are seen as limiting factors that hinder the GWI development in SSA.

The cost of well drilling, including both manual drilling of less than about 20 m and motorized drilling has been increasing with the complex technologies from simple to more advanced ones. As shown by Abric *et al.* (2011), the prices for low-cost shallow manual drilling in West Africa is approximately one-tenth of the prices given for deep wells. Hence, manual drilling wells have been promoted and adopted widely in West Africa as a suitable approach for smallholder irrigation. In terms of the operation and maintenance farmers in most of the regions in SSA, have been using manual lifting devices including bucket with rope and treadle pumps due to the high cost of motorized pumps, which are operated by fossil fuel and electricity. In another study Easter and Liu (2005) observe that while the capital investment is financed by the government and transferred to smallholders, operation and maintenance costs are high, while beneficiaries' willingness and ability to pay these costs are very low, posing bigger risks on financial feasibility and sustainability of such projects. As a result, manual drilling shallow wells are seen as a convenient alternative for smallholder farmers due to its affordable investment cost.

However, financial viability of the groundwater use for irrigation could be the determinant factor of whether or not to promote it.

2.4 Challenges Facing Irrigation Investments by Smallholder Farmers

There are many challenges that face smallholder farmer when deciding to invest in irrigation technologies. According to Foster *et al.* (2012), GWI development has often been affected by operational and/or problems such as import restrictions on well equipment like pumps, absence of a related service sector, investment capital, energy costs and supply chains, harvesting techniques, and prices of inputs and outputs. In addition, lack of understanding and poor appreciation of groundwater resource has inhibited investment in this technology. Giordano (2012) identifies various factors which to a significant extent constrain groundwater irrigation development in SSA. Such factors include lack of community tradition, high capital cost of well drilling, low levels of rural electrification and inadequate farmer access to financial credits.

A study by Villholth *et al.* (2013) in the Usangu Plains reveals that the development of GW small-scale irrigation would be either driven or restricted by socioeconomic and policy factors rather than other factors such as hydrological and environmental factors. On the other hand, a study by Obuobie *et al.* (2013) in north-eastern Ghana shows that groundwater irrigation is profitable although there are withstanding constraints such as lack of access to credit facilities, limitations to land access, lack of appropriate drilling technologies, and access to market and extension services. Therefore, social economic factors are important parameters in the investigation of financial viability of investments in groundwater small- scale irrigation in order to determine its affordability.

In assessing the factors influencing the adoption of GWI technology in Ghana Owusu *et al.* (2013) revealed that household's size and membership of farmer-based organizations tend to have positive significant impacts on the probability of adopting groundwater irrigation whilst extension contacts and farm size have negative impacts. In addition, age, gender, farmer's education level, access to credit, farm size, and land availability also tend to have significant positive effects on the probability of adopting groundwater irrigation technology. The authors also suggest that to promote the adoption of groundwater irrigation technology, enhancement of skills and knowledge of farmers on the existing irrigation technologies through frequent participation in workshops and training programs is inevitable. The authors recommend further that, smallholder farmers must be supported to access micro-credit facilities for groundwater irrigation development. Both of these studies highlight the significance of socio-economic characteristics of the farmers in the adoption of farm-based initiatives/technologies. The study findings highlight the importance of examining farmers' socio-economic factors to the influence adoption of GW small scale irrigation in Usangu Plains.

2.5 Approaches for the Analysis of Financial Viability

Various techniques ranging from discounting to non-discounting are being used to analyse the financial viability of investment. Discounting technique Cost Benefit Analysis (CBA) through it decision criterial cost-benefit ratio, net present value, and internal rate of return. Non-discounting measures on the other hand include payback period and rate of return (Hoevenagel, 1994).

Discounting techniques measure the project's worth by discounting all the monetary future costs and benefits (Boardman *et al.*, 2001). Cost-benefit analysis (CBA) is a discounting measure of project worthiness which originated in the USA in 1936 and has become a world-wide tool of evaluating choices between alternative projects in decision making (Pearce *et al.,* 2006). CBA is more useful when a choice has to be made out of several options and when the project involves a stream of benefits and costs over time. Unlike the discounting technique, the non-discounting techniques of measuring investments worthiness do not explicitly consider the time value of money.

The Contingent Valuation decision rule (CVM) can be used in CBA to evaluate the policy option on the natural resource which cannot be evaluated by pricing mechanism (Awad *et al.,* 2010). The CVM develops a framework of a hypothetical market used to elicit valuations for environmental goods preference, expressed in terms of Willingness to Pay (WTP) and Willingness to Accept (WTA). The technique has great flexibility that can allow valuation of a wider variety of non-market goods and services than all the indirect valuation techniques. However, the method has some weaknesses: first, it does not produce valid measurements when it concerns the goods that people are not used to. This means CVM does not provide valid estimates when people are unfamiliar and inexperienced with the goods. Also, validity could be a problem, since it is very difficult to describe a natural good in such a way that all its attributes are accounted for. Puttaswamaiah (2002) observes that CVM works best for those goods resembling ordinary commodities, which means that it is best suited for valuing consumption goods that people consume more as their income increases. Also when goods are not easily commoditized, CVM results are doubtful. Inspite of the weakness, CVM has remained to be a sound technique for estimating values for public policy decisions.

The choice between discounting and non-discounting measures of project worthiness depends on the nature of investment/project to be evaluated. Since this study is primarily towards gathering initial information on GWI development in Usangu Plains, only the cost and benefit that have market price and can be monetised were considered. Decision criterion including NPV, IRR and CBR were used to analyse the financial viability of investing in GWI by smallholder farmers.

2.5.1 Cost benefit analysis

2.5.1.1 The concept of CBA

The Cost-benefit analysis (CBA) is a widely discounting measure technique which allows for the determination and evaluation of the economic cost and benefits of an investment (Van Tongeren and Beghin, 2009). CBA is designed to evaluate if the estimated total benefits of an investment can be deduced to the cost incurred in running it, so as to facilitate decision making between different alternative projects through the evaluation of all costs and benefit in monetary terms (Pearce *et al.,* 2006). Cost-benefit analysis (CBA) is widely used by governments and economists to evaluate a long-term financial viability of an investment and it requires the forecasting of inputs, outputs, and their marginal social values in order to determine the expected net present value (NPV) of the investments (Florio *et al.,* 2016). It is also used as an analytical tool aimed at informing decision making on the financial viability of projects, programs, policies or regulatory initiatives by identifying all the costs and benefits and measuring them through a monetary value of the welfare change attributable to them (Boardman *et al.,* 2010; Florio, 2014).

The purpose of CBA is to support a more efficient allocation of resources, demonstrating the convenience for the society of a particular decision against possible alternatives including the ‘do nothing’ or ‘business as usual’ alternatives (Boardman *et al.,* 2010). Accordingly, the comparison between different alternative will show the expected results of a project in terms of financial returns. The CBA conclusion provides not only the relatively better choice according to the results but also any unexpected or surprising results caused by research limits that might be important to the decision maker (Florio *et al.,* 2016).

The CBA is an appraisal technique when all the expected costs and benefits of the intervention are identified and valued. It represents a framework where all project benefits and costs are identified, quantified, valued and compared against a range of optimality criteria on an ex-ante (before project) and ex-post (after project) basis. It becomes complicated when components of either cost or benefit are not easily quantified or valued. The benefits that have market value can be monetized using market data, whilst if there no information either from conventional markets or from related markets for some benefit items, termed as non-market benefits are used. The main purposes of CBA are to evaluate whether resources are used efficiently in a project compared to some pointed alternative and to highlight the fact that the cost is not greater than the net benefit of the society.

Despite the shortfalls, CBA has been used in many development projects, especially in developing countries such as Tanzania. Balkema *et al*. (2010); EAC (2010) and Akyoo and Lazaro (2008) have used cost-benefit analysis methods to analyse the financial viability of different projects in Tanzania. CBA method uses decision criteria such as Net Present Value (NPV), Cost Benefit Ratio (CBR) and Internal Rate of Return (IRR) to evaluate public projects and policies. NPV is a central tool in discounted cash flow analysis, and it has been used in capital budgeting, and widely throughout economics, finance, and accounting to measure the investment return over time (Lin *et al.,* 2000). The NPV assists in measuring the absolute benefits which are obtained from a development project. It is also capable of dealing with both capital and recurrent costs incurred in a development project (Potts, 2002). The weaknesses of NPV include its high sensitivity to the discount rate, a slight change in the discount rate causes a large change in the NPV as it often relies on uncertain forecasts of future cash flows. Its magnitude however depends on how uncertain the forecasts are. The correction of these pitfalls can be attained by calculating a range of NPV numbers using different discount rates and scenarios (Lin *et al.*, 2000).

The IRR is a rate of return used in capital budgeting to measure and compare investments profitability. IRR is defined as the rate of return on an investment which will equate the net present value of benefits and costs (such that the net present value of the investment becomes zero (Cuthbert and Cuthbert, 2012; Osborne, 2010). Therefore, it is the actual rate at which the net present value of a development project is zero (NPV=0). IRR is used to measure the investment worth and helps to determine the relative profitability of the investment. The IRR approach takes into account the time preference of the development project, which the NPV method do not, and can be discounted or estimated without a discount rate benchmark (Potts, 2002). Often IRR results lead to the similar decision as the NPV although there are some exceptional to this general rule (Jovanovic, 1999).

The CBR decision criterion assesses and presents the investment to the ratio of the present value of benefit to that of the costs. This approach and its procedures assume that it is at this ratio the investment is expected to generate more benefits than the costs. Thus, CBR technique verify the efficiency of development investments (Potts, 2002).

Despite the shortcomings; NPV, IRR and CBR have been used in analysing financial viability of different project investments in SSA. Hagos and Mamo's (2013) case study on the financial viability of GWI and its impact on livelihoods of smallholder farmers in Eastern Ethiopia, used decision criteria, net present value (NPV) to measure the worthiness of well construction. Also, Gebregziabher's *et al*. (2013) study on cost-benefit analysis and ideas for cost sharing of groundwater irrigation in north Ethiopia employed NPV CBR and IRR in determining cost and benefits of groundwater irrigation.

These authors reported that CBA tools (NPV, CBR and IRR) are the approaches adopted from UNIDO and are commonly used for project cost-benefit analysis, especially in developing countries. Thus, in the present study, NPV, IRR and CBR decision criteria were adopted in analysing the financial viability of using GW for irrigation by smallholder farmers.

2.5.1.2 Decision criteria

The aim of undertaking CBA in this study was to evaluate the long-term financial viability of using groundwater for irrigation by smallholder farmers. According to NPV, the criterion accepts the investment with positive NPV and rejecting it if the NPV is negative (Ifediora, 1993). In IRR, decision criterion accepts the project investment if the trial rate is higher than the discounting rate and vice versa. If the IRR greater than the cost of capital, accept the project and if the IRR is less than the cost of capital, reject the project. In CBR project investment is accepted when the ratio of the discounted benefit and cost is at least 1. The CBR of 1 indicates that NPV is equal to zero which is also the IRR of the investment project. Projects with a BCR of 1 or greater are economically acceptable when the costs and benefit streams were discounted at the opportunity cost of capital. The absolute value of the BCR varies depending on the discount rate chosen; the higher the discount rate, the smaller the BCR. In this study, GWI investment using deep wells, and shallow wells was used as an alternative project investment while surface water irrigation was used as a "business as usual scenario".

2.5.1.3 Sensitivity analysis

Since project investment involves future cost and benefits, there are several sources of uncertainty (i.e. increase of the price of inputs and outputs, decline in production) which are associated with the analysis of costs and benefits. Thus, it is very important to evaluate sensitivity of the results if small changes in key variables occur. One factor is the discounting rate whereby a higher discount rate implies that the present value of future benefits and costs decreases. Due to the fact that the choice of discount rate is arbitrary to some extent, it is important to evaluate how sensitive the result is to changes in the discount rate (Hanes and Lundberg, 2008). In addition, other factors that need to be considered in sensitivity analysis are changes in the prices of inputs and outputs and the scale of production which may change the decision criteria. In this study, sensitivity analysis was carried out in order to assess the strength and reactions of the project feasibility.

CHAPTER THREE

3.0 STUDY APPROACH AND METHODOLOGY

3.1 Description of the Study Area

Usangu Plains are found in the Southern Highlands and are surrounded by the Poroto and Kipengere mountains. The plains fall in two regions and eight districts, with the larger part (about 60%) falling within the Mbeya Region, and primarily in Mbarali District. The study was conducted in three villages namely Nyeregete, Ubaruku and Mwaluma. All the study villages are found in Mbarali District, which lies between Latitudes 7^{o} 41’ and 9^{o} 25’ south, and between Longitudes 33^{o} 40’ and 35^{o} 40’ east at an altitude range of 1 010 to 1 100 meters above the sea level. Also, the area is part of the upper Great Ruaha River catchment (URT, 2010). It encompasses an extensive wetland, comprising seasonally flooded grassland and a much smaller area of a permanent swamp commonly known as *Ihefu* which collects water from all the rivers in the Uporoto and Kipengere mountain ranges. This makes the area critical to Tanzania for livelihood options of smallholder farmers and agro-pastoralists. Furthermore, the area is of importance due to its wetlands and associated biodiversity and catchments that provide crucial waters to the downstream of Ruaha National Park, and Mtera-Kidatu hydropower plants which produce more than 70% of the national hydroelectric power, before joining the Rufiji River and emptying its water into the Indian Ocean (Mwakalila, 2011; Walsh, 2012).

The climate of the area is mostly semi-arid with seasonal temperature and rainfall variations. Temperatures range from 20 to 25 ^{o}C, whereas the annual rainfall varies between 500–700 mm/year. The area receives the unimodal type of rainfall from

November to May, and which normally scattered and varies across the Usangu plains. Rainfall is generally unreliable, and with common localized droughts (URT, 2010).

Land use and land cover in the area include settlements, scattered croplands, grassland with scattered croplands, open bush-land, seasonally inundated grassland, and perennial swamp (Kashaigili, 2006; Mwita, 2016). Communities in the Usangu Plains are smallholder farmers who depend mainly on small scale agriculture. About 90% of the population rely on agriculture, while livestock keeping, petty businesses are also important economic activities. Other small-scale economic activities such as fishing, handicrafts, sand mining and ritual activities are also common in the Plains (Kashaigili, 2006). Paddy is the dominant crop produced in the plains during wet season. The crop is produced mainly for subsistence by small scale farmers and to a small extent for commercial purposes. Besides irrigated paddy, other crops produced include maize and vegetables, and onions and tomatoes which are produced mainly for commercial purposes.

The Usangu area had a total population of about 790 500 people in 2012 national census data with an annual growth rate of 2.7 (URT, 2013). The population is multi-ethnic and multi-cultural in which Sangu are the indigenous ethnic group. Other ethnic groups include Bena, Hehe, Maasai, Sukuma, and Nyakyusa. There has been a huge change in ethnic composition with increasing competition in land-use systems (SMUWC, 2001). Figure 1 shows the map of the study area.

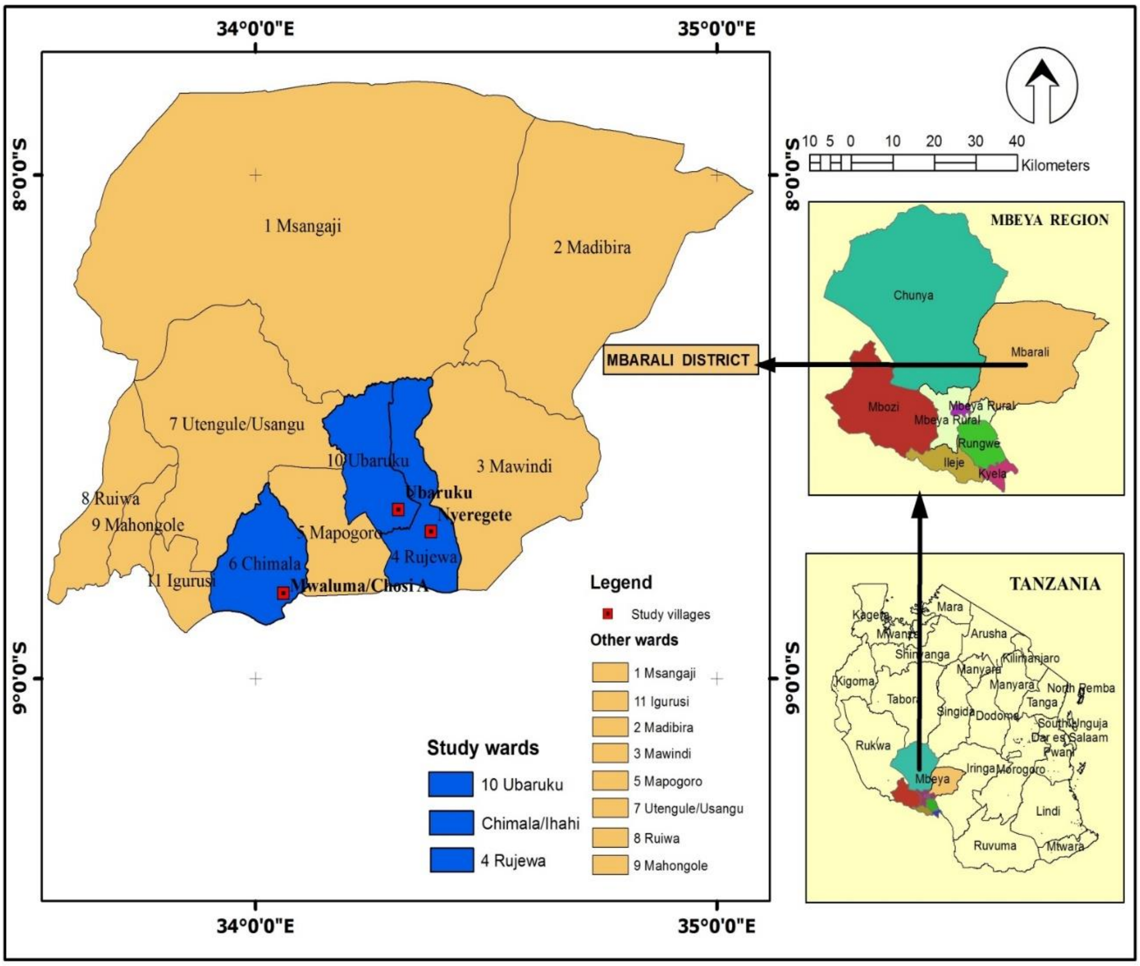

Figure 1: Map of Usangu Plains and location of the study villages

3.2 Study Design

The present study focus towards gathering initial information on the development on GWI in the Usangu Plains. The study employed two designs, a case study and descriptive cross-sectional research designs. Under the case study design, detailed information associated with GWI were studied and observed. This design was crucial for the present study because currently the use of GW in the Usangu Plains is mainly for domestic purposes and to a small extent for irrigation. Montfort Secondary School is one of the places in the Usangu Plains which use GW to supplement SWI for small-scale irrigation activities. Thus, Mont Fort Secondary School was used as a case study where detailed information which is associated with functioning of GWI was studied. Also, the study employed a descriptive cross-sectional research design. Under this design, data from households were collected once examined and the relationship between variables was determined. The study design was advantageous as it was compatible with the available time and resources (Bryman and Bell, 2015).

3.2.1 Sampling procedures

Usangu Plains was purposively selected due to the existing plan of promoting GW irrigation as an alternative to surface water as proposed by WB Report of 2006. In Usangu Plains, three villages namely Nyeregete, Ubaruku and Mwaluma were selected purposively. The households were randomly selected using a random number table technique from the population of smallholder farmers in the study villages.

Key informants were purposively selected based on their experience on GW irrigation. These included drilling companies, the Rufiji Basin Water Board officials, extension officers and village leaders.

3.2.2 Sample size determination

According to Fisher *et al.* (2002), sample size is one of the most important determinants of survey estimates, and that depends on precision (amount of sampling error which can be tolerated by the researcher) and confidence level (level of certainty that the true value of the variable being studied is captured within the standard error or sampling error). The authors reveal further that the greater the precision of estimate and confidence in the results, the larger the sample size needed. According to the authors another factor , which is equally important, in determining the sample size is the amount of resources (time, money, and personel) available for the study. According to Gay and Diehl (1992), generally the number of households for the study depends on the type of reseach descriptive, correlational, or experimental. For a descriptive research, the sample should be 10% of the population. But if the population is small, then 20% of the population may be required. For correlational reseach at least 30 subjects are required to establish the relationship. For experimental reseach, 30 subjects per group is the minimum. According to Bailey (1994), a sample size of at least 30 households is statistically adequate. This is consistent with Boyld's *et al.* (1981) observation that a sample size should be at least 5% of the total target population. This study adopted the guidance by Bailey (1994). Accordingly, a total sample of 97 households was interviewed (Nyeregete village, 33 households; Ubaruku village, 34 households; and Mwaluma village, 30).

Furthermore, four key informants were selected from Mbarali District Council, one from the Rufiji Basin Water Board Office at Rujewa office in Mbarali and three drilling companies. Also, six people were selected for focus group discussions in each village based on age group, gender, experience of the area, and education level.

3.2.3 Data collection

3.2.3.1 Primary data

Both qualitative and quantitative data were collected. Quantitative data were collected using formal surveys through semi-structured questionnaires (Appendix1) containing both open-ended and closed questions. The questionnaire was administered to households. The information collected includes households' socioeconomic and demographic information, economic activities, groundwater information, information on previous crop production season and the existing price for inputs and outputs. Qualitative data were collected through Focus Group Discussion using probing questions (Appendix 2) and Key informant checklist (Appendix 3). Furthermore, direct observation and informal discussion were also carried out to counter check some of the responses from farmers and to get an insight on the actual field conditions. In addition, an in-depth interview was carried out to gather more information associated with cost and benefit of GW use for irrigation.

3.2.3.2 Secondary data

Secondary data were obtained from both published and unpublished relevant documents from Mbarali District Council, drilling companies, Ubaruku-Mpakani Water User Association, and internet searches. The data were used to supplement and in some cases to compare with the primary data which were collected from the field. Efforts were made to ensure that the gathered data were pertinent to the study objectives.

3.2.4 Data analysis

3.2.4.1 Descriptive analysis

Descriptive statistics, including means, minimum, maximum, percentages and frequency distribution were used to summarise the quantitative. The general purpose of descriptive statistical method is to summarise, and simplify a set of scores (Gravetter and Wallnau, 2007). In the present study, the central tendency (average or representative score) for numeric data was determined by mean. The central tendency determination for discrete variables was a mode. The measure of variability within the numeric data was standard deviation.

3.2.4.2 Financial analysis

Gross margin and NPV, IRR and CBR decision criteria were employed to analyse data for objective number one.

NPV, IRR and CBR were applied to evaluate the long-term financial viability of using groundwater for small scale irrigation while gross margin was used to evaluate the profitability of using groundwater against SW for irrigation as an alternative scenario in a short run period of time. Information on surface water irrigation was included in this analysis in order to compare the profitability with and without groundwater irrigation while other factors such as climate change notwithstanding. Sensitivity analysis was carried out to study the effect of a change in fluctuating factors such as prices of inputs and outputs scale of production and discount rate on NPV and CBR.

NPV, IRR and CBR was obtained using the following formula (Lin *et al.*, 2000):

$$NPV = \sum_{i=0}^{n} \frac{B_t - C_t}{(1-r)^t} \quad (1)$$

$$CBR = \frac{\Sigma_{t=1}^{T} \frac{B_t}{(1+r)^t}}{\Sigma_{t=1}^{T} \frac{C_t}{1+t^t}} \quad (2)$$

IRR was obtained by using the following formula

$$IRR = \Sigma_{t-1}^{T} \frac{B_t - c_t}{(1+r)^t} = 0 \quad (3)$$

Where for all equation 1, 2 and 3

Σ = is the sum of the discounted cost and benefits

B = benefits at year at year 2016 (market value of yield at year 2016)

C = Cost at year 2016 (market value of inputs, fees and other production costs)

t = the time in years i.e. 30 years (t=30)

r = discount rate 12%, 18% and 20%

$(1 + r)^t$ = discount factor

Microsoft excel program was used to calculate NPV, IRR and CBR. The cost component included the initial capital cost of the borehole, operation and maintenance cost, water fee, market prices of inputs, the cost of ploughing, planting weeding, and harvesting.

Discounting reflects the time value of money. Benefits and costs are worth more if they are experienced sooner such that all future benefits and costs should be discounted to its present value for the investments with long life span. The higher the discount rate the lower the present value of future benefits and costs. For projects with the costs concentrated in early periods and benefits following later, raising the discount rate tends to reduce the net present value. The discounting rate of 12% was used in this analysis as per the Bank of Tanzania (BOT), and as indicated in the Monthly Economic Review of Feb 2017. Apart from constant discounting rate from the Central Bank in Tanzania (BOT), the study also considered 18% and 20% of interest rates that are used by different microfinance banks of Tanzania as they are the main credit sources for smallholder farmers. However, there is considerable uncertainty over the correct discount rate and also high uncertainties are expected in agricultural production and which include an increase in the production costs and a decrease in returns that can affect investment financial viability. Different scenarios were assumed to check the investment sensitivity.

Scenario one anticipates the increase of production cost and reduced income while scenario two assumes an increase in production cost and increased income. Therefore, scenario one assumes a 25% increase in the production costs and 10% decrease in income while scenario two assumes 100% increase in the production costs and 25% increase in income. However, Gebrehewaria *et al*. (2016) also revealed that the size of land for production affects the investment economic viability. This is due to the economies of scale whereby the cost per unit of an output generally decreases with an increase in the scale of production. Sensitivity of the investment was measured when 0.4 ha of land is used. Based on these scenarios, sensitivity of investing in GW for small scale irrigation was tested at 12%, 16% and 20% discounting rates.

Estimating the life of a project or program is difficult, subjective and widely debated. It depends on the assessments of the program’s physical life, technological changes, shifts in demand or fashion, competing products that emerge and the general state of the world many years in advance. However since this GWI involves fixed cost which is capital intensive, lifespan is one of the important variables of determining the viability of an investment. This takes into account the entire income stream for the whole lifespan of the investment. For example, the available evidence shows that boreholes are drilled and function for a lifespan of 20 to 50 years (Carter *et al.*, 2014). This study opted for 30 years investment lifespan. However, the life span of wells can last less or more than the opted lifespan. Such lifespan was selected so as to avoid underestimation or overestimation of the financial viability of such investment.

Cost-benefit analysis (CBA) was applied to estimate the direct costs and benefits accrued from investing in GW irrigation by smallholder farmers. In-line with the CBA framework, the analysis was carried out on the basis of the following considerations:

i. All costs and benefits are estimated in incremental terms as opposed to surface water irrigation as a business as usual alternative.
ii. The analysis starts at (year 0) when the initial investment costs of the GWI facilities occurred while the maintenance and operation cost were assumed to start from the second year after the investment.

iii. All production costs and benefits from using groundwater for irrigation were regarded with the crude assumption that, since it was difficult to forecast the cash flows for the entire lifespan of the investment, constant value was used in measuring project viability throughout the lifespan of the project. Costs and benefits have been quantified and valued in TZS using Nov – Dec 2016 market prices.

iv. Two production seasons in a year for groundwater irrigation were assumed where paddy could be produced during the wet season and during the dry season the same field would be used to cultivate any other crop. This is due to the argument that through GW, the farmer has an added advantage of irrigating his/her farm during the dry season. Empirical evidence was observed during data collection, whereby some households that owned wells (mostly dug wells) had irrigated back yard gardens during the dry season. Vegetables and tree fruits were grown in these gardens for their own consumption and for sale in the local market. At Mont Fort secondary school paddy seedlings, vegetables, onions and orchard crops were found grown on school gardens using GWI in the dry season.

v. This analysis used onion as the second crop during the dry season. This was due to the argument that paddy was reported as both a cash and food crop grown during wet season, while onions, water melon and vegetables were reported as cash crops grown in the dry season. Thus, paddy and onion were selected in estimating the viability of investing in GW irrigation by smallholder farmers. By considering such scenarios, a relative profitability of using GW for small scale irrigation was established.

vi. Operation and maintenance were estimated to take 10% of the investment cost per year. This was estimated from the communal deep well supplying water to the villages Ubaruku and Mpakani where hydroelectric power is used as a source of energy.

Gross Margin Analysis

Gross margin was used to analyse profitability of using groundwater for small scale irrigation. As performance from agriculture varies from season to season and crop to crop, gross margin analysis is useful for production cycles of less than a year as this enables costs and returns to be directly linked to a particular activity. It also allows establishing profitability of the enterprise (Makombe *et al.*, 2007). The Model for gross margin analysis is presented as follows.

$GMI = \sum TR - \sum TVC$ ………………………………………………………………….... (4)

$TR = P_y.Y_i$ ……………………………………………………………………….......... (5)

$TVC = P_x.Xi$ ………………………………………………………………………........... (6)

Where GMI = Gross Margin Income

TR = Total Revenue

TVC = Total Variable Cost

Py = Unit Price of Output Produced

Y = Quantity of Output (Kg)

Pxi = Unit Price of Variable input used

Xi = Quantity of Input.

3.2.4.3 Logistic regression analysis

Factors influencing the use of GW for irrigation by smallholder farmers have been defined as binomial variables taking the value of one in case a farmer uses GW for irrigation, and zero if otherwise. Binary logistic regression technique was used to determine the relationship between independent variables (age, education level, household's size, occupation, and credit access and income level) in influencing GW use for irrigation. The independent variables are categorized into two distinct groups that are binary and continuous) in the binary category coded 1 becomes the reference category upon which the logit inference is drawn. If the sign of the logit is negative (-ve), this implies less likelihood of the event defined by the reference category occurring.

The Hypothesis here was concerned with the influence of household characteristics on the GW usage. Binary Logistic regression analysis was used to test this hypothesis:

$$Logit(Y) = \ln\left(\frac{\pi}{1-\pi}\right) = \alpha + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n + \varepsilon_i \quad .... (7)$$

Where: π is the probability of the event, α is the Y intercept, β_s are regression coefficients, and Xs are a set of predictors.

$H_0 : \beta_1 = \beta_2 = \beta_3 = ... = \beta_k = 0$ ....
(8)
(i.e. households' socio-economic and demographic factors have no effects on GW usage)

H_1 : At least one of the $\beta_s \neq 0$ .... (9)

(i.e. some household's socio-economic and demographic factors do have effects on GW usage)

The variables used in the regression are presented in Table

Table 1: Description of variables used in the Logistic Regression Model

Variable	Description
Y	GW use for irrigation (1 = yes, 0=no)
X_1	Gender of households head (1 = female , 0 = male,)
X_2	Households size
X_3	Age of the respondent (years)
X_4	Access to financial institutions (1= yes; 0 = no)
X_5	Education level of households head (1= educated; 0 = illiterate)
X_6	Households income (TZS)
X_7	Social network membership (1 = yes, 0 = no)

Gender: it is a dummy variable which takes a value of 0 if the respondent is male and 1, otherwise. In most cases male headed households have better access to information on the available opportunities and are more likely to adopt new technologies than female. Therefore sex of the household head was expected to positively influence GW use for irrigation.

Age: This variable refers to the age of household head at the time of the survey, measured in years. Age may capture experience and exposure to various technology and ability to foresee uncertainties and shocks of the new technologies. On the other hand, age can being associated with loss of energy, short planning horizons and being risk averse. Thus the impact of age on discovering new farming opportunities is ambiguity prior being tested.

Household size: Household size in this study refers to the number of members who are currently living within the family. Large family size is an indicator for availability of labour provided that the majority of the family members are within the age range of active labour force. Availability of labour in the household is again one of the important resources GWI. Based on this assumption, this family size was hypothesized to have positive relationship with the use of GWI.

Education level: It measures formal education of household head in the family. It is a dummy variable, which takes a value 1 if the farm household is literate (can only read and write), and 0 illiterate. Education enhances farmers' ability to perceive, interpret and respond to the available opportunity. Therefore, in this study education was expected to positively influence GW use for irrigation.

Socio network membership: It is a dummy independent variable represented by 1 if the household head participates in farmer socio network during the study year and 0, otherwise. Being in socio networks increases chance to timely and vital information that can influence farmer's decision to use GW for small scale irrigation. Thus, being a participant in famer socio network was expected to affect the use of GW irrigation positively.

Access to financial services: This variable is measured in terms of whether respondents have access to any financial services. It is a dummy variable, which takes a value 1 if the farm households have access to financial institution or 0, otherwise. GWI requires high initial investment thus farmers who have access to credit may overcome their financial constraints and therefore be able accommodate the GWI initial investment.

Household income level: it is a continuous variable determined by household annual income in term of Tanzania shillings. It was expected to be positively associated with the use of GW for irrigation. This means household who have a relatively high income level would be more initiated to GW use for irrigation.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

4.1 Socio- economic Characteristics of Households

Households' characteristics were important parameters in this study since they have economic and socio influence in facilitating smallholder GW irrigation investment. In this section, different characteristics of the sampled households mainly age, gender, marital status, education level, and households' size are summarised in Table 2

Table 2: Respondent Characteristics

Parameter		**Nyeregete (n=33)**	**Ubaruku (n=34)**	**Mwaluma (n=30)**	**Total (N=97)**
Household heads' age group (years)	18 - 38	8 (24.2)	6 (17.6)	9 (30)	23 (23.7)
	39 - 59	15 (45.5)	19 (55.9)	14 (46.7)	48 (49.5)
	≥ 60	10 (30.3)	9 (26.5)	7 (23.3)	26 (26.8)
Household heads' sex	Male headed	22 (66.7)	29 (85.3)	24 (80.0)	75 (77.3)
	Female headed	11 (33.3)	5 (14.7)	6 (20.0)	22 (22.7)
Household heads' marital status	Single	0 (0)	1 (2.9)	0 (0)	1 (1.0)
	Married	27 (81.8)	30 (88.2)	22 (73.3)	79 (81.4)
	Divorced	2 (6.1)	1 (2.9)	1 (3.3)	4 (4.1)
	Widow	4 (12.1)	2 (5.9)	7 (23.3)	13 (13.4)
Household heads' education level	Primary	26 (78.8)	26 (76.5)	18 (60)	70 (72.2)
	Secondary	0 (0)	2 (5.9)	0 (0)	2 (2.1)
	Illiterate	7 (21.2)	6 (17.6)	12(0)	25 (25.8)
Household size (group)	2-5	16 (48.5)	14(41.2)	23 (76.7)	53 (54.6)
	6-9	14 (42.4)	20 (58.8)	7 (23.3)	41 (42.3)
	≥ 10	3 (9.1)	0 (0)	0 (0)	2 (3.1)

Number in brackets are percentages

4.1.1 Distribution of the households' by age groups

As shown in Table 2, the majority (73.2%) of household heads were aged between 18 and 59 years, and this is within the economically active age group. As defined by URT (2008), economically active age group is the persons in the age-group of between 10 and 64 years. This age group is considered as economically active age group and a workforce for engagement in various economic activities. They also have great socio-economic responsibilities for their families. The findings also indicate that this is the age group that has a longer planning horizon and more willing to discover new opportunities for investments. This implies the potential availability of the most active working age groups in the family as a labour force for agricultural activities rather than the dependent age groups. As observed by Overholt *et al.* (1991), age is an important parameter in the social analysis since it has a great influence on different roles. These findings are similar to those reported by Giliba (2011) who observed that most people that are found in the villages are those who can participate in various economic activities and utilize the economic incentives available in the study area.

4.1.2 Sex of the households' head

Results in Table 2 indicate that a small proportion of respondents in this study were female headed households. The findings show there were more male headed household (77.3%) as compared to female headed households (22.7%). High percentage of male headed households was due to the fact that people in the area follow a patriarch system whereby men are considered to be the head of the households and also many economic activities are owned by males. However, sex of the household heads influences resource ownership as well as investment decision. This findings is also supported by Hess *et al.* (2008) in a study on livelihoods in the Uluguru Mountains of Tanzania that reveal that most of the household heads are males than their female counterparts.

4.1.3 Education level of the household head

The education level of individuals within a particular community is an indicator of the level of community's human capital. In social analysis, education level of the household head is an important factor that can help in estimating the adoption rate, the degree of risk taking and the ability of diversifying the available resources for livelihood support. Table 2 shows the education level of the households heads whereby majority (72.2 %) had primary formal education while only 2% had attained secondary education. The high number of heads of household with formal education in rural areas implies high degree of accepting and using new technologies.

As Kajembe *et al.* (2009) argues, education plays a major role in the socio-economic development of many societies through the adoption and innovation of new initiatives in the effort of improving the standard of living and livelihood. Also, Bartle (2002) ascertain that, education broadens individuals' understanding and physical abilities or skills of pursuing their lives. Thus, higher level of education puts households in a better position of understanding the existing livelihood challenges and the right decision making that can lead to better alternatives s and utilization of the available natural resources for livelihood support.

4.1.4 Households size

Table 1 depicts households' age categories whereby the majority (54.6%) of the surveyed households had average households size of less than 6 individuals; while 42.3% had more than 10 individuals. This suggests that smallholder agricultural activities were associated with large household sizes probably due to labour requirement for performing various activities.

4.2 Income Generating Activities

Socio-economic activities of the households was an important variable in this study since it offered the overall picture of the studied population in determining the potential of investing in GWI as well as the viability of the investment. Table 3 shows a considerable percentage (61.9) of the farmers was engaged in crop farming. This observation indicates that crop farming plays a significant role in income and livelihood support of many smallholder farmers. Other economic activities practised together with crop farming include livestock keeping, petty business (crop selling and buying in the local market, local brewing, handcrafting, tailoring and bricks making. Off-farm activities were observed to provide sufficient income to households to enable them meet their basic requirement particularly during the dry season.

Table 3: Percentage distribution of households in economic generating activities

Variable	Nyeregete n= 33	Ubaruku n=34	Mwaluma n=30	Total (n=97)
Crop production	12 (36.4)	20 (58.8)	28 (93.3)	60 (61.9)
Crop production and livestock keeping	14 (42.4)	3 (8.8)	0 (0)	17 (17.5)
Crop production and petty business	2 (6.1)	9 (26.9)	1 (3.3)	12 (12.4)
Employment and crop production	0 (0)	1 (2.9)	1 (3.3)	2 (2.1)
Crop production livestock keeping and business	4 (15.2)	1 (2.9)	0 (0)	6(6.2)

Number in brackets are percentages

4.2.1 Crop production

The results showed that, almost all of the households were engaged in crop production whereby 61.9% were predominantly crop farmers while the rest practiced both crop farming and other activities including livestock keeping and petty business. These findings imply that crop production is the main economic activity and a source of income in the study area. It also implies that smallholder farmers have the potential of supporting GWI development since water is a key factor in crop production. These results are consistent with Giordano’s (2009) observation that farmers’ economic activities have some influence in the adoption of certain technology. The crops grown include irrigated paddy as a predominant crop, maize, vegetables, onions, watermelons, sweet potatoes, and fruits.

In another study, Kaswamila (2012) found that most of the households in rural areas are mainly practising crop production as their primary economic activities. Also according to the World Bank (2008), agriculture is said to provide livelihoods to an estimated 80% of the population in Tanzania; and the sale of agricultural products is the main source of cash income for many households.

Vilholth *et al.* (2013) observe further that crop cultivation is the main source of income in Usangu Plains. Also there is great impact of irrigation on crop production. Their study revealed a big difference on crop yield and rural development between areas with and areas without access to irrigation. Table 4 depicts the mean average annual income from agricultural crops which was estimated to be TZS 2 421 575. Since crop farming is the main source of income in the study villages the majority of the household are believed to be above the global poverty line which is estimated to be USD 1.9 (TZS 4205) per day and TZS 1 538 876 per year as reported in April 2017.

Table 4: Households annual farm income (n=97)

	Minimum	Maximum	Mean	Std. Deviation
Annual farm income	12 000	11 670 000	2 421 575.26	2 525 673.14

Data represent farm income statistics from the harvest of the 2016 cropping season

4.2.2 Livestock keeping

Apart from crop farming, livestock keeping is another important source of income. Livestock is used as a proxy for household's wealth. This is because animals like small and larger ruminants were reported as a sign of respect and wealth in the community. Findings from focus group discussion indicated that, cattle is an indicator of wealth, respect and also is used as a banking system" whereby after harvesting some of the farmers sell part of their crops purposely to buy calves or cows that will be kept as a bilateral asset that could be sold in the future when there is an important need.

About 17.5% of the households were found to be engaged with both livestock keeping and crop farming (Table 2). The maximum value of livestock per households was TZS 35 740 000 with an average of TZS 2 081 300. This implies that livestock is an important asset in the community, and that the enterprise helps to generate income and act as a saving and or a banking system that can be used when the need arise including the need for capital for making investments. Apart from generating income bulls were used with oxen in agricultural activities. On average ploughing with oxen costs TZS 50 000 per acre. That means an individual who owns a bull can earn and or save some amount of cash for other activities as well as using it for agricultural activities.

4.2.3 Income from petty business

The findings show high percentage (87.6) of the households with an off-farm income level below the poverty line of TZS 1 538 876 per year as indicated in Table 5. This implies that smallholder farmers have low ability of securing non-farm income sources to complement farm opportunities. The findings reveal further that smallholder farmers depend much on agriculture as a source of income. During years of irregular rainfall many of the households are unable to meet their basic needs and other livelihood requirements. In such a situation, the majority of the households has to work on meeting their basic needs on non-farm business rather than engaging in farm investment. As Foster *et al.* (2012) observe groundwater irrigation development has often been affected by many factors including economic status of the farmers; however, its development could promote socio economic development and also could increase alternatives of off-farm opportunities. In another study, Namara *et al.* (2011) reveal that small farmers in Ghana have significantly improved their livelihoods through access to GWI which also stabilized rural community due to increased livelihoods and employment opportunities.

Table 5: Households of farm income categories (TZS)

	Frequency	Percent
below 153 876	85	87.6
1 538 876 and Above	12	12.4
Total	97	100.0

USD1 = TZS 2219 exchange rate in July 2017

4.3 Access to Credit and Financial Services

The majority (80%) of the households had no access to financial institutions and services including both informal and formal financial services (Table 6). This reflects the low monetary flow which characterise smallholder farmers and thus farmers are unable to make some investments since capital is acquired through capital enhancement as farmers can either use their accumulated capital or acquire the capital through borrowing from financial facilities. Furthermore, this finding reflects high incidence of non-commercial agriculture with little investment that limits monetary and capital flows among smallholder farmers. Similar observation was also reported by Chokkakula and Giordano (2013) who found that loans from formal credit institutions are often out of reach of farmers as these facilities are not present in the rural areas especially because of their high interest rates and collateral requirement which are not affordable by farmers.

Table 6: Households access to credit sources

	Bank	VICCOBA	SACCOS	Others
Nyeregete	2 (6.1)	2 (6.1)	0 (0)	29 (87.9)
Ubaruku	4 (11.8)	5 (14.7)	1 (2.9)	24 (70.6)
Mwaluma	0 (0)	0 (0)	0 (0)	30 (0)
Total	6 (6.2)	7 (7.2)	1(1)	83 85.6)

Number in brackets are percentages

In general, there is a relatively small number of individuals who access financial facilities among those who can acquire credit from these institutions for different activities including farming and also petty business. The reported financial facilities comprise of both formal including VICOBA and informal financial or local facilities that include village social networks groups and relatives. acquiring credit from Informal financial facilities particularly from relatives and other people in the village was reported to be apparent during the farming season whereby relatives and other community members with high income levels were reported to finance smallholder farmers ranging from TZS 30 000 – 50 000 with an agreement of being paid one bag of paddy (150 kg) during harvesting.

4.4 Membership to Social Networks

Relatively high percentages (73.2) of the households were not linked with community social networks (Table 7). Social networks were regarded to be community or societal linkages or association in the villages with the certain agreed objective. Wollni *et al.* (2010) argue that social network allows and facilitates access to financial services and information transmission among members. Thus through the socialnetwork, small farmers could overcome financial constraints as financial facilities are easy to reach farmers in groups rather as individuals. Apart from facilitating credit access, social networks reduce transaction costs and increase the farmers' bargaining power.

Table 7: Membership to social networks

Parameter	Frequency	Percent
Yes	26	26.8
No	71	73.2
Total	**97**	**100.0**

4.5 Groundwater Irrigation Practice in the Study Area

Small extent of GWI was observed in Nyeregete village that is found in the downstream. Shallow wells including manual drilling wells (dug wells) and also drilled shallow wells were observed to be used both in home gardening domestic purpose and also for livestock consumption. The crops irrigated using GW were mostly found in home gardens and include tree fruits (mango and guava), banana trees, vegetables, onions, and paddy seedlings at Mont Fort Secondary school.

Plate 1: GW irrigation at Mont Fort Secondary School

The GW wells found at the study site were of different sizes and ownership. Both manual and motorised drilling wells were found. Manually dug wells were mostly observed in Nyeregete village where groundwater was reported to be the only source of water not only for domestic consumption but also for livestock as well as for home gardening to a limited extent. The drilling of dug wells were reported to be financed by households themselves. The mean average cost for drilling a dug well was estimated to be TZS 250 000 that includes lined walls with brick and a top cover (made with timber or aluminium) of depth 9-23 meters. Foot driven manual pumps and bucket with rope are the water fetching devices that were observed in this type of wells and their average cost ranged from TZS 500 000 to TZs 20 000. In the case of boreholes, ownership was the public and they have been financed by either the Government or Non-Governmental Organisation or donors. The depth of these wells ranged from 14 up to 100 metres while the drilling cost was estimated to range from TZS 150 000 to 180 000 per meter depth and the preliminary drilling cost that includes survey ranged from TZS 1 000 000 – 1 500 000 depending on the distance between the drilling company and the drilling site. Community boreholes were reported to be used mostly for domestic water consumption while at Mont Fort secondary school a borehole was found to be used not only for domestic water supply for the school compound but also for the livestock unit, fish farm and also for small scale irrigation for an orchard, vegetables and paddy seedlings.

Plate 2 and 3: GW irrigation technologies

4.6 Cost and Benefit Analysis

4.6.1 Short term cost benefit analysis

Table 8 shows the results on the use of both surface and groundwater for irrigation on annual basis. Both SW and GW small-scale irrigation had a positive gross margin of TZS 630 415 and 4 820 415 respectively. However this is highly influenced by crop value, the prices of inputs and outputs and the prevailing market situation. The revealed gross margin implies that the use of both groundwater and surface water for irrigation was able to cover all its associated cost of production.

However, it is worth noting that, highest gross revenue was obtained from the use of GW for irrigation despite the doubled production cost. The possible reason for this may have been the available advantages of using GWI which include the opportunity of having more than one production season per year. The analysis however, ignores the fact that relative profitability per unit area does not necessary imply profitability of the GWI where farmers need to operate economically including investing in high crop value for maximum benefits. From the revealed findings, the use of GWI by smallholder farmers is economically viable. A study by Shah *et al.* (2013) ascertains that GWI is economically worthwhile since it supports dry-season irrigation of smallholder farmers.

Table 8: Profitability of using GW for irrigation

Operation	Parameter	Surface water (TZS/ ha)	Groundwater (TZS/ ha)
Production Cost [a]	(Wet season) **Paddy**		
	Nursery management	40 000	40 000
	Ploughing	162 500	162 500
	Furrowing	162 500	162 500
	Inputs (fertiliser, seeds, and pesticides per acre	296 250	296 500
	Planting	210 000	210 000
	Weeding	165 000	165 000
	Bird scaring	50 000	50 000
	Harvesting	500 000	500 000
	Total cost of production (paddy)	**1 586 250**	**1 586 250**
	Dry season (Onion)		
	Nursery management	NA	60 000
	Ploughing and basin preparation	NA	212 500
	Inputs (fertiliser seeds and pesticides)	NA	1 775 000
	Planting	NA	150 000
	Harvesting	NA	212 500
	Total cost of production (onion)		2 410 000
	Water use fee per year	50 000	150 000
Other cost	O and M [b]	0	2 300 000
	Others total cost	50 000	2 450 000
	Total Production cost	1 636 250	6 446 250
Benefits			
Crop yield (ton/ha/year)	Paddy Onion	4.25 NA	4.25 20
Output price (TZS/ton)		533 333 NA	533 333 450 000
Total revenue (TZS/ton/year)	Paddy 4.25 Onion 20	2 266 665	11 266 665
Gross Margin [c]		630 415	4 820 415

Data represent farm statistics from the harvest of the cropping season 2016

Production cost [a:] Production cost per hectare per season

O and M cost [b]: Operation and Maintenance Cost per year

Gross margin [c:] Total revenue from sale of crop — total cost of crop production

4.6.2 Financial viability of GWI

The depth of the wells used in CBA was adopted from the dug wells and also from motorised wells found in the study area; as per report from the Mbarali District council and from the Rufiji Basin Water Board and also well labels. About 25 dug wells and 5 functioning machinery drilled wells were observed during the survey. Their depth ranged from 9 to 23 for dug wells with an average of 15 meters and 14 to100 meters for machine drilled wells. This study focused on three different types of well depths namely, 40, 50, and 100 meters. This is due to the reason that, the GWI demands for initial capital increases as the well depths increases. Also shallow wells (both dug and machinery drilled wells) were reported to have low recharge capacity and sometimes they dry up completely during the off rain season. As a result a 40 meters well depth was chosen as a yardstick in the analysis of well depth to support small scale GW irrigation due to the empirical evidence observed during case study survey at Mont Fort secondary School where by their 40 meters well depth supports water to the compound for domestics, livestock, fish pond and also small-scale irrigation.

Table 9 shows a summary of NPV, IRR and CBR calculations for 1 hectare of paddy and one hectare of onion. Detailed cash flow calculations are presented in Appendices 4 and 5. As shown in Table 9, the highest NPV was observed while investing in 40 meters depth with the value of TZS 38 636 794, 23 032 915, and 19 807 103 at the discounting rate of 12% 18% and 20% respectively. Likewise, investing in 50 and 100 meter depth had positive NPVs at the same discounting rate although less than that observed when investing in 40 meters deep well. The possible reason for this was due to the increasing cost of drilling as the well depth increases. The business as usual scenario gives the NPV of TZS 4 534 025, 2 947 353 and 2 615 663 which was lower than when investing in GW use for irrigation.

Investing in GWI had positive NPVs at a discounting rate of 12% 18% and 20% per hectare in all adopted well depth; this implies that the present value of benefits stream was greater than the present value of the cost stream. Therefore according to the NPV criterion, investing in GWI by smallholder farmer is financially viable since the NPVs are above zero. Thus, upon decision making process, smallholder farmers' investment in GWI is economically viable. This implies financial viability of GWI by smallholder farmers tend to decrease with the increasing cost of investment.

The BCR was also greater than one and according to decision criteria, projects with BCR which is positive and greater than one are financially viable because the discounted benefits are higher than the discounted costs. The IRR was greater than all the discount rate which was used to compute NPV and BCR, and as a general rule the project with an IRR higher than the discount rate is deemed to be acceptable. The maximum interest rates (IRR) for the investment projects were to recover its investment and operating expenses in its lifetime and to break even.

These results supports to the observation made by Abric *et al.* (2011, Dittoh *et al.* (2013) and Namara *et al.* (2011). In different parts of Sub-Saharan Africa, GW has been developed by many smallholders' farmers because of its low investment that might be affordable by smallholder farmers also the investment was expected to have high return.

Table 9: Summary of the results of Cost Benefit Analysis

Parameter	40 meters deep (TZS/ha)	50 meters deep (TZS/ha	100 metres deep (TZS/ha)	Surface water irrigation (TZS/ha)
Investment	7 800 000	9 437 500	23 000 000	_
Production cost				
Maintenance cost and Operation	780 000	943 750	2 300 000	_
Inputs cost	3 996 250	3 996 250	3 996 250	1 586 250
Water use fee	150 000	150 000	150 000	50 000
Total Production cost	4 926 250	5 090 000	6 446 250	1 636 250
Crop Value	11 266 665	11 266 665	11 266 665	2 266 665
Net Benefit	6 340 415	6 176 665	4 820 415	630 415
NPV at 12%	38 636 794	35 997 029	14 133 330	4 534 025
NPV at 18%	23 032 915	20 879 629	3 045 165	2 947 353
NPV at 20%	19 807 103	17 763 101	833 783	2 615 663
CBR at 12%	6.55	5.27	1.69	-
CBR at 18%	4.48	3.61	1.16	-
CBR at 20%	4.05	3.26	1.04	-
1RR	81%	66%	21%	

4.6.3 Sensitivity analysis

Sensitivity analysis was carried out to test the changes in NPV, CBR and IRR as a result of changes in market prices of variable inputs, price of outputs, and the scale of production. Sensitivity analysis was made for the increase in the production cost, decrease income and reduction in land size. The NPVs at all the discount rates in all developed scenarios were positive when 40 meters deep well was used. Investing in 50 meters well depth, gives a negative NPV at the discounting rate of 20% and in one acre piece of land which was used in production contrary to the NPVs of 100 meters well depth, which were consistently negative at all the discounted rate (Table 10). The CBRs were also greater than one when investment was to made in 40 -50 well depth for scenario one and two with the exception of 50 meters whereby at a discounting rate of 20% meters and reduced area of cultivation to one acre the CBR is less than one. This reflects that the financial viability of GWI by smallholder farmer tend to decrease with an increase capital cost and reduced area of cultivation. The findings imply further that a decrease in the scale of production leads to a decrease in the financial viability of GWI, at such investment in GWI by smallholder farmer should be made at not less than one acre. The maximum IRR was also observed in all the scenarios when the investment was to be made through 40 and CBR was greater than one.

Table 10: Sensitivity analysis GWI

Parameter estimated	40 meters well depth	50 meters well depth	100 meters depth
Scenario 1 :25% Increase in production costs 10% decrease in income			
NPV at 12%	21 676 107.88	18 652 014. 89	-5 560 364.92
NPV at 18%	12 007 582.56	9 604 463. 82	-9 756 766
NP Vat 20%	10 022 542.35	7 756 823. 39	-10 527 440.28
CBR at 12%	4.11	3.21	0.73
CBR at 18%	2.28	2.2	0.50
CBR at 20%	2.54	1.99	0.45
IRR	51%	40%	8%
Scenario 2: 100% increase in production costs and 25 increase in income			
NPV at 12%	23 464 396.48	19 646 920. 81	-11 971 102.86
NPV at 18	13 170 063.57	10 251 204.30	-13 924 080.57
NPV at 20%	11 054 199.76	8 330 781.7	-14,225,772.5
CBR at 12%	4.37	3.33	0.42
CBR at 18%	2.99	2.28	0.29
CBR at 20%	2.7	2.06	0.26
IRR	54%	41%	3%
Scenario 3: Land size for production is one acre **(0.4 ha)**			
NPV at 12%	6 615 647 59	3 975 882.97	-17 887 816.37
NPV at 18%	2 217 496 59	64 211.02	-17 770 253.45
NPV at 20%	1 334 215 77	-709 784.93	-17 639 103.67
CBR at 12%	1.95	1.47	0.12
CBR at 18%	1.34	1.01	0.09
CBR at 20%	1.21	0.91	0.08
IRR	24%	18%	-4%

4.7 Socio-economic Factors Determining the use of GWI by Smallholder Farmers

The analysis of socio-economic factors that influence the use of GWI by smallholder farmers was undertaken using the logit model. The model was statistically significant ($P < 0.001$) as suggested by Omnibus Tests of Model Coefficients (likelihood ratio test), which gives an overall indication of how well the model performs. The results of the logit model are presented in Table 11. This study found that all selected factors affect the decision of the household on the use of GW for irrigation. It further highlight the importance of household size in explaining the use of GWI by smallholder farmer. Households size was statistically significant ($P < 0.05$) and positively related to the use of GWI by smallholder farmers. This implies that, when, the household size increases by one unit, there is an increase in the probability that the households will use GW for irrigation by 38.3% the coefficient estimates (Table 11). The plausable explanation for this situation is availability of adequate labour to be deployed in groundwater small scale irrigation. Furthermore, this finding indicates that an increase in the number of the households leads to an increase in the ability and desire to diversify the available resource for food security and livelihoods support.

Table 11: Logistic regression analysis result

Variable	**B**	**S.E**	**Sig**
Gender	1.181	0.979	0.228
Households size	0.383	0.190	0.043*
Age	0.020	0.30	0.501
Education level	16.224		0.777
Access to financial institution	19.235	10073.519	0.998
Social network membership	1.275	1.163	0.273
Households income level	0.000	0.000	0.777
Constant	-42.232	30063.844	0.999

The findings indicate that the model with descriptors performs better than the null hypothesis. The results show further that the model performance is statistically significant (χ^2 (44.045) = 8, $p < 0.001$). The inferential test for goodness-of-fit, the Hosmer & Leme show (H-L) statistic, indicates that the model fits the data well at $p > 0.05$. The descriptive measures of goodness-of-fit also supports that the model fits the data well (Cox & Snell R^2=0.189; & Nagelkerke R^2=0.388). The descriptor which is statistically significant as the determinant of GW use is: *households size* ($P < 0.05$).

The findings further suggested positive association between gender of the household head and the use of GW for irrigation, male headed household are more likely to use GW for irrigation as compared to female headed household indicating that male headed households are more have more benefits on use GW for irrigation than female headed households. This is because women have less access to resources like land, education and production assets (Ndiritu *et al*., 2011).

The positive relationship between the use of GW for irrigation and age imply that, older farmers are more likely to invest in GW irrigation as compared to younger farmers. This can be associated with their experience for foresee event and also capital accumulation. In term of household income level is positively related to the use of GW for irrigation, suggesting that household with high level of income are more likely to invest in GW irrigation as compared to poor households. This is consistent with findings of study carried out in Ethiopia (Gebregziabher *et al.*, 2013) which found that farmers with limited incomes are reluctant to adopt unfamiliar technologies.

The result also suggest, there is positive association between the uses of GW for irrigation with the farmers linked with farmer's social networks, income level, gender and assets accumulation. This imply the importance of strengthening farmer's formal and informal associations. Finally the findings suggest the use of GW irrigation by smallholder farmers is influenced by farmer's socio economic characteristics includes household size.

4.8 Affordability of Smallholder Farmers to Invest in GWI

Household’s annual income level, asset ownership and access to credit determine ability of the smallholder farmer to invest in GWI. From the study villages income of individual household’s was determined by household farm income and also income from petty business. Income from livestock was also established since livestock were recognised as an important source of income and also as a banking system. Households annual farm income level ranges between TZS 12 000 to 11 670 000 where by almost all surveyed household are practising crop production. About 17.5% of the individual were livestock keeper with the average income of TZS 2 081 300. Further about 80% of the household were not linked with financial institutions. The revealed cost GWI development ranged from TZS 7 8000 000 to 23 000 000. Thus in comparison household’s annual income does not satisfy investment in GWI. This is because of the higher initial cost to invest in GWI relative to household’s income level.

Further, there are social, environmental and economic constraints confronting the development of groundwater for irrigation in the study villages are presented in Table 12. Lack of awareness of using groundwater for small irrigation, distance to the well, lack of capital to investing in GWI facilities and impossibility of groundwater to be used for multiple uses were the major identified constraints in the three studied villages. Other constraints included unsuitability of groundwater for plant growth, land shortage and competition for water with pastoralist. These results are similar to Villholth *et al.* (2013) who argued that in the Usangu plains, the development of groundwater for irrigation can be driven or restricted by socio-economic and policy factors rather than hydrological and environmental factors.

Table 12: Constraints associated with development of GWI

Constraints	**Nyeregete (n=33)**	**Ubaruku (n=34)**	**Mwaluma (n=30)**	**Total (N=97)**
Lack of awareness	19 (57.6)	20 (58.8)	21 (70)	60 (61.9)
Well distance	4 (12.1)	12 (35.3)	2 (6.7)	18 (18.6)
Lack of capital	7 (21.2)	6 (17.6)	2 (6.7)	15 (15.5)
Unaffordability of GW for multiple use	0 (0)	3 (8.8)	2 (6.7)	5 (5.2)
Unsuitability of GW for plant growth	1 (3.0)	11 (32.4)	1 (3.3)	13 (13.4)
Pastoralist competition	4 (12.1)	0 (0)	0 (0)	4 (4.1)
Land shortage	0 (0)	2 (5.9)	2 (6.7)	4 (4.1)

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The study set out to assess whether it is financial viable for smallholder farmers to invest in GWI. Investment in GWI by smallholders farmers was found financial viable when evaluated at 12%, 18% and 20% discount rate. The calculated NPV, BCR and IRR values were positive, greater than one and greater than the discount rate respectively upon decision criteria. The CBA was carried out on 40, 50, and 100 meters depth well and surface water irrigation as a "business as usual" alternative. Investing in GWI in the sampled villages were found to be financially viable when evaluated at a discount rate of 12, 18 and 20. It is therefore worth to invest in GWI by smallholder farmers since the present worth of the benefit stream was greater than the present worth of the cost stream for each alternative depth in the surveyed villages. Furthermore, the findings on profitability analysis revealed that GWI had higher profit than surface water irrigation.

Based on the logistic regression analysis, factors that have influence to GWI in the study area are, household size, gender, income level and membership in social networks. The findings further show that household size has a statistical significance to the influence of GWI at $P < 0.05$. Constraints to GWI were lack of awareness on the potential of GW use for irrigation, long distances to the wells and also lack of capital to invest in GW irrigation. It is therefore a change these factors will have influence of GWI

On the affordability of smallholder farmers to invest on GW use for irrigation the results shows that, a substantial number of households more than 80% were not able to engage on

GW use for irrigation investment. This is due to household's low income, level ranging between 12 000 and 11 670 000 and lack of access to financial facilities contrary to costs for investment in GWI that ranges between TZS 7 8 000 000 and 23 000 000. It is therefore expensive for smallholder farmers to invest in GWI.

5.2 Recommendations

Based on the findings and conclusions, the following recommendations are made:-

i. Strengthening and improving GWI investment

It has revealed that, GWI investment cost is too high for the smallholder farmers which is constraining the development of GWI investment. It is therefore recommended that the government and other development partners participate in development of GWI investment through subsidisation of the drilling equipment and pumps and/or tax exemption of GWI devices. Amendment of policy for the purpose of including guidelines that attach GWI investment is also recommended.

ii. Improving benefits from agricultural crops

GWI investment by smallholder famers is a financially viable as it has high ability to improve smallholders' livelihood through crop production. It is recommended to intensify GWI through inclusion of more valuable crops and value addition of agricultural crops in order to increase benefit to GWI investment.

iii. Strengthening education, training and extension programs

Given that, GWI investment is highly influenced by socio-economic factors such as household size, income level, education and membership to farmer's networks it is recommended to improve of extension services, training programs on ground water use for irrigation such as farm field school and short courses.

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APPENDICES

Appendix 1: Questionnaire for Households survey

FINANCIAL VIABILITY OF GROUNDWATER USE FOR IRRIGATION TO SMALLHOLDERS FARMERS IN USANGU PLAINS, MBARALI DISTRICT, TANZANIA.

Questionnaire No………………..Date of Interview………………………………….

Division……………………Ward……………………………..Village……………….

Interviewer's name………………………………………..

Name of Respondent/ Number……………………………………...

A. Socio-economic characteristics

1. Age of the households head (in complete years)………………………..
2. Gender of the households head………………. [1=male, 2=female]
3. Marital Status of households head …………………………… [1=single, 2=married, 3=divorced, 4=widowed/ widower]
4. Highest grade of school completed ……………………. [1=none, 2=adult education, 3=primary education, 4=secondary, 5= above secondary education
5. Households size..............................
6. Household's composition by age category.

	Below 10	10-17	18-39	40-59	Above 60
Men					
Woman					

7 Occupation of the Households Head

[1] Crop farming [ ] [2] livestock keeping [ ] [3] petty business [ ] [4] Other [ ] specify……………………………..

8. Did your households own livestock? 1=yes ( ) 2=no ( )
9. The amount in numbers per each type of livestock ...…..
10. Average current market value/unit

B: Households' on-farm and off-farm employment and source of income

12 Production costs

Type of crop grown	Cropping season per year	Plot size	Tenure system (Use code 1)	Amount and cost of Seed used - For intercrops use the main crop			Amount and cost of Fertilizer used			Cost of pesticide/ fungicide/ herbicide	Source of labour. (use code 2)	Other non-labour input expense (transport, loading, unloading, etc.))
				Quantity	Unit	Total cost.	Quantity	Unit	Total cost			

Code 1. **(1)** Inherited (2) Bought (3) Receive from the village government (4) Rented (5) Others

Code 2 (1). Hired (2) Family (3) both family& hired

What is the main source of water for the plants in your field?

(1) Rainfall only [ ] (2) Rainfall supplemented with surface irrigation scheme [ ]

(3) Irrigation scheme only (5) Groundwater [ ]

Amount and value of production

Type of Crop grown	What is the main purpose of the crop? 1= Home consumption; 2 = for sale; 3 = Both	How much was harvested from this plot?		
		Quantity	Unit	Average market price/unit

13 What are the major problems do you face in crop production? List if any

14 Off-farm livelihood activities

Livelihood Activity	Did anyone in your households do this activity (1=Yes 2=No)	Total annual income earned while doing this work? Per annum
Employment Self-Employment & Income Generation		
Employment in government organization		
Agricultural labourer on others farm		
Daily labourer on non-farm activities		
Buying and selling crop e.g. paddy		
Selling forest products (firewood charcoal etc.).		
Blacksmithing or metal-work		
Selling drink and food (Food vendor)		
Kiosk		
Remittance from relatives		
Other (specify)		
Other (specify)		

C. Groundwater resource and use

15 What is the main sources of water in the village?

(1)= shallow wells [ ] (2) = boreholes [ ] (3) =others (specify)……………

16 What type of technology/material used for construction?

1=labour (manual), 2=drilling machine, 3=other, specify……………………………

17 Who paid for the construction/digging of the well? And what was the cost?

1=self, 2=government, 3=NGO, 4=community, 5=other, specify……………………

18 What is the well-used for?

1=irrigation, 2=domestic use, 3=livestock, 4=irrigation and livestock, 5=irrigation and domestic use, 6=all, 7=other, specify……………..

19 If the well is used for irrigation, what is the size of land currently irrigated in acres?

And

20 What were the driven factors to use it for irrigation? …………………………

If no

21 What are the restriction factors not to use it for irrigation? ....

22 Method of water abstraction for irrigation

1=diesel/petrol pump, 2=electric pump, 3=solar pump, 4=Rope & Washer pump, 5=treadle pump, 6=bucket, 7=other, specify ……………………………….

D. OTHER INFORMATION

23 Do you have access to a financial facility? (Tick the appropriate)

Bank (NMB, CRDB, FINCA OTHER)

SACCOS

VICCOBA

Some combination of the above.

24 What services are you obtained from a financial facility? ....

25 Are there any local social networks in the village? 1. Yes ( ) 2. No ( )

If yes, what are they?

26 Are you a member?

27 If yes what are the role of the local socio network you're involved too?

THANK YOU FOR YOUR COOPERATION

Appendix 2: Interview guide for Mont Fort Secondary School

When did the school start to utilise groundwater for irrigation?

Why did the school decide to use groundwater for irrigation?

What processes was followed to have borehole? And what were the associated costs?

Who were the drillers?

How much did the drilling cost?

Is there any recovery that has already made since the establishment of borehole? And what are the cost?

What kind of lifting device are you using?

How much did it cost to purchase and install lifting devices?

What kind of daily operations is needed to use a borehole for irrigation? And how much do it cost?

What type of cropsare you irrigating using groundwater?

What size of the farm are you irrigating using groundwater?

What kind of inputs are you using in production?

How much did the inputs cost?

What was the yield per each crop in last seasons?

What was the market price of produce?

Is there any GW charge system? If yes how much do it cost?

THANK YOU FOR YOUR COOPERATION

Appendix 3: Interview guide for Key Informant

1. **Drilling Companies and Rufiji River Basin Officer.**

What procedures needed to drill a borehole? And what are the associated costs?

What is the common size of the borehole in Mbarali District?

How much do you charge to drill per each size?

What are the other costs to accomplish the establishment of the borehole apart from Apart from drilling?

What was the total cost of establishing a well (shallow and deep)?

2. **Extension officer and Community development officer.**

What were the sources of income in the village?

What are the opportunities found in the village?

Among mentioned what is the priority opportunity?

What are the limitations to agricultural development in the village?

3. **Focus Group Discussion**

What were the uses of groundwater in the village?

What are the economic factors to facilitate or/and hinder groundwater irrigation in the village?

What environment concern to hinder or/and to facilitate groundwater irrigation?

Are there any social issues to facilitate the development of groundwater irrigation?

What are the other factors to facilitate groundwater irrigation development in Usangu Plains?

THANK YOU FOR YOUR COOPERATION

Appendix 4: Stream of cost and benefits associated with investing in 100 meters well depth.

Year	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Cost											
Investment	23000	0	0	0	0	0	0	0	0	0	0
Operation and Maintenance	0	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300
Water fee		150	150	150	150	150	150	150	150	150	150
Season 1 (Paddy)											
Nursery management			40	40	40	40	40	40	40	40	40
Ploughing			162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Furrowing			162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Inputs			296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3
Planting			210	210	210	210	210	210	210	210	210
Weeding			165	165	165	165	165	165	165	165	165
Bird Scaring			50	50	50	50	50	50	50	50	50
Harvesting and Transportation			500	500	500	500	500	500	500	500	500
Season 2 (Paddy)											
Nursery Management			60	60	60	60	60	60	60	60	60
Ploughing and Basin Operations			212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Inputs			1775	1775	1775	1775	1775	1775	1775	1775	1775
Planting			150	150	150	150	150	150	150	150	150
Harvesting			212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Season 1 Production cost		1586	1586	1586	1586	1586	1586	1586	1586	1586	1586
Season 2 production cost		2410	2410	2410	2410	2410	2410	2410	2410	2410	2410
Total production cost		6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2
Benefits											
Season 1	0	2266	2266	2266	2266	2266	2266	2266	2266	2266	2266
Season 2	0	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Total Benefits	0	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7
Net Benefit	-23000	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4

Year	11	12	13	14	15	16	17	18	19	20
Cost										
Operation and Maintenance	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300
Water fee	150	150	150	150	150	150	150	150	150	150
Season 1 (Paddy)										
Nursery management	40	40	40	40	40	40	40	40	40	40
Ploughing	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Furrowing	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Inputs	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3
Planting	210	210	210	210	210	210	210	210	210	210
Weeding	165	165	165	165	165	165	165	165	165	165
Bird Scaring	50	50	50	50	50	50	50	50	50	50
Harvesting and Transportation	500	500	500	500	500	500	500	500	500	500
Season 2 (Paddy)										
Nursery Management	60	60	60	60	60	60	60	60	60	60
Ploughing and Basin Operations	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Inputs	1775	1775	1775	1775	1775	1775	1775	1775	1775	1775
Planting	150	150	150	150	150	150	150	150	150	150
Harvesting	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Season 1 Production cost	1586	1586	1586	1586	1586	1586	1586	1586	1586	1586
Season 2 production cost	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410
Total production cost	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2
Benefits										
Season 1	2266	2266	2266	2266	2266	2266	2266	2266	2266	2266
Season 2	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Total Benefits	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7
Net Benefit	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4

Year	21	22	23	24	25	26	27	28	29	30
Cost										
Operation and Maintenance	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300
Water fee	150	150	150	150	150	150	150	150	150	150
Season 1 (Paddy)										
Nursery management	40	40	40	40	40	40	40	40	40	40

Ploughing	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Furrowing	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Inputs	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3
Planting	210	210	210	210	210	210	210	210	210	210
Weeding	165	165	165	165	165	165	165	165	165	165
Bird Scaring	50	50	50	50	50	50	50	50	50	50
Harvesting and Transportation	500	500	500	500	500	500	500	500	500	500
Season 2 (Paddy)										
Nursery Management	60	60	60	60	60	60	60	60	60	60
Ploughing and Basin Operations	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Inputs	1775	1775	1775	1775	1775	1775	1775	1775	1775	1775
Planting	150	150	150	150	150	150	150	150	150	150
Harvesting		212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Season 1 Production cost	1586	1586	1586	1586	1586	1586	1586	1586	1586	1586
Season 2 production cost	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410
Total production cost	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2
Benefits										
Season 1	2266	2266	2266	2266	2266	2266	2266	2266	2266	2266
Season 2	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Total Benefits	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7
Net Benefit	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4

Appendix 5: Stream of costs and Benefits associated with investing in 40 meter well depth.

Year	0	1	2	3	4	5	6	7	8	9	10
Cost											
Investment	7800	0	0	0	0	0	0	0	0	0	0
Operation and Maintenance		780	780	780	780	780	780	780	780	780	780
Water fee		150	150	150	150	150	150	150	150	150	150
Season 1 (Paddy)											
Nursery management		40	40	40	40	40	40	40	40	40	40
Ploughing		162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Furrowing		162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Inputs		296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3
Planting		210	210	210	210	210	210	210	210	210	210
Weeding			165	165	165	165	165	165	165	165	165
Bird Scaring		50	50	50	50	50	50	50	50	50	50
Harvesting and Transportation		500	500	500	500	500	500	500	500	500	500
Season 2 (Paddy)											
Nursery Management		60	60	60	60	60	60	60	60	60	60
Ploughing and Basin Operations		212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Inputs		1775	1775	1775	1775	1775	1775	1775	1775	1775	1775
Planting		150	150	150	150	150	150	150	150	150	150
Harvesting		212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Season 1 Production cost		1586	1586	1586	1586	1586	1586	1586	1586	1586	1586
Season 2 production cost		2410	2410	2410	2410	2410	2410	2410	2410	2410	2410
Total production cost		6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2
Benefits											
Season 1		2266	2266	2266	2266	2266	2266	2266	2266	2266	2266
Season 2		9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Total Benefits		112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7
Net Benefit	-7800	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4

Year	11	12	13	14	15	16	17	18	19	20
Cost										
Investment	0	0	0	0	0	0	0	0	0	0
Operation and Maintenance	780	780	780	780	780	780	780	780	780	780
Water fee	150	150	150	150	150	150	150	150	150	150
Season 1 (Paddy)										
Nursery management	40	40	40	40	40	40	40	40	40	40
Ploughing	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Furrowing	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Inputs	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3
Planting	210	210	210	210	210	210	210	210	210	210
Weeding	165	165	165	165	165	165	165	165	165	165
Bird Scaring	50	50	50	50	50	50	50	50	50	50
Harvesting and Transportation	500	500	500	500	500	500	500	500	500	500
Season 2 (Paddy)										
Nursery Management	60	60	60	60	60	60	60	60	60	60
Ploughing and Basin Operations	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Inputs	1775	1775	1775	1775	1775	1775	1775	1775	1775	1775
Planting	150	150	150	150	150	150	150	150	150	150
Harvesting	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Season 1 Production cost	1586	1586	1586	1586	1586	1586	1586	1586	1586	1586
Season 2 production cost	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410
Total production cost	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2
Benefits										
Season 1	2266	2266	2266	2266	2266	2266	2266	2266	2266	2266
Season 2	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Total Benefits	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7
Net Benefit	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4

Year	21	22	23	24	25	26	27	28	29	30
Cost										
Investment	0	0	0	0	0	0	0	0	0	0
Operation and Maintenance	780	780	780	780	780	780	780	780	780	780
Water fee	150	150	150	150	150	150	150	150	150	150
Season 1 (Paddy)										
Nursery management	40	40	40	40	40	40	40	40	40	40
Ploughing	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5
Furrowing	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5	162.5

Inputs	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3	296.3
Planting	210	210	210	210	210	210	210	210	210	210
Weeding	165	165	165	165	165	165	165	165	165	165
Bird Scaring	50	50	50	50	50	50	50	50	50	50
Harvesting and Transportation	500	500	500	500	500	500	500	500	500	500
Season 2 (Paddy)										
Nursery Management	60	60	60	60	60	60	60	60	60	60
Ploughing and Basin Operations	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Inputs	1775	1775	1775	1775	1775	1775	1775	1775	1775	1775
Planting	150	150	150	150	150	150	150	150	150	150
Harvesting	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5	212.5
Season 1 Production cost	1586	1586	1586	1586	1586	1586	1586	1586	1586	1586
Season 2 production cost	2410	2410	2410	2410	2410	2410	2410	2410	2410	2410
Total production cost	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2	6446.2
Benefits										
Season 1	2266	2266	2266	2266	2266	2266	2266	2266	2266	2266
Season 2	9000	9000	9000	9000	9000	9000	9000	9000	9000	9000
Total Benefits	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7	112666.7
Net Benefit	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4	4820.4