ADOPTION AND IMPACT OF TREADLE PUMP ON FARM PRODUCTIVITY: A CASE OF MBARALI DISTRICT, MBEYA REGION

BY

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ABSTRACT

This study was undertaken with a view of assessing factors determining adoption of treadle pump and how it impacts farm productivity in Mbarali district, Mbeya region. The specific objectives were: to identify factors determining adoption of treadle pump; analysing financial and economic performance; examining relationship between treadle pump adoption and farm productivity; determining whether treadle pump complements adoption of other improved technologies and finally to make suggestions on sustainable usage and dissemination of the treadle pump. Nature of the study was descriptive and exploratory involving both primary and secondary data. Prior to data collection, rapid rural survey was conducted. Purposive and simple random sampling techniques were employed to get adopters and non-adopter of treadle pump. The study employed Probit model, Cobb-Douglass production function, Chi-square and gross margin as analytical tools for addressing the specific objectives. Analytical results showed that, household size and presence of male members in a household have a positive influence on adoption of treadle pump. Such an observation reflects labour intensity of the treadle pump where the technology is more suited to man. On the other hand increased education, age and income reduce the chances of adoption. At farm level, treadle pump contributes to farm productivity and has positive gross margin. Results indicated that, adoption of treadle pump has complemented adoption of insecticide used at farm level. From the survey, treadle pump is associated with vegetable grown year round and agro-pastoral farming system. From the study findings it is recommend that, manufacturing of the treadle pump be improved to avoid gender biasness associated with the present model, which is labour intensive. Current distribution channel should be improved to insure that, product reach the end users. The project should be replicated to other areas with similar conditions and need of addressing poverty. Policy makers should recognize and orient resources towards the technology as one with potentials of improving crop production and alleviating poverty among the smallholder farmers in Tanzania.

DECLARATION

I, Nassoro Nzao Hussein do hereby declare to the senate of the Sokoine University of Agriculture that the work presented here is my own original work and has not been submitted or concurrently submitted for a degree in any other university.

Signature................

Date......15/03/2006

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TPC	=	Tanzania Planting Company
Km	=	Kilometre
FAO	=	Food and Agriculture Organization
URT	=	United Republic of Tanzania
SMUWC	=	Sustainable Management of Usangu Water Catchment
Ha	=	Hectare
DED	=	District Executive Director
WWF	=	World Wild Fund
NGO's	=	Non Governmental Organizations
DAAD	=	Germany Academic Exchange
TANESCO	=	Tanzania Electrical Supply Company
NGO	=	Non Government Organization
SWMnet	=	Soil Water Management network
IFPRI	=	International Food Policy Research Institute
TARPII	=	Tanzania Agricultural Research Phase II
SUA	=	Sokoine University of Agriculture
IDE	=	International Development Enterprise

CHAPTER ONE

1.0 INTRODUCTION

Reliance on rainfed agriculture has frequently placed Tanzania at negative balance in food requirement and deprived foreign earning from exports of a range of agricultural products. Bad weather condition lead to crop failure resulting in food shortage and generally intensify poverty. Some of the short-term strategies adopted to deal with the situation include food importation and emphasise on growing short-term drought resistant crops such as sorghum. Bank of Tanzania, monthly economic review (2004) suggest that despite the fall in total imports of food and foodstuff, maize import increased by more than three folds from 8500 tons to 30,000 tons reflecting food shortage.

However government recognises that the economy will continue to depend heavily on agriculture at least in the foreseeable future (Kalinga *et al.*, 2001). This indicated in government of Tanzania report (2005), which suggests that, Tanzania's economy cannot reach growth rate of 8-10 per cent per annum, the rate needed to have a lasting impact on poverty, without significant investment and improvement in agriculture. The Tanzania development vision (2000), stipulates that, by year 2025,the economy will have been transformed from a low productivity agricultural economy to a semi-industrialized one led by modernized and highly productive agricultural activities, which are effectively integrated and buttressed by supportive industrial and service activities in the rural and urban areas. Agricultural growth spreads its benefits widely. Growth in incomes of the farmers and farm labourers create increased demand for labour and non- farm products and services (FAO, 2002).

However agricultural development cannot be achieved under the prevailing situation of relying on erratic rainfall. The critical factor to agricultural growth is irrigation (URT, 2005). And further that, no matter what else we do to improve agricultural performance, we cannot attain food self-sufficiency without overcoming problems associated with the fickleness of weather. In addition to food security, irrigated agriculture significantly contributes towards generating rural employment and maintains rural livelihoods (Shah *et al.*, 2000) and therefore generally contributes towards poverty reduction.

1.1 Development of irrigation sub-sector in Tanzania

Initial investment of the government in irrigation started with large-scale scheme. The first irrigation scheme to be constructed was TPC Moshi, in 1930, for sugarcane production. Other large irrigation schemes were constructed thereafter such as Kapunga, Mbarali, and Lower Moshi to mention just few. FAO (1998) suggests that, most of the initial investment in irrigation in the 1960's and 1970's were directed towards large –scale irrigation development involving the construction of large scale hydraulic structures irrigating thousands of hectares of land, often combined with hydropower generation. Despite heavy investment, these irrigation schemes have not realised the proposed benefits. Kalinga *et al.* (2001) reported that, the performance on operation and maintenance of all irrigation schemes has been below the expected levels. Competition for water across sectors is among factors hindering good performance of the irrigation sub-sector. Costs of irrigation are growing rapidly and even more complex irrigation structures are required to mitigate decreasing water resources. To overcome constraints in government-managed scheme, a policy of disengagement has been promoted to transfer management from direct control towards a limited government involvement and put farmers in charge of operation and maintenance (FAO, 1998). Much emphasis has been placed on small-scale irrigation as an option. To reduce costs and raise rural living standards through irrigated agriculture more rapidly, small-scale irrigation has been increasingly recognised as a valid and attractive option in irrigation development (FAO, 1998). URT (2005) reported that, irrigation, especially, simple and small-scale irrigation systems are the key to food security and improved yield. Among the outputs of the irrigation master plan is to come up with specific recommendation on irrigation development with particular emphasis on smallholder irrigation schemes using low cost appropriate technology. Such emphasis depicts that benefits are expected to be achieved from the small-scale irrigation.

1.2 Importance of small scale irrigation

Small-scale irrigation is seen as one of the success stories in many African countries, at a time when large-scale development has failed to come up to expectation (Kay and Brabben, 2000). To reduce costs and raise rural living standards through irrigated agriculture more rapidly, small-scale irrigation has been increasingly recognised as a valid and attractive option in irrigation development (FAO, 1998). Smallholder irrigation is used to emphasize the fact that target group for irrigation development is farmers with limited means. In this case, technological development is crucial however; it should be adapted to their conditions.

Small-scale irrigation was recognised and practiced by farmers ever since. This type of irrigation is characterized by use of simple, relatively cheap technologies and affordable to smallholder farmers. Small scale water management approaches for strategic supplementary irrigation designed to increase water availability at root zones and to increase plant uptake coupled with proper management of the soil, use of fertilizers, and tillage were identified as doable options (SWMnet, 2004).

Some of these technologies are environmental friendly; provide irrigation access to farmers under a situation of water shortage. As such, include technologies for control, storage, diversion and distribution of water and may include river diversion, small dams or reservoirs, small pumps, well drilling techniques, water harvesting and drainage improvements (FAO, 1998). Small-scale irrigation has different definition in different places, in some areas referred to as minor irrigation or micro-irrigation.

1.3 Introduction of treadle pump in Tanzania

Over the past decade, small but significant revolution has been taking place in small-scale irrigation in the developing world with the introduction of the treadle pump (Kay and Brabben, 2000). The pump is expected to have a significant contribution particularly in Africa, where the cost of buying, operating and maintaining a motorized pump are so high, beyond the reach for most smallholder farmers.

In contrast to smallholder schemes of the past that relied on agencies or farmers ability to co-operate to share water and organise the management and maintenance aspects of the scheme, the manual pump can be owned, operated and managed by a household or individual. Because treadle pump reduce the time taken for irrigation, some farmers now hire out their pumps, though to a limited extent, as they fear breakdowns caused by carelessness. This why group ownership of the pump is socially unacceptable. Individual ownership is mostly preferred (Kay and Brabben, 2000).

Telefood (2002) report, suggest that in Zambia growers have doubled their cropping area and introduced new varieties like tomatoes, cabbage and onion. Women in particularly profited from the technology, being able to better feed their families, while generating additional income. Shah *et al.* (2000) report on eastern India, pointed out that, for a marginal farm in this region with US$ 12-15 to spare, there could hardly be a better investment than a treadle pump, which has a benefit –cost ratio of 5, an internal rate of return of 100 percent and a payback period of one year. Social –culturally, some farmers are slowly changing their cultural calendars of resting and attending to traditional ceremonies in the dry season, as they have to grow crops throughout the year. Irrigated crops have proved to be more profitable than rainfed farming, so some farmers are beginning to abandon rainfed maize in preference to horticultural crops (Kay and Brabben, 2000).

In Tanzania, non-governmental organizations have been motivated to promote the technology and generally regard it as a poverty reduction tool. Enterpriseworks and Approtech provide an example of non –governmental organizations promoting the use of the treadle pump. Among the area in which the technology has been promoted is Mbeya region, particularly Mbarali district. The district is within the Usangu plan, where water is received the highlands and thereafter the area acts as a source of water for domestic, livestock, wildlife, irrigation and generation of electricity in Mtera and Kidatu. Mbarali is characterized with relatively very low rainfall (semi arid area) and increasing pressure on water resource. The overall situation is described as a stumbling block towards achievement of the national goal of poverty reduction. Introduction of treadle pump has an objective of providing smallholder farmers with an opportunity of mitigating the drought condition by accessing the little water available, increase crop production and thus improve their livelihood.

Treadle pump is used to irrigate crops from different water sources such as river, different types of water reservoir and underground water (from shallow aquifer). Mtei (2004) reported that, in order to escape from the poverty trap, not only should we devise policies and create environment to rapidly commercialise agriculture and make it profitable, but the small scale farmer must be assisted to adopt technologies that will increase his acreage and production as well as improve his productivity and the quality of his produce. Using treadle pump, smallholder farmers can produce high value crops for local and distant markets, or produce food during the dry season and thus increase household incomes and improve livelihood security. Adoptions of small-scale irrigation technologies have a direct or indirect link with poverty reduction (Shitundu and Luvanga, 1998). Treadle pump could create employment in supplying raw materials, manufacturing, marketing and operation of the treadle pump at the farm level.

1.4 Problem statement and justification

Productivity in rainfed agriculture is much lower than that of irrigated agriculture and also displays larger annual variations. Thus food production necessary to meet population increase in the near future will inevitably have to depend heavily on production from irrigated agriculture (Osamu *et al.*, 2002). However decreasing water resources coupled with increasing water demand for industrial, household, agriculture and wildlife calls for increased efficiency in water use. Several low cost micro-irrigation and a series of other low cost technologies related to small scale micro-irrigation like treadle pump have a good potential to allow a large number of smallholder farmers to access scarce water resource and utilize efficiently.

Many claims have been made about the benefits of the treadle pump technology, it self select the poor, it is easier to install and operate and its benefit –cost ratio is high. Treadle pump users are able to grow a wider menu of crops, cultivate their land more intensively and increase their cropping intensity and crop yield (Shah *et al.*, 2000). Such benefits prompted introduction of the technology particularly in Mbarali District, which is within Usangu plain. Water flows from Usangu plain have always been very small, and in some years would dry up (SMUWC, 2001). This situation presents an impediment towards the poverty reduction efforts of the Mbarali district dwellers. Therefore treadle pump technology was introduced with the assumption that, farmers will adopt the technology and be able to mitigate dry condition and hence enjoy benefits such as those recorded elsewhere it was introduced. However though still promoted, very little is known as to whether the proposed benefits have been realised or not. Since its introduction in Tanzania, treadle pump has received less attention in terms of research.

Study done by Shah *et al.* (2000) found out that, in India abundant family labour was crucial requirement for adoption and, a prior, we should expect labour –surplus families to embrace treadle pump technology than others. The fact suggests, that there are certain crucial factors necessary for adoption. Knowledge on those factors influencing adoption is important in designing an appropriate promotion program.

Due to management constraints and limited capacity to mobilise resources, smallholder adoption will and probably should be incremental and gradual given the need to ensure food security and reduce risks (Kisusu, 2003). It's from this ground, a study was proposed to assess factors determining adoption of treadle pump and identifies how the technology impacts. farm productivity. The study is in line with existing policy of poverty reduction and findings will help farmers, researchers, policy makers, and extensionist. Output for this work will provides future input in national irrigation policy formulation.

1.5 General objective

To assess factors determining adoption of treadle pump and how it impacts farm productivity.

1.6 Specific objective

(i) To identify factors determining adoption of treadle pump in Mbarali district

(ii) To analyse the financial and economic performance of the treadle pump

(iii) To examine the relationship between treadle pump adoption and farm productivity

(iv) To determine whether treadle pump complements adoption of other technologies

(v) To make suggestions on sustainable usage and dissemination of treadle pump

1.7 Hypothesis

From the aforementioned objectives the following hypothesis were tested:

i) Factors other than farm, household, technological and institutional influence adoption of treadle pump.

ii) There is no relationship between treadle pump and adoption of other improved technologies.

iii) Treadle pump is not economically viable to smallholder farmers.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Irrigation

Irrigation (in agriculture) is the replacement or supplementation of rainfall with water from another source in order to grow crops. Kay (1983) in Juma (2000) defined Irrigation as the artificial method of applying water for supplementary rainfall, to improve crop yield. The primary objective of irrigation is to increase agricultural production, make it possible to cultivate areas with little rainfall and stabilise water supply in regions containing variations of rainfall. There are various ways of delivering (irrigation) water to the plant root zone. Various types of irrigation techniques differ in how the water obtained from the source and distributed within the field. In general, the goal is to supply the entire field uniformly with water, so that each plant has the amount of water it needs, neither too much nor too little. Such ways are termed as irrigation systems. Different systems have different efficiencies of delivering water to the plant.

2.2 Water situation and development of irrigation sub-sector

The importance of water for crop production and the development of mankind in general are obvious. Water is important for food production not only because of its direct effects on yields and cultivated area, but also because reliable, water supplies induce farmers to invest in other essential crop inputs such as improved germplasm, fertilizers and capacity building for better resources management(Rosegrant *et al.*,1997, as cited by Sindi, 2004). Water scarcity has been experienced in many places due to unreliable rainfall multiplicity of competing uses, degradation of sources and catchments. All these have led to water user conflicts between sectors of the economy (Sindi, 2004). A situation where water is diminishing, is posing a challenge to the development of irrigation and the overall agricultural sector. With a growing population, agriculture will face more competition from industrial and domestic water users. This is why agriculture will have to use water more efficiently (FAO, 2003). When looking at the issue of water scarcity, there comes a need for considering the new approaches in irrigated agriculture, termed modern irrigation (Mbogo, 2001). Investments for smarter water-saving agricultural practices and better water management are urgently needed. In a situation where large irrigation schemes have failed to discharge the expected goal, much emphasis has been placed on small-scale irrigation. According to FAO (1998), specific aims of small-scale irrigation may be defined as to increase smallholder productive capacity and to improve household food security by up grading and expanding cultivated areas under improved control of water resources.

2.3 Irrigation in Tanzania

Tanzania has a very large irrigable land for farming, out of which only a small coverage is utilized (Mkavidanda and Kaswamila, 2001). The potential for irrigation development has been estimated at an over 1.0 million hectares, based on the soil and water availability – that is 2% of the available arable land. An exact figure about the total area under irrigated agriculture is not known, however it is estimated to be between 106,000 to 150 000 ha. And that medium to large schemes make up the balance, ranging from 20 000 to 50 000 ha (Asenga and Mero, 2001). Mrema (1984) in Mkavidanda and Kaswamila (2001), pointed out that ,irrigation farming in Tanzania can be grouped in three main categories namely, traditional smallholder irrigation owned by individual or groups of farmers, who have attempted to harness the available water from rivers, springs, and large river floods plains. The second category is the modem small-scale holder /village irrigation schemes, normally planned and constructed by the central or local government. The last category is large-scale irrigated private/public farms. Lack of capital, low technological level and high maintenance cost of large irrigation schemes for majority of rural farmers in Iringa and Tanzania in general, necessitates the need to look into the potential for traditional irrigation practices in increasing agricultural production and alleviating poverty (Mkavidanda and Kaswamila, 2001). In 2001, government of Tanzania, through Ministry of agriculture and food security, had a strategy of developing small-scale irrigation scheme, covering 98 600 ha of land, rain water harvesting programmes covering 27 600 ha of land and rehabilitation of traditional irrigation schemes covering 82,200 ha (URT, 2005).

Nearly all irrigation activities are based on surface water coming from rivers, stream, and springs. Technologically, we having been basically, relying on this type of irrigation in almost all schemes, whether traditional or improved. Only few modern farmers are irrigating using drip or sprinkler irrigation system. Apart from those, other irrigation technologies used in Tanzania, includes hosepipe, bucket, trench, motorized pump, etc. Generally there has been little public investment on development of irrigation technologies despite the advantages they carry. Agricultural and industrial sectors are disjointed; this is manifested in different form. Among is the situation where parts, which could be manufactured locally, are imported, the fact, which hinder development of basic industries, design and technology.

Irrigation in Sub-Saharan Africa is in the great majority of cases performed using a rope and bucket (or other traditional means) to raise and distribute water from a shallow open well (Perry and Brian, 2004). Systems such as drip or sprinkler are may be very ideal system appropriate for large-scale farmers. To smallholder farmers such systems are unaffordable, unless in a situation where there is public investment directed to assist them.

Therefore absence of affordable and productive irrigation technology, seriously hinder smallholder farmers' efforts to increase crop production and expand irrigated area. Manufacturing of simple irrigation equipments, which are affordable and adaptable to smallholder farmers' situation should be encouraged, as this could provide a beginning towards building up a capital goods industry for more technically complex products. Kalinga *et al.* (2001) reported that, many farmers would benefit from low –cost techniques more suited to their conditions needs and which also ensure an improved water use efficiency and conservation.

2.3.1 Treadle pump

This is a foot operated devise, which is used to pump water from shallow aquifers or shallow depth from any water source such as pond, tank, canal, or catchments basin or from tubeless up to a maximum height of 7 meters (Shah *et al.*, 2000). The technology was firstly developed in Bangladesh by International development Enterprise, in its attempt to improve agricultural productivity after an initial surge in yields and total farm production. The technology was introduced in the so-called poverty square comprised of the Nepal, India and Bangladesh. The region, which contains of the world's poorest people, has one of the world's most remarkable ground water resources available at a depth of 1.5- 3.5 square metre (Shah *et al.*, 2000).

By changing from it being operated by arms and hands to feet and legs, operation of this devise has been simplified. Because the muscles are powerful capable of lifting much more water. In most African countries, improved water lifting technologies are currently limited to motorized pumps. While these pumps may be appropriate for large-scale farmers, they are unaffordable and uneconomical for majority of farmers who irrigate relatively small plots of land. In the absence of affordable, more productive equipment to increase irrigation capacity, typical farmer in Africa is seriously handicapped in efforts to boost production through larger irrigated surface area and greater yields (Perry and Brian, 2004). The process of technological transformation may be undertaken relying on the design, testing, upgrading and developing indigenous technology or by augmenting local technology with imported technology in a complementary way (Semboja, 1990). Manufacturing of the pump is simple in the sense that, it requires locally available raw materials and can be manufactured in simple metal workshop.

2.3.2 Advantages of the treadle pump

The technology though can be shared, but it is mostly individually owned and used. The cost is relatively cheap, a privilege to smallholder farmers whom majority are poor and therefore can hardly afford motorized pump. Motorised pumps provides a next step technology for treadle pump users who have raised their revenue sufficiently to graduate to a greater level of productivity and technological sophistication (Enterpriseworks, 2003). Other envisaged benefits of the treadle pump includes, increased land area under irrigation, reduced work time compared with bucket irrigation, fully irrigation of fields, resulting in improved crop quality and reduced frequency of irrigation to two or three times per week.

2.3.3 Types of treadle pump

Generally there are two types of treadle pump, namely suction and pressure pump. The two types of the treadle pump were developed with different purposes. The suction pump is for lifting water from a shallow water source and discharges it over a spout into a canal (trench) to facilitate gravity irrigation. The pressure pump is basically operating with the same principal, only that the delivery end is designed such that water .can be fed under pressure. It is also better at lifting water from deeper sources than the suction pump (Kay and Brabben, 2000).

2.4 Productivity

Given the limitation of traditional resources namely land and labour along with the high cost of incorporating these resources in the production process it is apparent that increased factor productivity through technological improvement is a crucial for the development process (Romano, 1987, as cited by Isinika, 1995). Technical change should accelerate growth in productivity. Productivity refers to the relationship between inputs, such as labour, capital and natural resources, measured in real terms based on the concept of production function. And further that, a production function can be expressed in a mathematical relationship between the output and various inputs. Productivity is a measure of efficiency in resource use or technical efficiency. Higher agricultural productivity comes from two main sources, the use of additional input and higher productivity resulting from improved technology (Isinika, 1995).

2.4.1 Measuring productivity

Productivity can be measured using a number of ways. The approaches to productivity measurement in literature range from the Cobb Douglass functions, linear programming, indexes based on the Translog Transformation function, the Divisia index, Laspeyers quantity index and many other econometric transformations based on modern production theory (Nabbumba and Bahiigwa, 2004). However the simplest measure is the ratio of output to a single input such as land productivity (yield per hectare). Though easy to compute however could mislead as it takes into account of only one input instead of mult-inputs.

Hussain *et al.* (2000) used both Cobb-Douglass and Data envelopment analysis to measure productivity as yield per hectare for maize and litres of milk per lactating animal. Isinika (1995) used Cobb-Douglass function to study the effect of agricultural research expenditure on agricultural productivity in Tanzania. The choice of method to use has generally depended on the nature of problem being addressed and the available database (Nabbumba and Bahiigwa, 2004). Hussain *et al.* (2000) used Cobb Douglass production function based on algebraic signs, plausibility of estimated parameters and their statistical significance.

2.5 Adoption

One would think that development of appropriate technology is a sufficient criteria of considering the existing to problem to have been solved, however that is only a step towards approaching a solution for the problem. Once the technology is adopted then, the existing problem may be solved. Adoption of innovation is defined as a decision to apply innovation and continues to use it (van de Ban and Hawkins, 1988). Rogers (1983) defined the adoption process as the mental process through which an individual passes from first hearing about an innovation to final adoption. His definition contains four elements, which are: (1) Innovation (2) communication (3) time (innovation decision process. time for one to adopt, innovator's rate of adoption) (4) social system a set of interrelated units that are engaged in joint problem solving to accomplish a common goal. Willingness to change and desire to try new ideas are the main cause of innovative behaviour.

2.5.1 Factors determining adoption of a technology

Lugendo (2003) considered age, gender. education and income as important variables determining adoption. On technological issue he pointed out that farmers make decision to adopt technology based on benefit consideration and will adopt new technology if the benefit of new technology exceeds the old one. The role of institutions in influencing adoption cannot be ignored, such institutions include, credit institution, marketing organizations to mention just few.

2.5.2 Household characteristics

Large families tend to be more likely to adopt new technologies, as there is a greater availability of labour to carry out additional work or use it for reciprocating other goods and services. Farming experience and age also plays a role. Generally, older people have more experience, but their receptivity to new ideas and techniques typically decrease with age (Steel, 1995). As one gets older the chances of taking a new innovation normally decreases. Young and energetic people have proved to be more venturesome, active and ready to try innovations (Nanai, 1993). Older people have more experience but their receptivity to new ideas and technologies typically decreases with age (Steel, 1995). Probably aging is associated with development of fair and or lack of trust on what ever comes as a new technology or idea.

Hella (1992) found out that, age of respondents was one of the factors influenced the adoption of hybrid maize seed in Iringa region. And that, adoption of hybrid maize seed was high among farmers aged between 26-50 years and recommended that efforts should be directed to that age group if the hybrid seed was to be adopted. However in certain situations, particularly in rural areas, young people cannot readily accept new ideas before their elders have accepted it.

2.5.3 Income

Wealth and innovativeness vary together. That is there is a cause and effect relationship, such that people innovate because they are rich and become rich because they innovate (Rogers and Showmaker, 1971). Though there is no definition of a richer person, however suffice to say that, innovations are associated with income. Development of technology has a cost outlay; therefore for one to adopt the technology ought to have some money or anything to offer for exchange. In this respect, income becomes important factor influencing one to take new technology. Rogers and Showmaker (1971) reported further that, only the wealthy units in a social system may be able to adopt these innovations. Lack of capital is many times cited as a major factor in adoption of different technologies, especially when the amount of finance required is relatively high. Many times farmers with more resources in the form of land, labour or capital, are able to take advantage of new technologies and practises (Msuya, 1998).

2.5.4 Education

Education provides people with the potential to learn, to respond to new opportunities, to adjust to social and cultural changes and to participate in the political cultural and social activities (World Bank, 1980). Education can make a farmer more receptive to advice from an extension worker or more able to deal with technical recommendations that require a certain level of numeracy or literacy (Matijo, 2001). This is because information is transmitted in the form of written materials. Therefore those with the ability to read and write stand a better chance of adopting. Rogers and Shoemaker (1971) reported that; earlier adopters are more likely to be literate than late adopters. Therefore farmers' education is an important factor in determining the readiness to accept and apply an innovation.

2.5.5 Gender

The introduction of new techniques into rural sector is not one-day activities. Traditional methods rooted and form an integral part of the agriculture, which binds the community together. In most rural societies the social status of women is inferior to that of men. Due to this, they become a disadvantaged group especially when it comes to the introduction of new technologies and practices in their areas (Shayo. 1990). In most cases development of technology may be gender neutral, however it's introduction to the society often end up becoming a gender biased. Evidence from Tanzania shows that it is difficult for extension agents to hold meetings or address female farmers freely (Msuya, 1998).

2.5.6 Environmental characteristics

Edaphic and climatic factors play an important role in adoption of technologies. A farmer who is close to river or any other water source may decide to adopt certain irrigation technologies. The possibility of drought or flooding makes farmers worry about investing in some technologies and practices (Msuya, 1998).

2.5.7 Measuring adoption

Adoption can be considered in two different approaches, one is a situation whereby either one has taken a particular innovation or not. A second situation is that of considering adoptions inform of a rate e.g. size of land under cultivation.

2.5.7.1 Probit model

This is an estimating model that emerges from the normal cumulative distribution function, sometimes referred to as normit model. The logit model uses the cumulative logistic function but this is not the only cumulative distribution function (CDF) that one can use. In some applications the normal CDF has been found useful (Gujarat, 1995). The two approaches are used when the dependent variable is dichotomous. The chief difference between the two is that the logistic has slightly flatter tail, than the normal or probit curve. Also their parameter estimates are not the same. The reasons for this is that the variance of standard variable (the basis of probit) is one, where as the variance of the logistic distribution (on the basis of logit is $\Pi^2/\sqrt{3}$ (Gujarat 1995).

$$p = pr(y=1) = pr(1i \leq 1i) = F(1i) = \frac{1}{\sqrt{2\pi}} \int_{-\sigma}^{I i} e^{-t^2/2} dt$$

2.6 Economic performance

Evaluating the performance of a project requires the consideration of social as well as economic aspects. Various studies have adopted economic approach to examine impact of development projects (TARP II –SUA, 2001). The strengths of economic analysis approach are those, that encourage the use of policy decisions that are based on quantitative assessments (Van de walle, 1998). In evaluating the performance of Mwea irrigation scheme, a social benefit-cost analysis of the scheme was carried out. Bariwa (20001) used benefit cost ratio as a criterion for evaluating the performance of Dakawa rice farms. Audice (1996) suggested that, economic analysis is related to the profitability of the project in question as a whole, while financial analysis explores the profitability from the standpoint of the entrepreneur or the firm, which undertakes the project. Generally economic approach uses measures like benefit –cost analysis, economic surplus models, economic efficiency estimation and gross margin or gross profit. The benefit- cost ratio is obtained when the present worth of the benefit stream is divided by the present worth of the cost stream. A project displaying benefit cost ratio less than 1, suggest that the present worth of the cost at a particular discount rate have exceeded the present worth of the benefits and therefore such a project is not worth undertaking.

The formal selection criterion for the benefit -cost ratio measure of project worth is to accept all independent projects with a benefit-cost ratio of 1 or greater when the cost and benefit streams are discounted at the opportunity cost of capital (Gittinger, 1984). The computation of benefit -cost ratio doesn't use gross benefit and gross cost, but rather the present worth of net benefit and the present worth of investment costs plus the operation and maintenance cost. According to Gittinger (1984), project economic cost is the sum of installation costs, operation, maintenance, and replacement cost, and induced costs.

Benefit and cost calculations were applied to the production of paddy under two large irrigation farms in Tanzania, namely, Kapunga and Madibira. It was concluded that the success of the large farms would depend on above all on the availability of technical and managerial skills and on a correct assessment of water availability. Though the calculations were only indicative they strongly concluded that the scheme would be socially profitable subject to the above issues being resolved satisfactorily (Bariwa, 2001). Kisusu (2003), used gross margin approach when evaluating adoption and impact of dairy and irrigated rice technologies on poverty alleviation in Dodoma. And suggested that, although all methods are used, the common and simple one is gross margin analysis, which is sometimes known as gross profit analysis. And the merit of gross margin includes enabling assessment of profitability of most economic activities. Gross margin analysis is easy to compute, it can be understood and it shows the relationship between the economic and technological parameter. However it carries the disadvantage as well, in the sense that, it neglects the fixed cost structure and it does not make allowance for complementary and supplementary relationship between enterprises (Kisusu, 2003).

2.7 Chi-square

Chi Square is a non-parametric test of statistical significance for bivariate tabular analysis. Bivariate tabular analysis is used when you are trying to summarize the intersections of independent and dependent variables and understand the relationship (if any) between those variables (Linton, 2001). Chi-square was used to determine whether there was a significant difference between farmers with and without SG-2000 credit in terms of adoption of wheat technologies (such as fertilizer, herbicides, improved seed and cultural practices (Mlambiti and Isinika, 1999). Matijo (2001) used Chi-square test to analysis whether there was any association between source of seed and adoption of 15% NACL solution, of which he found no statistical significant at P $\leq$0.05 level.

2.8 Factor analysis

Factor analysis is a generic name given to a class of whose purpose often consists of data reduction and summarization (Paul *et al., 1988*). Joyce *et al.* (1995) defined factor analysis as a set of models for transforming a group of variables into a useful form. It is rarely provided in theory that things like love, risk, altruism or creativity can be measured directly. Unlike variables such as weight, temperature, humidity, etc, that can be measured using instruments and in units e.g. kilograms, degree, centigrade etc. The above named variables cannot be measured directly; one can look at them as unifying constructs or labels that characterise responses to a related group of variables (Senkondo, 1999).

Many of the concepts often used to describe human behaviour seem to consist of a number of different aspects. Factor analysis is used as a tool for bringing order to the way we see things by determining which of them are related and which of them are not (Joyce *et al.*, 1995). The latent variable approach has been widely used to capture socio-economic or psychological variables which are linked to economic analysis. To measure things such as love, risk, attitude, altruism etc, there is a need for constructing some type of measuring device, usually a scale or test composed of a variety of related items (Senkondo, 1999). Physical attributes of a product such as its appearance are capable of influencing perception of it. Most definitions seem to agree that an attitude is a state of readiness, a tendency to act or react in a certain manner when confronted with certain stimuli. Thus, the individual attributes are present but dominant most of the time they become expressed in speech or other behaviour only when the object of the attitude is perceived (Oppenheim, 1966). Smidts (1990) applied the latent variable technique in analysing marketing strategies.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Conceptual framework

Increase in farm productivity lead to improved household income. Income level is used to describe the level of poverty experienced by a household. Therefore impacts of improved incomes on poverty alleviation are supposed to be reflected in the changes in individual's welfare explained by increased assets, food security, health etc. One way of improving farm productivity is through application of productivity enhancing technologies. Most rural development projects, aim at improving the livelihood of people through different approaches. One of the approach include introduction of improved irrigation technology. However, farmers may decide to adopt or not to adopt. As such, adoption of the technology is influenced by several factors such as institutional, household socio-economic, farm and technological factors. In a situation where the technology has been adopted, other improved technologies may be adopted as well. The combination of which contribute to increased farm productivity and hence improved living standard.

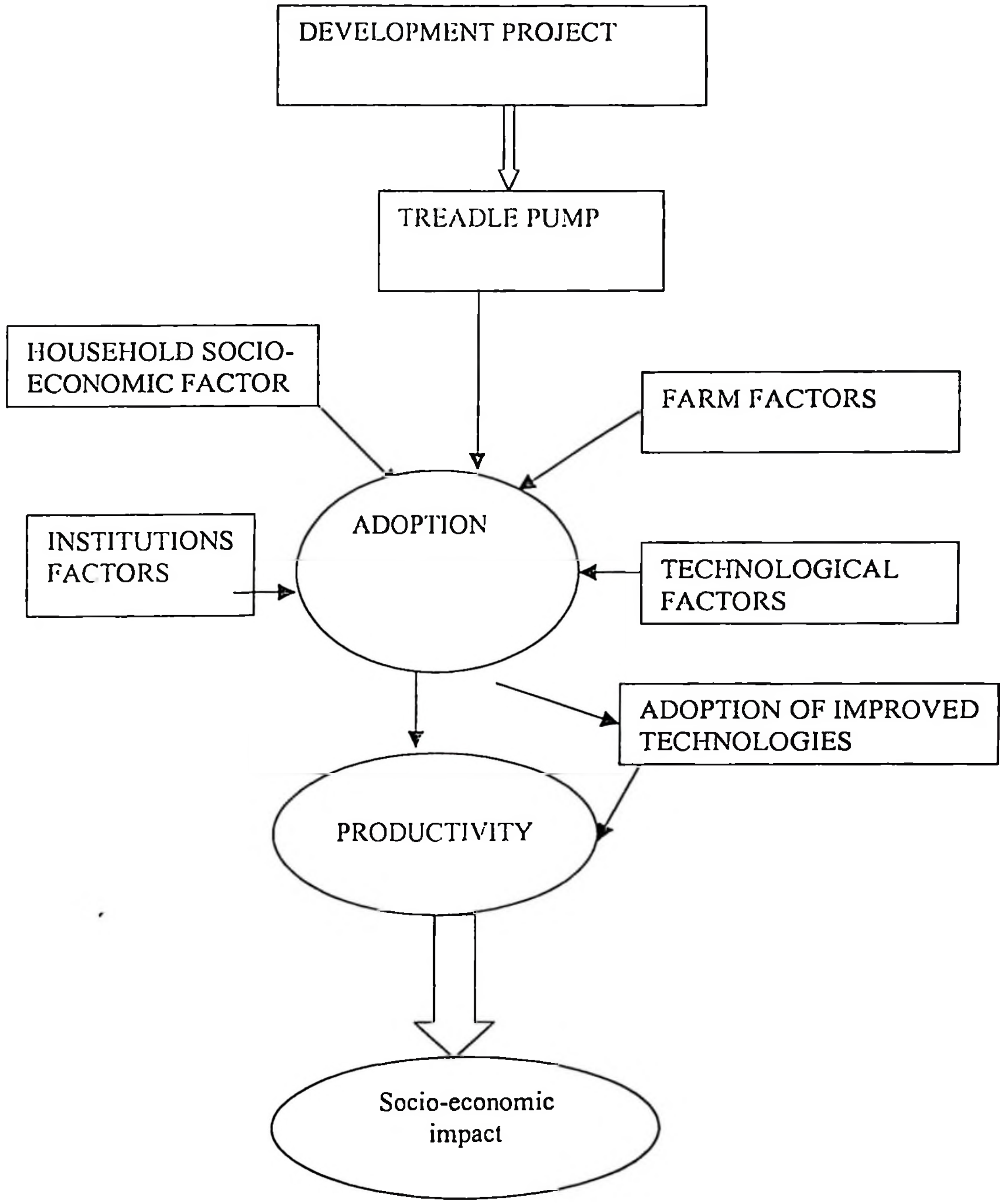

Figure 1: Conceptual Framework

Source: Modified from Kisusu, 2003

3.2 Location of study

The study was conducted in Mbarali district. The Mbarali district lies between latitude 7 and 9 south and longitude 33.8 and 35 east. It borders Chunya district on northern side, northeast is Iringa rural district, northwest it borders Mbeya rural, while on the western side there is Makete district. The southern part it borders Njombe district and on the southeast it borders Mufindi district.

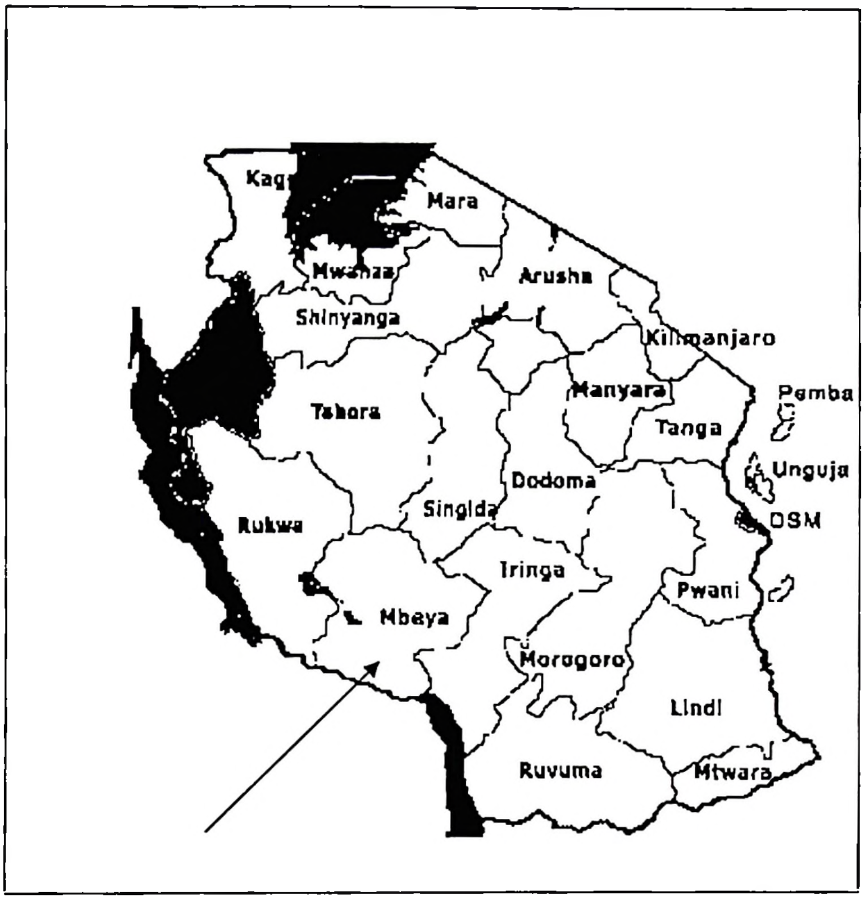

Figure 2: Arrow showing location of Mbeya region within Tanzania

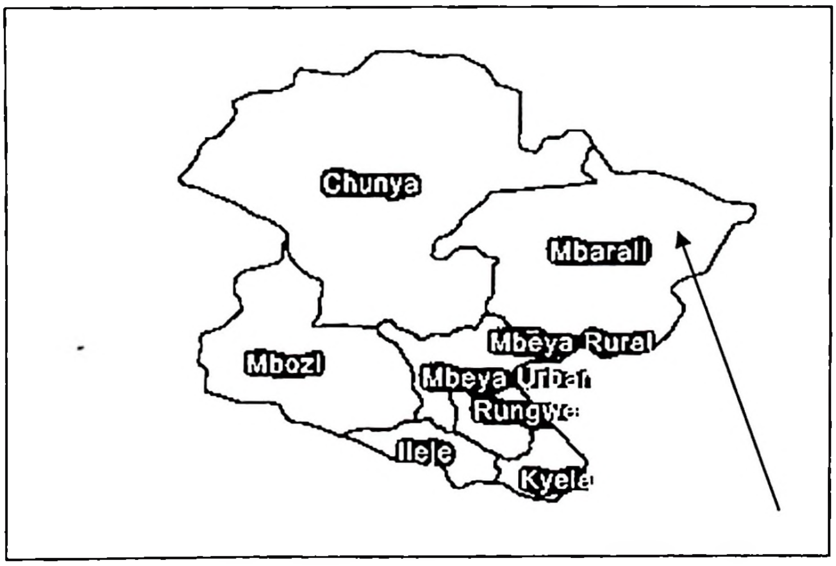

Figure 3: Arrow showing Mbarali district

Key:

Water bodies

Rufiji river basin

Usangu plain

Figure 4: Map Showing location of Usangu plain in Tanzania

3.2.1 Size

The district has a total area of 16,634 square km. Out of this area, wetland covers 4,049 square km while arable land is 1,960 km. The district has a forest area which covers 172 square km, game reserve is 5200 square km. Grazing land covers 2590 square km while water bodies in totality is 2596 square km. Land for other uses covers 67 square km.

3.2.3 Administration

Administratively the district has two divisions namely, Rujewa and Ilongo respectively. Ilongo division covers 11,736 square km while Rujewa covers just 4,898 square km.

Table 1: Division of Mbarali district

Division	Land area in square km	Number of wards	No. of villages (registered)
Rujewa	4 898	5	43
Ilongo	11 736	6	43
Total	16 634	11	86

Source: DED Mbarali district (2003)

3.2.4 Human population

According to 2002 human population census, Mbarali district was found to have a total population of 234908 people. The following table gives population information

Table 2: Mbarali district by Sex and number of households

Female	Male	Total	Household	
			Number	Average size
119628	115280	234908	55354	4.2

Source: DED –Mbarali (2003)

Information on population size of a particular area is an important aspect. The more people you have the more food, water, arable land and other essential materials from the natural resources pool you will need to make available (Kauzeni, 2003). Census of 1988 suggest that the population growth was 2.7% and that population density was 9.2 while according to district basic data report, population density projection for 2000 and 2002 were 13.2 and 13.9 respectively, suggesting an increase by 0.7.

3.2.5 Weather condition

Weather condition is very important and a major determinant factor of livelihood of people particularly in where agriculture forms a major economic activity. The following table shows amount of rainfall experienced within the district.

Table 3: Rainfall distribution Mbarali district

Year	Amount of rainfall in mm
1998/1999	426.0
1999/2000	498.7
2000/2001	714.0
2001/2002	885.7

Source: DED-Mbarali (2003)

The weather data above are only for four years, which is not enough to make a conclusion regarding the area, however perhaps can be an indication of the type of weather condition experienced within the area.

3.2.6 Crop production

The livelihood of the people in Mbarali district is largely depending on agricultural products (Kauzeni, 2003). District basic data (2003), suggest that, total arable land is 196,000 ha and on average cultivated area amount to 106,100 ha. Information on major crops produced in this district suggests that, up to 2001/02 maize, paddy, sorghum, finger millet, sweet potatoes and cassava are the major crops. Others are beans, groundnut, onion, tomato, sugar cane and sunflower. Too a large extent paddy and sunflower are used as food and cash crop. Though other crops such as maize, groundnuts are also traded, but not at a quantity which can oblige to term it as a cash crop. District basic data (2003) suggest that, cotton used to be grown in Mbarali district, however outbreak of red ball worms, lead to complete ban of cotton production. Arable land under paddy is very intensively used sometimes two paddy harvests are obtained per year (Kauzeni, 2003).

3.2.7 Livestock

Data suggest that livestock population in Mbarali district has been declining at a rate of 45.6 %, 1998/9 – 2001/02 for cattle. The population of goat has shown a more or less stable population of pigs has not registered any change. In terms of livestock infrastructure, Mbarali district that in between 1998/9 to 2001/2002 there has been 29 dips, dips operating were only 19. There is a seasonal vegetation variation and livestock are managed to take advantage of this variation by moving from one area to another. During the wet season, wetlands are flooded; the livestock graze on the fans. Here the rainy season provides new grass while the rivers from the highlands provide water (Kauzeni, 2003). While livestock population vary from day to day and according to season.

3.2.8 Land ownership within the area

Easy access to water for irrigation had attracted and continues to attract people from all over the country to make a living despite the associated problems (Kauzeni, 2003). Most of these people were aware of the regulations governing land ownership and therefore took the advantage and seize relatively big area and some applied for water right. Since good land is under few, then most of the farmers are obliged to rent land especially for cultivation of paddy rice.

3.2.9 Water resource

Mbarali district has a total area of 2596 km^2 of water bodies and about 4049 km^2 of wet area (DED, 2003). Water resource within the area is central to Mbarali's economy and directly supporting the livelihood of people. One cannot think of irrigation before identifying a source of water. Therefore availability of water is a determinant factor for utilization of treadle pump.

The Usangu plain receives very little rainfall, and all of this is lost by evaporation. The water that floods the plain is brought by the rivers, which flow from the highlands. These are Ruaha, Mkoji, Luna, Majenge, Chimala, Itambo, Kimani, Mbarali etc, which join together and form the great Ruaha river. Water resource more specifically in Usangu plain, of recent has raised a lot of controversial. People believe that, the amount of water within the Usangu plain is diminishing (SMUWC, 2001).

Major consumer of water in Usangu is agriculture through irrigation. Apart from agriculture water is used for electricity generation and for livestock. In the highlands, where valley bottoms are flat and broad enough to allow cultivation, many gardens have developed. These take water from the rivers during the dry season thus reducing the volume of water used for electricity production downstream (Kauzeni, 2003). Water that used to go down the river, is now used to irrigate crops. Water shortage in Usangu plain has lead to conflict. At the sectorial level, different interest and aspiration has been the root course of conflict. While Agricultural sector strive to improve production is found consuming a lot of water and the cause of water pollution through agrochemicals. TANESCO, the power utility company strives to make profit by producing more units and raise tariff.

Environmental conservators such as Usangu game reserve, who are among stakeholders of the water resource, level allegations on the TANESCO, for creating a vicious cycle, through raising electricity tariff, it means the urban and rural people will resort to a cheaper source of energy (fuel), which is charcoal and firewood. This means more disturbances on the environment, of which the outcome is intensification of the problem of water shortage. In such situation, conservators consider TANESCO a problem on its own and blame it for just concentrating on talking about water levels in Mtera and Kidatu instead of dealing with the root cause of the problem.

Within the agricultural sector itself, Kauzeni (2003) reported that, the smallholder traditional farms have water management problems that lead to conflict among themselves, and mentioned problem related to water distribution to different farmers, maintenance of channels, wastage of water etc and suggested establishment of water user committees as a solution.

3.2.10 Irrigation

In terms of irrigation development, Mbarali district has traditional scheme, modern scheme and improved scheme. There are 33 traditional schemes; the total active area is 12000 ha, while the potential stands at 13350 ha. These schemes weren't scientifically constructed, but rather involve use of local methods of delivery water to the field and there is no return of surplus water to the river. There are two modern schemes within a potential area of 7000 ha, however area under irrigation is only 6000 ha. These were professionally constructed and thus have modern ways of controlling water flow in the channels and sub channels, with respect to the volume, spacing of sub-channel gradient. Also surplus water is returned to the river. Finally there are 17 improved irrigation schemes, however the potential area is 1193 ha, and the current total active area account for 1158 ha. Improved irrigation scheme were once traditional scheme, which were upgraded through scientific construction of water volume controlling channel and a provision for return of surplus water to the river.

Such improvement of traditional irrigation scheme lead to what is termed as small-scale irrigation schemes. Small-scale irrigation schemes concern the upgrading of irrigation works, where the simple diversion structures constructed by traditional communities with local means such as stone and brushwood have been replaced by small concrete or masonry weirs, which divert water in a more effective and durable way (FAO, 1998). Performances of the 2 state farms have been poor like many other areas where modern irrigation schemes were constructed. Despite the advantages of scale, large –scale irrigation projects are becoming increasingly marginalized by cost, performance and environmental constraints

(FAO, 1998). Mbarali rice farm depicts initial public investment in irrigation development, which however failed to bear the intended benefits due to multiple factors.

3.2.11 Irrigation technologies

Irrigation system within Mbarali district is surface irrigation; in areas under paddy production border strip is used. Vegetables production and other crops are irrigated by furrow irrigation system, however not scientifically constructed. During the rain season, rivers become full of water, therefore farmers find easy to direct water into their field. In most cases, type of crop that is cultivated during this time is paddy. Areas along the river or canals are being used for vegetable production, maize and other crops apart from paddy. Some farmers use water-lifting technologies to lift water and irrigate crops. Such technologies include bucket, motorized pump for very few farmers and the recently introduced treadle pump.

Crop growing pattern is such that, during the rain season, rice is being cultivated, and then off-season is for other irrigated crops such as vegetables. Kauzeni (2003) reported that, arable land under paddy is very intensively used and sometimes two-paddy harvests are obtained per year. However the problem of water shortage provides an obstacle to paddy cultivation to most farmers. During the dry season some farmers mitigate the season by cultivating vegetables. Water lifting devices such as bucket, motorized pump and treadle pump are being used. Such technologies allow farmers to diversify crops and thus improve household food security as well as income. Diversification to high –income cash crops under irrigation can provide an attractive income for farmers. Traditional rice farmers obtain better prices by diversifying into non-rice crops in the dry season, while lower water requirement of non-rice crops will irrigate large areas (FAO, 1998).

3.2.12 Conservation strategies

Increasing pressure on water resource in Usangu plain and emergency of water shortage has raised stakeholders' attention. On the government side, it has amended her water policy, which had some weakness and establishes a new water resource policy, which emphasize on multi-sectoral approach on management of water resources. The fact that water resource doesn't follow regional and district division has been recognised and lead to division of the whole Tanzania mainland into nine river basins, charged with management of water resources within the whole country.

The Usangu plain is within Rufiji river basin management team. According to Rufiji river basin management office there is bad water utilization practices in usangu plain, almost 50% of water is lost due to absence of control gate (personal communication, 2005). The responsibility of the office is capacity building on local communities from the village level on sustainable water management issues such as, promotion and establishment of water user association at the sub-catchments. To guide water users associations on establishing and registering their constitutions, so that it can be legally recognised.

Additionally the office, has been assigned the duty of ensuring that amount of water diverted for use doesn't exceed amount officially granted for use. In so doing they regulate utilization of water in Usangu plain. Increasing water shortage within the plain has been recognised and the office has taken a multi-sectoral approach in attacking the problem. Some of the initial strategies include promoting planting of water conserving tree up streams, establishment of local environmental conservation group and involve other stakeholders such as WWF to provide capacity building to particular groups. A new technological design of water control gate has been developed to ensure that what is diverted for use is what was granted within the contract.

3.3 Justification of the selected area

Choice of the area is based on the fact that, Mbarali district has been an area of focus for NGOs when introducing and promoting the use of the treadle pump for irrigation. Probably, they were moved by the situation within the area, which is characterized by increasing pressure on water demand accounted by high influx of people and poverty succumbing Mbarali district dwellers. Specific efforts towards the scourge have been directed towards improving household income through increased crop production. Since the area is characterized with low rainfall and high evaporation (semi arid) then, irrigation becomes undoubtedly a very important aspect, there the importance of the treadle pump as a technology comes forward.

3.4 Research design

A cross –sectional research design was used in this study. The cross sectional research designs allows data to be collected at a single point in one time and used in descriptive study and for determination of relationship of variables (Bailey, 1998). Limited time for fieldwork justifies the use of the selected design.

3.5 Rapid rural survey

Preliminary survey was done with a view of getting key information to be incorporated during the main survey, which involved administering of questionnaire. During the survey farmers with treadle pump, motorized pump and those who use bucket for irrigation were visited. Offices of the Entrepriseworks, Approtech agent in Mbarali, Mbambo metal works (manufacturer of treadle pump in Mbarali district) and Rufiji river basin were visited.

3.6 Key informants

One of the important diagnostic features of good qualitative enquiry is its full exploitation of insights from the key informants. During the survey, farmers who were known to have more information were identified and interviewed.

3.7 Sampling procedure

3.7.1 Population

The population of the study was all farmers using treadle pump as a tool for irrigation. Farmers who use other methods of irrigation such as bucket, motorized pump and surface irrigation were included. The sampling frame was obtained from the office of the Entrepriseworks Mbeya, Approtech agent in Mbarali and Bambo metal works (manufacturer of treadle pump) in Rujewa, Mbarali.

3.7.2 Sampling

Purposive sampling was used to select users and non-users of the treadle pump. One of the advantages of purposive sampling is that the researchers use his or her skill and prior knowledge to choose respondents. Then simple random technique was used to choose farmers with treadle pump from the sampling frame. Simple random sampling is usually considered adequate if the chances of selection are equal at any stage in the sampling process (Bailey, 1998).

3.7.3 Sample size

The entire sample size from which information was collected is 90 respondents, of which farmers with treadle pump were 44 while those with motorized pump were 7, farmers using bucket as a means of irrigation were 4 while those who use surface irrigation were 35

3.8 Data collection

The study used both primary and secondary data. Primary data were collected from farmers while secondary data were collected from different sources.

3.8.1 Primary data

A structured questionnaire was designed to capture both quantitative and qualitative data. This consisted of both close and open-ended questions. Variable such as age, education, farm size, crop type, income, yield, fertilizer, seeds, labour in man's day per hectare, presence of marketing organizations for output were captured using the questionnaire.

The unit of study was a household, therefore appointment was done through the local leaders and a visit was paid to respondents' residential area for interviewing. Since most of the farmers were busy with farm operations, then, in certain situations it was obliged to interview farmers at business area or at the farm after they have performed agricultural activities.

3.8.2 Secondary data

Table 4 below provides a summary of different sources and type of secondary data collected.

Table 4: Source and type of secondary information

Source	Type of data
Enterpriseworks	Sampling frame
	Background of the project
District agricultural office	Socio-economic profile of Mbarali district
Usangu game reserve	Conservation strategies
Rufiji river basin	Water conservation strategies
Bambo metal works	Sampling frame, manufacturing process
SUA	Irrigation, economics analysis, econometrics and policies
Internet	Information on irrigation and policy issues

3.9 Data processing and analysis

Data collected were sorted, coded and analysed. Analysis was done using the statistical package for social science (SPSS) computer software and Limdep. Descriptive statistics namely frequencies percentage and means were considered. Cross tabulation was done to establish,relationship between variables.

3.9.1 Factors determining adoption

Probit model was used to determine factors influencing adoption of treadle pump.

$$p = pr(y = 1) = pr(1i \le 1i) = F(1i) = \frac{1}{\sqrt{2\pi}} \int_{-\alpha}^{Ti} e^{-t^2/2} dt$$

I_i= a+B1Xi+...+BnXn+d1ZI+... +DnZn +U

Where B= vector of binary independent qualitative variable

a = constant

X = qualitative independent variable

Z = quantitative independent variable

D = parameter estimate of quantitative variable

Ii= utility index

U =error term

The model was estimated using Limdep computer soft ware, where adoption of treadle pump was assigned 1 while non-adopters it was 0. Qualitative independent variable was gender included as a dummy variable, 1 was for male and 0 for female. Quantitative variables were, household size measured in number of people within a household, education measured in number of years in school, number of males within the household, age of the household head, income in Tsh, and farm size measured in hectare.

3.9.2 Adoption of improved technologies

To determine whether treadle pump complements adoption of improved technologies, Chi-square was be used.

3.9.3 Farm productivity

Assessment on how treadle pump impacts farm productivity was done using a Cobb-Douglass production function. Cobb-Douglass production function is one of the model, which enables to capture contribution of input to yield in a multi-inputs scenario. Fertilizer used by farmers in most cases was chemical fertilizer measured in kg. During estimation the model was checked if it has suffered from multi-collineality, which is common for analysis using cross-sectional data.

$$Y = AS^{as}F^{af}T^{at}L^{al}$$

Where S = seeds in kg per ha

F = fertilizer as a sum of kg of N per ha.

T=Treadle pump (dummy variable)

L=Labour in man's day per ha a= partial elasticity (input coefficient)

Y=Yield in kg per ha

Assumption is, land suitability, variety and management practices are homogenous. Endogeneity problem was recognised, attributed to influence of treadle on adoption of other technologies. In this regard, the model was

$$F=(T, U)$$

Where U= error term

The problem was solved by following approaches proposed by Maddala (1989), that is constructing efficient instrumental variable by regressing the endogenous variable on all exogenous variables in the system and obtain predicted values which are treated as instrumental variables.

3.9.4 Economic performance

Economic performance can be analysed using measures such as benefit –cost analysis, economic surplus models, economic efficiency estimation, and gross margin or gross profit. However for the sake of this study, gross margin analysis was used to determine the economic performance of the treadle pump at the household. In addition to that, a share of labour to total cost was computed for treadle pump and bucket. The share reflected labour intensity of the two different technologies. Gross margin was calculated as the difference between total revenue and total variable cost as follows,

$$GM = TR - TVC$$

Where GM = Gross margin

TR = Total revenue from the sale of crop irrigated using treadle pump

TVC = Total variable cost

Revenue was considered form the value of horticultural crops, which were grown by farmers using treadle pump for irrigation. Price, which was considered, was the average market price within the area. Total variable cost included cost of labour, cost of fertilizer, pesticides, packaging material and seeds.

3.9.5 Farmers' perception on treadle pump

Factor analysis a statistical technique was used to reduce a set of variables to a smaller number of variables or rather factors, in order to know as to where farmers' preference towards the technology is based on. Factor analysis offers analytical potential for deeper probing of the nature of innovation perceptions (Rogers and Showmaker, 1971). Therefore attribute of preference were partitioned whereby farmers were asked to rank each attribute from strongly agree, agree, neither, disagree and strongly disagree. The mostly used criterion for judgement in factor analysis is eign value specification, of which a minimum eign value for a factor to be retained is one.

3.10 Limitation of the study

It was proposed before that, the sample size for this study could be 120, however the survey failed to get all those respondents. This was attributed to the fact that, farmers were busy engaging in agricultural activities, and their farms are located in areas, which were not reachable with a vehicle or motorcycle due to floods. Information sought from the farmers was based on past experiences. It was somehow trick, especially considering that farmers don't keep records. Again some farmers might have provided information with suspicion or prestige, which could compromise quality of the data.

To avoid that a more detailed interviewing had to be conducted, though it was time consuming. Use of secondary information to complement primary data was done. Therefore findings represent, what was actually happening in Mbarali district.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Household characteristics

Table 5 below suggests that, majority of the respondents knew how to read and write, an important attribute for adoption of technology. More often, information concerning the technology is in a written form, favouring literate people.

Table 5: Household characteristics

Household characteristics	n	Overall percent
Male	88	97.8
Female	2	2.2
No formal education	5	5.6
Primary	73	81.1
Secondary education	4	4.4
Post secondary	8	8.9
Household size (mean)	6.3	

Majority of the respondents were married, few were widow, only 2.2% as shown on table 6 below. Respondents, who were not married, were all male between 18-25 years. The proportion of female-headed household within the sample size is 2.2%, who were married only that their husband passed away. The fact suggests that, there were only few female farmers doing irrigation. Kiagho (2003) found a proportion of female farmers in Mbarali district to be 22% of the entire sample size and pointed out that the situation was attributed to the fact that irrigated agriculture is capital and energy intensive activity to the inconvenience of the majority of female farmers.

Table 6: Marital status

Marital status	n	Overall %
Single	6	6.7
Married	82	91.1
Widow	2	2.2
Total	90	100.0

Table 5 above suggests that, average household size is above the national average household size, which is 4.9 according to Household Budget Survey (2002). The fact may have attributed to migration of people from other areas to Mbarali district for economic reasons. Kauzeni (2003) reported that, easy access to water for irrigation in the Usangu Plain had attracted and continue to attract people from all over the country to make a living despite the associated problems. Table 7 indicates that, majority of the people within the area were between 18 and 50 years of age, probably a suggestion that majority of the people can engage in production activities.

Table 7: Age distribution

Age of household head	Years
Average	40.9
Stand deviation	9.1
Maximum age (years)	66.0
Minimum age (years)	18.0
Age between 18 and 50 years (%)	87.8
Age above 50 years (%)	12.2

4.2 Irrigation technology

Table 8 below shows that, within the sample size taken, 38.9% of the farmers practiced furrow irrigation, 48.9% irrigate using treadle pump, 4.4% used bucket for irrigation and 7.8 % used motorized pump. Most of the farmers who irrigate currently using treadle pump were previously using bucket for irrigation. Furrow irrigation was used mainly where there was plenty of water, in this case where there was a canal or river, water could be diverted to the farm. Those who managed to rent and grow paddy within the NAFCO farm, there is irrigation infrastructure therefore it was easy to get water.

From the survey, treadle pump is associated with two types of farming systems namely, mixed vegetables farming system (tomato, cabbage, onion, spinach, chilies, okra, egg plant etc) in year round and agro-pastoral farming system. Crop pattern and crop rotation practiced by the treadle pump users were different from those practiced by farmers using furrow irrigation or bucket irrigation. According to Shah *et al.* (2000) among the changes that treadle pump brought were, changes in the cropping patterns and farming systems adopted by smallholders and more significantly.

Identification of whether farmers had a habit of borrowing or renting treadle pump revealed that only 1.1% of the farmers with treadle pump admitted to have leased treadle pump to other farmers. And charged 1000/= Tsh every day of irrigation. Perhaps they fear breakdown of the pump, if passed over from one user to another. Similar observation was reported in Zambia by Kay and Brabben (2000), that individual ownership is mostly preferred.

Table 8: Distribution of farmers in respect to irrigation technologies

Irrigation method	n	Overall percent
Treadle pump	44	48.9
Bucket	4	4.4
Motorized pump	7	7.8
Surface irrigation	35	38.9
Total	90	100.0

4.3 Household characteristics for each group of farmer

Table 9, shows that, there is a significant difference between farmers using treadle pump and those who use surface irrigation in respect to mean age of the household and number of males within a household. The higher number of male among treadle pump users, probably is a reflection that treadle pump is regarded as a male technology. Table 10, depicts a comparison between treadle pump users and combined irrigation methods (bucket and surface or furrow irrigation) instead of surface irrigation alone as of the case in table 9.

Results of table 10 feature similar results with table 9 in respect to education level which is not significant. This is contrary to Nabbumba and Bahiigwa (2004) findings that, education directly influences adoption of improved technologies. Probably, it is possession of resources, which has favoured certain group of farmers to adopt treadle pump and not the level of education that one has.

Table 9: Household characteristics- treadle pump and surface irrigation users

	Treadle pump n=44	Surface irrigation n=35	t	Sign
Household size	7.4	5.2	0.9	0.02
Mean age	41.7	40.7	2.1*	0.01
Number of male	3.8	2.7	2.3*	0.03
Education level	7.8	7	1	0.05

*Significant at P ≤0.05,

In terms of household size results on table 9 suggests that, farmers with treadle pump are having the largest household size, though the t-test value is insignificant. However when treadle pump users are compared with a combination of irrigation methods (bucket and surface irrigation) on table 10 below, household size was largest and there was significant difference between the two groups of farmers. Perhaps a suggestion that treadle pump is a labour intensive technology. Large families tend to be more likely to adopt new technologies, as there is a greater availability of labour to carry out additional work or use it for reciprocating other goods and services (Kebede *et al.*, 1990 as cited by Steel, (1995).

Table 10: Household characteristics –treadle pump and combined irrigation methods

Characteristic	Treadle pump n=44	Combined irrigation methods n = 35	t	Sign
Household size	7.5	5.5	2.9*	0.03
Mean age	41.7	40.5	0.6	0.04
Number of male	3.86	2.8	2*	0.01
Education level	7.8	6.7	1.3	0.01

* Significant at P ≤ 0.05

Table 11: Capital assets – Between treadle pump and Surface irrigation users

Type of asset	Treadle pump users n =44	Surface (Furrow) irrigation users n = 35	t	Sign
Land size in acre	13.7	3.65	3.7	0.12
Livestock	23	8	1.2	0.57

4.3.1 Household capital assets

Household capital assets determine household or individuals livelihood platforms. From the results on table 11 and 12 treadle pump users seemed to own a larger area of cultivated land as well as number of livestock possessed. The fact suggests that farmers using treadle pump are wealthier than the rest of the others farmers. Perhaps treadle pump self-select farmers who are relatively rich in terms of capital assets. Report by Shah *et al.* (2000), observed similarly that, adopters had larger landholdings relative to pumpless and their labour to land ratio was expected to be lower than that of pumpless household.

Table 12: Capital assets owned by treadle pump and combined irrigation users

Type of asset	Treadle pump	Combined irrigation method	t	Sign
Land size in acre	13.42	4.3	3.5	0.00
Livestock	23	5.7	0.6	0.40

4.4 Irrigation schedule

On irrigation program results on table 13 and 14 show that, treadle users spend an average of 3.4 hours on irrigation and practice that for almost three times a week for an average area of 0.23 ha. Farmers using bucket irrigation spend on average 2.9 hours to irrigate average area of 0.05 ha and practice that daily. However the two was not compared statistically, due to a small sample of farmers irrigating using bucket. Nevertheless, the difference between the two types of farmers, perhaps is a reflection that irrigation by treadle pump is more efficient than using bucket, which is laborious, time consuming and most of the time done superficially as a result it deem to irrigate daily contrary to treadle pump. This means treadle pump users can allocate saved time on other economic activity. With regard to farmers using surface or furrow irrigation, less time is spent on irrigation than treadle pump, however is particularly applicable during the rain season, when rivers, canals are fully of water. This method is not very common during the dry season, since it is associated with consumption of a lot of water, which is seldom available during this time of the year. Therefore the furrow irrigation is applicable in one crop season.

Farmers with treadle pump show similar number of crop season with those with motorized pump users. According to Kay and Brabben (2000), in Kenya farmers using treadle pump had, on average 2.3 seasons per year. This is a privilege to treadle pump users, taking into consideration of the cost of the devise and the advantages it can offer. This means labour which could be held out during the off-season is being utilized in year round. Shah *et al.* (2000) reported similarly that, on the impact of treadle pump irrigation on smallholder farming, is that it frees the farmers from dependence on rainfed irrigation and provides the capacity to raise crops in winter and summer.

Comparison on area under irrigation on table 14, suggests a significant difference between the irrigation methods. It has been estimated that the area, that can be irrigated using the treadle pump is approximately 0.24 ha while using watering cans under similar conditions would reduce the area to 0.03ha (Kay and Brabben, 2000).

Table 13: Irrigation schedule –Using treadle pump and surface irrigation

Irrigation program	Treadle pump	Surface (Furrow) irrigation	t	Sign
Hours spent per day	3.4	3.5	4.8	0.02
Number of days per week	2.9	7	-4.8*	0.06
Number of crop season	2.3	1	3.6	0.04
Area under irrigation (acre)	0.57	0.13	3.4	0.10

* not significant at P ≤0.05.

Table 15: Irrigation schedule- Using treadle pump and combined irrigation methods

	Treadle pump	Combined irrigation methods	t	Sign
Hours spent per day	3.4	4.2	5	0.01
Number of days per week	2.9	6.5	-2	0.01
Number of crop season	2.3	1.8	1.7*	0.01
Area under irrigation	0.57	0.13	5.3	0.00

* not significant at P ≤0.05.

4.5 Economic performance of the treadle pump

Table 16, depict gross margin received by a farmer, using treadle pump as a tool for irrigation. The computation of the gross margin has not considered the value of family labour. While table 17, has included the value of family labour. Table 18 and 19; show a gross margin of farmers using bucket for irrigation.

The share of labour to total cost indicated by both tables 17 and 19, suggest existing difference value of share of family labour to total cost between the two technologies (bucket and treadle pump). The discrepancy reflects different labour intensity associated by the two technologies. In this respect, bucket irrigation showed a higher value than treadle pump, suggesting that irrigation using bucket is more laborious than if treadle pump is used. The comparison between the two, suggest that farmers do realize more economic benefit when they use treadle pump for irrigation, than as of the case with bucket. A typical income for a season using bucket irrigation is approximately US$80 in Kenya, and that when this is replaced with a suction pump, the income rises to US$351 and a pressure can increase this to US$690 (Kay and Brabben, 2000).

Table 16: Gross margin analysis without pricing family labour –Treadle pump

Farm activity	Man days	
Land preparation	8	
Planting	8	
Weeding	8	
Spraying	2	
Fertilizer application	4	
Irrigation	26	
Harvesting	6	
Material		Tsh
Seeds	50 grams	6,500
Fertilizer	100 kg	34,500
Insecticide	2 litres	16,000
Sprayer rental	2	2,000
Packaging material	40 pcs	12,000
Fungicide	4 kg	40,000
Total variable cost		111,000
Total yield	6,000 kg	
Price		100
Total revenue		600, 000
Gross margin		499, 000

Farm size = 0.23 ha, Crop= tomato, Price per kg =100

Table 17: Gross margin analysis after pricing family labour- Treadle pump

Farm activity	Man days	
Land preparation	8	10,000
Planting	8	8,000
Weeding	8	8,000
Spraying	2	4,000
Fertilizer application	4	4,000
Irrigation	26	52,000
Harvesting	6	9,000
Material		Tsh
Seeds	50 grams	6,500
Fertilizer	100 kg	34,500
Insecticide	2 litres	16,000
Sprayer rental	2	2,000
Packaging material	40 pcs	12,000
Fungicide	4kg	40,000
Total variable cost		206,000
Total yield	6,000kg	
Price		100 Tsh
Total revenue		600, 000
Gross margin		394, 000
Share of family labour to total cost		0.46

Table 18: Irrigating using bucket –Gross margin analysis before pricing family labour.

Farm activity	Person days	
Land preparation	2	
Planting	2	
Weeding	2	
Spraying	0.5	
Fertilizer application	1	
Irrigation	48	
Harvesting	2	
Material		Tsh
Seeds	20 grams	2,000
Fertilizer	10 kg	3,450
Insecticide	0.5 litres	400
Sprayer rental	2	2,000
Packaging material	5 pieces	1,500
Fungicide	1kg	10,000
Total variable cost		116500
Total yield	1,600kg	
Price	100 Tsh	
Total revenue		160 000
Gross margin		43500

Farm size =0.1ha acre Crop= tomato Price per kg=100

Table 19: Irrigating using bucket –Gross margin analysis after pricing family labour.

Farm activity	Person days	Cost in Tsh
Land preparation	2	5,000
Planting	2	5,000
Weeding	2	5,000
Spraying	0.5	1,000
Fertilizer application	1	1,500
Irrigation	48	96,000
Harvesting	2	3,000
Material		Tsh
Seeds	20 grams	2,000
Fertilizer	10 kg	3,450
Insecticide	0.5 litres	400
Sprayer rental	2	2,000
Packaging material	5 pieces	1,500
Fungicide	1kg	10,000
Total variable cost		135, 850
Total yield	1,600kg	
Price		100
Total revenue		160 000
Gross margin		24 150
Share of family labour to total cost		0.86

4.6 Treadle pump and farm productivity

Evaluation of the impact of treadle pump on farm productivity was carried out using Cobb-Douglass production function. During the survey it was established that, some farmers were using treadle pump to irrigate paddy nursery. However after transplanting treadle pump had no use. To avoid inflating the impact of the technology, paddy was not considered in analysing productivity. Instead, tomato a horticultural crop, which majority of the farmers grew was used to isolate the impact of the treadle pump. Cobb-Douglass production function was estimated. The dependent variable used was the yield per ha. The independent variables used in estimation include, seed (kg/ha, Fertilizer (kg/ha), labour (Man days /ha) and treadle pump was treated a dummy variable in this case farmers with treadle pump scored 1 and otherwise scored 0. Results of the Cobb-Douglass production shows that, all estimated partial coefficients were significant, with exception of the coefficients for fertilizer and labour.

Table 20: Treadle pump and farm productivity

Model	B	t	Sign
Constant	2.763	2.110**	0.037
Seed	1.252	6.346**	0.000
Treadle	0.281	2.036**	0.045
Labour	-0.564	-1.690*	0.095
Fertilizer	0.291	1.706*	0.092

**- Significant at $P \leq 0.05$

The partial elasticity for seed was the highest among all, indicating that the marginal productivity of seed is very high. The coefficient was significant at $P \leq 0.05$ level of significance. Probably a suggestion that, farmers are adopting improved variety of tomato seed. Analysis whether treadle pump is complementing adoption of improved seed, gave out positive results.

The coefficient for treadle pump is 0.28 which is significant at $P \leq 0.05$ significance level. This suggests that, treadle pump really contributes towards increasing productivity. Hussain *et al.,* (2000), analysed wheat production using Cobb-Douglass and found that estimated partial elasticities for irrigation varies from – 0.20 to 0.54. Therefore the analytical results fall within that range, a suggestion that, crop productivity can be achieved by using treadle pump as a tool for irrigation. The coefficient for labour was negative and not significant at $P \leq 0.05$. Meaning that farmers are facing a negative marginal return from labour. This may have been accounted by the fact that, family labour was the main source of farm labour, and since most of the data relied on the ability of the farmer to remember; probably misspecification might have been encountered. However analysis of the household characteristics, revealed that adopter of treadle pump has the highest average household size.

Coefficient for fertilizer as a variable, was greater than that of treadle pump, however not significant at $P \leq 0.05$. Average amount of fertilizer (in –organic) used by majority of the farmers is still very low. This amount cannot be compared with the amount of fertilizer applied on paddy. Probably farmers are more risk takers with paddy farming than with horticultural crops. The reason could be that, average size of land for vegetable production is small and hence the turn over, as opposed to paddy.

The Cobb Douglass production function was then re-estimated in this time with a due consideration of the endogeneity effect. Results suggest that, treadle pump has a positive and significant marginal productivity at $P \leq 0.05$ significance level. Labour and fertilizer featured a positive but not significant marginal return at same significance level.

Besides that, value of production was considered as a dependent variable and then Cobb-Douglass production function was estimated. In this instance farm size was considered among exogenous variables. Results obtained showed marginal return from treadle pump and seeds to be positive and significant at $P \leq 0.05$. Farm size depicts a negative marginal return, however not significant at $P \leq 0.05$ significance level. Probably is accounted by misspecification during estimation by farmers. On other hand, perhaps farmers fail to manage a relatively big farm.

Table 21: Impact of treadle pump on farm productivity

Model	B	t	Sign
Constant	-4.54	-0.42*	0.68
Treadle	0.85	10.07**	0.00
Labour	12.28	0.53*	0.60
Fertilizer	15.35	1.72*	0.11

**= Significant at $P \leq 0.05$,

4.7 Supplier of treadle pump

The survey found out that, there are two suppliers of treadle pump within the area, namely Enterpriseworks and Approtech respectively. The Enterpriseworks has introduced a brand of treadle pump known as Mkombozi pump, while Approtech have named their brand Moneymaker. From the entire sample size farmers with treadle pump, 79.5% purchased Mkombozi pump, while 19.4% purchased Moneymaker. Only 1.1% of the farmers with treadle pump reported to purchase both types of treadle pumps. Results show that majority of farmers purchased their treadle pump in 2003. During this year 59.1% of the farmers with treadle pump purchased their pump. Probably this is first the time they became aware and convinced of the technology.

4.8 Operation of the pump

Results on household size suggest that, farmers with treadle pump had a highest average household size. This is may suggest that the technology is labour intensive. Study found out that, operation of the treadle pump is regarded as a male activity, particularly to households where livestock keeping is not a major economic activity. Female farmers find difficult to operate treadle pump. One of the female respondent, purchased treadle pump however couldn't use it because her son refused to engage in farming (personal communication). And therefore she was looking forward for a joint venture with a male farmer who can operate treadle pump. Most technologies are considered gender neutral in themselves, but often become gender biased during their introduction and use by societies (Steel, 1995). Perhaps, this is one of the technology of which designing failed to consider gender. Too frequently technology has been male designed in controlled environment of a workshop or research station (Steel, 1995). However, negative attitude towards the technology is also accounting towards rejection of the treadle pump among female farmers. For instance, male farmer lamented that he has been forced to stop growing vegetable, because he felt sick and her daughter refused to operate the pump on the disguise that she will develop strong leg muscle and appear awkward (personal communication). Kay and

Brabben (2000) reported that, earlier there was skepticism that, woman who use treadle pump excessively would not conceive because the movements during operation affect the womb.

4.9 Marketing of treadle pump

Enterpriseworks (Tz) and Approtech have different distribution network of treadle pump. Distribution network or rather supply chain is very crucial aspect in ensuring that product marketed reach the end customers. In this regard, NGO's have adopted different approaches. Approtech has established a supply chain consisting of manufacturer, wholesalers, retailers and customers. While Enterpriseworks has a very short supply chain consisting of manufacturer and customers. Supply chain could play a big role in terms of enhancing sustainability, especially once the project has phased out. The supply chain that obliges customers to purchase only from the manufacturer may not be very efficient. Particularly in situation where there is only one manufacturer, located in just one locality, which was the case in Mbarali district.

Wholesale make marketing system more efficient by buying a variety of products in fairly large quantities and selling these items on to other business who require relatively small quantities of variety of goods (Crawford, 1997). The challenge faced by Enterprise works (Tz), was to get retailers with capital or access to credit and who are ready to take risk. Similar problem was experienced in Zambia. Under that situation, IDE, decided to establish two-supply chain. The first involved the supply of pumps from the manufacturer to the retailers while IDE acted as a distributor.

4.9.1 Pricing policy

Always when talking about a product, price becomes an integral part of it. Price is important because it affects demand and an inverse relationship between the two usually prevails (Onkvisit and Shaw 2000). Under the Enterprise works arrangement price setting is upon to Enterpriseworks itself and that is one of the clause stipulated in a contract between both parties. Pricing method used is cost –plus pricing, which in this case ensure that, the technology is reaching farmers at low price and at the same time allow a certain margin for manufacturer. In a situation where cost of raw materials has gone up, Enterpriseworks adjust the price accordingly to reflect the new cost of manufacturing treadle pump. However among the disadvantages of the method is where there is no consideration of distance and its effect on increasing the cost of sourcing raw material. Consequently the method lead to different profit margin while favouring manufacturers situated close to source of raw material. The cost –plus pricing is a considered as a very elementary method of pricing as it neglects exiting demand and competition within a market. Any pricing method that ignores current demand and competition is not likely to lead to the optimal price (Kotler, 1985).

However in a situation where the technology is initially introduced to farmers, it is difficult to estimate demand and competition and therefore use the information to set price. Apart from the draw back it carries, the method simplify pricing task to sellers, as they don't have to make frequent adjustment on demand changes. The minimum price for a small pump could cost 35,000/= Tsh initially, however high price of steel has pushed it to 45,000/=Tsh. Approtech have similar arrangement, only that her distribution chain is long starting from manufacturer, wholesalers, and retailers throughout to customers.

Table 22: Showing change in price for treadle pump

NGO	Introductory price (2002)	Price at present (2005)	Percentage Change
Enterpriseworks	35 000.00	45 000.00	28.57
Approtech	69 950.00	99 000.00	41.53

4.9.2 Promotion campaign

In terms of promotion again each organization has identified it's own best perceived promotion method. Approtech advertise retailers and the pump through banners distributed everywhere such retailers are maintained. While Enterpriseworks rely mainly on field demonstration and agricultural show, executed by project extension officers. Similar approach was adopted by IDE in Zambia, where demonstration are organized in field days and agricultural shows. At these events pamphlets, leaflets and brochures providing information about the pump are distributed to clients (Kay and Brabben, 2000). Besides, farmers who purchased treadle pump are visited by Enterpriseworks (Tz) project staff to see how they have adapted to the technology. Enterpriseworks approach seemed to be successfully compared to the approach by Approtech, if number of pumps sold within the area, should be taken as a proxy for efficiency of the approach.

Table 23: Showing number of pumps sold up to 2005 during the survey

NGO	Number of Pump sold	Overall percentage
Enterpriseworks	150	83.33
Approtech	30	16.67
Total	180	100.00

Higher pump price may also have been attributed to low purchase of the Approtech pump. However Approtech pump is seem to be robust and tolerant to harsh environment compared to Enterprise work pump.

4.10 Treadle pump and farmers perception

Factor analysis was performed and results indicated that, statement with highest Eign value of 2.794 explained 23.28% of the variations. Results were grouped into three categories for easy and clear discussion. The categories were nature of the technology, operation and performance. With regard to nature of the technology, farmers described treadle pump as one, which is capital intensify and not complicated. However initial analysis showed that treadle pump is associated with higher household size. Perhaps farmers described it while comparing with bucket, which is more laborious and therefore irrigate a relatively small area, unlike treadle pump which irrigate a relatively big area.

From the results, farmers described treadle pump, as a potable technology, this is according to table 24 below. Which means farmers can utilize it full. There were few reported cases of leasing out to other farmers. In terms of operation at farm level, factor loadings indicates that, the technology is associated with gender biases ness. From the survey female farmers declined to operate treadle pump on the disguise that it is difficult to operate. This is inconsistent with Kay and Brabben (2000) in Zambia that, women operate treadle pump without any traditional or religious restriction, as of the case in Asian countries, where women do not wish to be seen working treadle pump. With regard to performance, results show that, the technology is efficient in water use, however not durable, amid frequent breakdown of the treadle pump reported form the survey.

Table 24: Farmers' perception

Variable	Component				
	1	2	3	4	5
Capital intensify	0.134	**0.864**	0.192	0.009	0.282
Easy to shift	-0.050	0.305	0.127	0.170	**0.876**
Easy to use	-0.244	**0.870**	-0.025	0.091	-0.080
Not labour intensive	0.208	0.115	0.088	-0.046	0.195
Exploit underground water	0.382	0.086	0.200	0.775	0.085
Spares are easily available	0.267	-0.066	0.058	-0.900	0.005
Economical in water use	**0.728**	0.166	-0.438	0.022	0.019
Affordable	0.330	0.455	-0.450	0.378	0.288
Irrigate large area	0.002	0.082	**0.839**	0.149	-0.131
Has high water pressure	**0.655**	-0.079	0.195	0.228	-0.244
Durable	**-0.798**	-0.091	0.198	-0.168	-0.004
Gender sensitive	0.281	0.496	0.257	0.192	**-0.656**

Bold figure indicate factor loadings accounted towards farmers perception.

4.11 Adoption of other improved technologies

Results show that, 20% of the respondents within the entire sample used insecticide, the proportion is very low despite the fact that majority reported their crops to have suffered from the insect pest attack. Analysis on relationship between irrigation methods used by a farmer and application of insecticide, revealed that, only two groups of farmers used insecticide, namely treadle pump users and motorized pump users. Within the group of adopters of treadle pump, only 38.6% reported to have used insecticide and the average amount was 1.5 litres, as opposed to an average of 2.00 litres of insecticide used by those who used motorized pump. Comparison between the two groups using Chi-square showed that a Pearson Chi-square value of 1.324, significance level is 0.724, which means not significant at $P \leq 0.05$.

The survey had also the interest of identifying whether adoption of treadle pump complements adoption of improved variety. In this regard, farmers were asked whether they used improved variety seeds or obtained seeds from previous harvest, results show that, 62.5% of the farmers within the entire sample size used improved seeds of horticultural crops and maize. Out of the group of those who used improved variety seeds, farmers with treadle pump accounted by 82%. While, farmers using bucket and motorized pump accounted by 18%. Farmers who use surface irrigation did not use any improved variety. Then farmers were compared using Chi-square, results show a Pearson Chi-square value of 68.978 significance level of 0.000, which is significant at $P \leq 0.01$. This shows that the difference showed in proportion of farmers using improved variety for each group is significant. With regard to fungicide, 20% of the farmers within the sample size, applied fungicide to horticultural crops with the aim of protecting them against fungal disease.

However, it is only treadle and motorized pump users who used fungicide. On average treadle pump users applied 2.265 kg of fungicide as opposed to 3.00 kg applied by motorized users. However in terms of proportion, 38.6% of farmers using treadle pump applied fungicide, while only 14.28% of the farmers with motorized pump applied fungicide. Comparison between the two groups, using Chi-square revealed a Pearson value of 5.294, which is not significant at $P \leq 0.05$ significance level. Finally farmers were compared in terms of application of fertilizer; average amount of fertilizer used was 59.56

kg, treadle pump users were having 50.32 kg, bucket users show 8.75 kg while motorized pump users had 110.0 kg. Analysis by Chi-square show that a Pearson Chi-square of 64.094 which was significant at $P \leq 0.01$. The fact that farmers using surface irrigation show a highest average amount of fertilizer used. Perhaps is because, this is their major cash crop. However this amount was applied on paddy, as they were not doing vegetable farming. The majority of treadle pump users applies fertilizer on vegetables, and grow paddy without fertilizer. Probably accounted by the fact that, adopters of treadle pump consider vegetables as cash earning crop, therefore allocate inputs, which includes fertilizer.

4.12 Factors determining adoption of treadle pump

Factors influencing adoption of treadle pump were analysed using Probit model. Table 25 below suggests that, household size, price of the treadle pump and farm size have a positive influence on adoption of the treadle pump. Large household size is normally associated with more consumption stress, the fact may increase the likelihood for the household to adopt improved technologies, in order to produce more and meet the household demand. On the other hand, availability of family labour for farm activities may have accounted as well. This is consistent with the results on household characteristics, which showed treadle pump users to have the largest household size.

Table 25: factors influencing adoption of treadle pump

Variable	Coefficient	Standard error	P>IzI
Household size	3.71	137230.80	1.00
Number of male	0.89	135532.52	1.00
Education	-1.80	16138.10	0.99
Age	-0.36	10189.34	1.00
Gender	-13.01	186748.65	0.99
Price	0.70	1.11	0.99
Farm size	0.24	1500.55	1.00

Chi-square=124.722, degree of freedom= 6 Prob (Chi-square> Value) = 0.000

Due to endogeneity problem between income of the household and the rest of the variables, income was dropped during analysis of the factors determining adoption of treadle pump. From the results. price features a positive influence on adoption of the treadle pump. Increases in farm size, increase the chance of adoption by farmers. Perhaps explained by the fact that, farmers owning a relatively small piece of land prefer to use bucket for irrigation, however with increased farm size, treadle pump is more convenient to use than using bucket. Number of male within a household shows a positive influence towards adoption of the treadle pump. Perhaps due to labour intensity nature of the treadle pump operation, presence of male labour force is important.

Education level of the household head is significant but negative, suggesting that increase in education level, reduces the chance for one to adopt treadle pump. This is contrary to findings by Nabbumba and Bahiigwa (2004), the higher number of years spent at school, the higher the level of profits realized from growing maize and that is perhaps associated with the ability to appreciate and take up improved technology. Another report by Sserunkuuma and Ainembabazi (2004) from Uganda, suggested that educated farmers may have other non-agricultural income sources that make it easier for them to pay the irrigation users fees. Therefore education enables one to engage in non- agricultural activities as well. From the survey, it was revealed that, majority of the households with stable source of income from formal employment tend to concentrate on paddy farming which does not necessarily require the use of the treadle pump.

Analytical results show that, age is significant and influence adoption of treadle pump negatively. Meaning that increase in age of the household head reduce the chances for him or her to adopt the treadle pump. This is consistent with Steel (1995) report, that older people have more experience but their receptivity to new ideas and technologies typically decreases with age. From the survey, respondent aged above 50 years, reported that, they could not operate the treadle pump, since it requires much energy, which they could not provide; amid their age. Therefore may be the explanation is a combination of two, both age in terms of neglecting to accept new ideas and in terms of less energy to operate the treadle pump.

On gender perspective, results show a significant and negative influence on adoption of treadle pump. A suggestion that, the treadle pump is not a gender-neutral technology. Similar observation was reported by Kay and Brabben (2000), which explained that, because an operator is elevated above the ground, women don't feel comfortable standing on the pump for long period. They feel exposed and consider it undignified.

4.13 Treadle pump maintenance

Majority of the farmers reported to have to experienced breakdown of their treadle pump, this is according to table 26. Out of this, those who purchased Mkombozi pump, a brand promoted by Enterpriseworks, contribute a large proportion. The fact suggests lack of quality standards adherence by the pump manufacturer, perhaps contributed by lack of experience. Seal is the most complained part of the pump.

Table 26: Cases of pump breakdown

	If ever experienced pump breakdown		
Source of treadle pump	Yes, percentage	Percentage	Overall percent
Entrepriseworks	65.90	13.64	
Approtech	2.28	18.18	
Total	68.18	31.82	100.00

Lack of proper knowledge on pump maintenance may have contributed as well. Similar cases were observed in Niger by Kay and Brabben (2000). And that importing of better quality leather (seal) from other West African countries was suggested as an alternative. However feared increased annual cost for the pump users and replacing a local material with an imported one.

4.14 Source of water for irrigation

From the table 21, it seems majority of the farmers rely on canal as a source of water for irrigation. As such many farms for vegetable production are located along the water canal leading to Mbarali farm. Therefore owners are capitalizing on strategic location of their farms. It seems treadle pump has afforded some farmers to utilize underground water. These are farmers located far away from the source of water. From the survey it was observed that such farmers use the underground water for domestic utilization, livestock and irrigation. Such household with tube well are generating income from selling water to their neighbours.

Table 27: Source of water

Source of water	Means of irrigation				
	Treadle pump	Bucket	Motorized pump	Total	Percent
Shallow well	5	3	0	8	14.55
Pod	1	0	0	1	1.80
Tube well	7	0	0	7	12.70
Canal	24	1	6	31	56.36
River	7	0	1	8	14.55
Total	44	4	7	55	100

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This chapter brings forward the conclusion, policy implication and recommendations based on findings of this study. The overall objective of the study was to assess factors determining adoption of treadle pump and how it impacts farm productivity.

More specifically the study aimed at:

Identifying factors determining adoption of treadle pump. Analysing financial and economic performance of the treadle pump. Examining relationship between treadle pump adoption and farm productivity. Determining whether treadle pump complements adoption of other improved technologies.

It was hypothesized that factors other than farm, household characteristics, technological factors and institutional influence adoption of treadle pump. There is no relationship between treadle pump adoption and adoption of other improved technologies. Treadle pump is not economically viable to smallholder farmers.

This study employed probit model to assess factors influencing adoption, whereby adopters we assigned 1 and non-adopters 0. Performance of the treadle pump was analysed using gross margin and Cobb-Douglass production function. While perception of the farmers on treadle pump was analysed using latent variable approach (factor analysis). Finally Chi-square was employed to check whether there was any relationship between treadle pump and adoption of other improved technologies.

5.2 Key findings

i. This study has found out that household size, number of male and farm size showed a significant positive influence on adoption of treadle pump. On the other hand, education and age seemed to affect adoption negatively.

ii. This study has showed that treadle pump contribute to increased farm productivity.

iii. Analysis on the economic performance of the treadle pump has displayed a positive gross margin, indicating monetary benefits to farmers accounted by increased area under cultivation, better crops yield, reduced time spent on irrigation, and better cropping pattern.

iv. This study found out that, there is a significant relationship between adoption of the treadle pump and the use of insecticide at farm level.

v. Farmers described treadle pump as a capital intensive, associated with high pressure; thus irrigate a relatively large area; economical in water use; however associated with gender biasness.

vi. Treadle pump has enabled farmers to access and utilize underground water reserve. The underground water is used for irrigation, domestic purposes and livestock.

vii. Supply is only at the point of manufacturing, lack of distributors oblige farmers to purchase directly from the pump manufacturer as for the case of Mkombozi pump. There is also a frequent breakdown of the pump, which is not supported by readily available spare parts.

5.3 Policy implication

i. Treadle pump is an important irrigation technology for improving agricultural productivity within a community of smallholder farmers. The extra income generated from farm production raises the need for output from and participation in non-farm activities, a result of which is poverty reduction.

ii. To ensure more equitable socio- economic development, there is a need of incorporating gender aspect in any technological development, so as to avoid gender biasness.

iii. Simple technologies, which can enable rural dwellers to access and utilize underground water, should be given a priority. Such technologies will provide rural households with water for irrigation, domestic utilization and livestock, of which total effect will be improved livelihood platform of the vast majority.

5.4 Recommendation

i. Proper supply chain determines sustainability of the entire intervention. In this respect ways and means should be devised to put in place a supply chain, which will enhance sustainability of the treadle pump project.

ii. Since treadle pump has enabled smallholder farmers to access and utilize underground water then a separate project on water supply should be established to ensure household far form the water supply can utilize underground water.

iii. Farmers should be mobilized to form water users associations and secure water right. This will ensure that farmers have access to water.

iv. Non- governmental organizations promoting the use of the treadle pump should join hands with the government extension officers, in order to enhance sustainability of the entire intervention.

v. Since the project has a positive impact at household level, then should be replicated to other areas with similar characteristics, as one of the approach towards poverty reduction.

vi. Modification of the treadle pump should be considered in relation to gender dimension. This will insure that no body is being marginalized by the intervention.

vii. On policy scenario, treadle pump should be incorporated within the national irrigation policy as one of the small-scale irrigation technology that is adaptable to smallholder farmers and one with potentials of improving living standard.

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APPENDICES

Appendix 1: Photo showing treadle pump

Appendix 2: Questionnaire for adoption and impact of treadle pump on farm productivity

Type of farmer is: 1 = adopter( ) 2 = Non-adopter ( )

A: BACKGROUND INFORMATION

1. Questionnaire number: ____________________Date:______________________
2. Interviewer's Name________________
3. Division______________ Village ______________
4. Household head's Name ______________________________ Age _________
5. Gender: 1 = Male ( ) 2 = Female ( )
6. Marital Status: 1 = single ( ) 2 = married ( ) 3 = Divorced ( ) 4 = Widow ( ) 5=never married ( )
7. Household Size _______________
8. Household Head: ____________________
9. Relation to household head:1 = Husband( ), 2= wife( ), 3=daughter( ), 4=son( ) 5=Relative( ) 6=non relative ( )
10. Level of education of the household head:

Level of education	Tick appropriate level	Years of schooling
No education		
Primary education		
Secondary education		
Other certificate courses		
Diploma course		
Degree		
Adult education		

11. Household composition

Age group	Actual age	Number of Males	Number of females
Below 10 years			
11-20 years			
21-30 years			
31-40 years			
41-50 years			
Above 50years			

12. Main occupation of the household head: 1 = No occupation ( )
2 = crop farming ( )
3 = livestock keeping ( )
4 = fishing ( )
5 = bee keeping ( )
6 = employed by government ( )
7 = employed by NGO ( )
8 = employed by private sector ( )
9 = self employed in business

10 = self employed in partisan (carpentry, tailoring) ( )

(13) major crop enterprise

Crop	Rainfed (area in acres)	Irrigated (area in acres)	Number of season growing per year.
Tomato			
Maize			
Rice			
Chinese cabbage			
Onion			
Others (specify)			

B: ADOPTION OF TREADLE PUMP.

(1) number of treadle pump owned -------
(2) year of purchase---------------
(3) supplier of the pump (a) Enterpriseworks ( ) (b) Approtech ( ) (c) any other specify ( )
(4) price ---------
(5) source of information regarding treadle pump-----------------------------
(6) source of finance for purchasing treadle pump (a) own saving ( ) (b) credit ( )
(7) please mention any other item purchased and used with the treadle pump-----------------price-------------------
(8) Have you ever needed to repair treadle pump (1) yes ( ) (2) no ( )
(9) How many times it has been repaired --------------
(10)Where do you purchase spare parts (a) stockist ( ) (b) pump manufacturer ( ) (c) any other specify ( )
(11)Is there a problem of spares parts availability (a) yes ( ) (b) no ( )
(12) How do you use treadle pump
  (a) brick making
  (b) for irrigation
  (c) for drawing water for domestic use
  (a) any other (specify

(13) what is the source of water (a) shallow well( ) (b) pod ( ) (c) tube well ( ) (d) canal ( ) (e) any other specify

(14) What type of irrigation system do you use
(a) treadle pump with sprinkler
(b) treadle pump with furrow
(c) treadle pump with bucket
(d) treadle pump only
(e) any other specify

I like treadle pump because it is	Strongly agree 1	Agree 2	Neither 3	Disagree 4	Strongly disagree 5
Capital intensive					
Mobility					
Easy of operation					
Price is affordable					
Area under irrigation					
Water pressure					
Reduce water loss					
Enable to exploit underground water					
Any other specify					

15. What was the reason for adopting treadle pump
(a) irrigate more land
(b) reduce time spent on irrigation
(c) easy to use
(d) cheaper

16. What method of irrigation were you using before starting to use treadle pump-------
17. What is your opinion regarding treadle pump------------------------------------

C: FARM PRODUCTION AND BUDGET

Crop type			
Farm size in acre			
Producer price in Tshs			
Revenue in Tshs			
FARM OPERATIONS	**Man days**	**Family or hired labour**	**Cost per acre**
Land preparation			
Planting			
Weeding			
Spraying			
Fertilizer application			
Irrigation			
Harvesting			
Bird watch			
Threshing, winnowing			
Packaging			
Transporting			

MATERIALS	QUANTITY USED	PRICE PER UNIT	TOTAL COST
Seeds in gram or kg			
Fertilizer in kg or bags			
Herbicide in litres			
Insecticide in litres or kg			
Fungicide in kg or litres			
Spray rental			
Packing material			
Any other specify			
Marketing			
Total variable cost per acre			
Total revenue per acre			
Gross margin per acre			

D: IRRIGATION AND AGRONOMIC PRACTICES

(1) How many times within a week do you irrigate a particular farm?

Area in acres or m2	Crop type	Yield in kg or debe	No hours used in irrigation per day	No of irrigation days per week	Irrigation method (i.e. treadle pump, furrow, bucket, etc)

(2) Who normally practice irrigation?

Irrigation method (i.e.teadle pump, bucket, ect)	Male	Female

(3) How far is the source of water to the farm

(a) very near
(b) near
(c) far

(3) Indicate whether there was pest attack

(a) Weed infestation
(b) Insect attack
(c) Fungi attack
(d) Any other specify

(4) Indicate whether the following practice were done during last crop season

(a) weeding
(b) insecticide application
(c) fungicide application
(d) none
(e) any other specify

(5) Was there a fertilizer application Yes=1 ( ) No=2 ( )

(6) Mention type of fertilizer applied

Area applied in m2 or acre	Crop type grown	Type of fertilizer	Amount of fertilizer used in kg

(7) Please indicate whether any of the activity was practiced.

(a) intercropping
(b) furrowing
(c) manure application
(d) crop rotation
(e) application of composite
(f) application of inorganic fertilizer

(8) where did you obtain seeds for planting

(a) from agro-shop (input supplier)
(b) form previous harvest
(c) any other specify

(9) Mention crops, which are under rainfed

Area in acre or m2	Crop type	Yield in kg or bags or debe

E:HOUSEHOLD INCOME

(1) What is major source of income

(a) Salary/wages ( )
(b) Off- farm activities ( )
(c) Farming activities ( )
(d) Others (specify) ( )

(2) Indicate crops produced if is for market or domestic consumption

Crop type	Amount marketed in kg	Market price	Revenue in TShs	Domestic consumption (amount in kg)

F:OFF FARM INCOME

(3)Apart from the crop farming activities, list other activities that bring income into your household,

Source of income	**Number of people employed in Household**	**How many females**	**How many male**	**Amount earned in Tshs.**
Formal employment				
Casual labor				
Livestock sales				
Brewing and selling local brew				
Carpentry				
Selling charcoal/firewood				
Small business				
Brick making				
Masonry				
Lumbering				
Others (specify)				
Total				

G: DAILY EXPENDITURE

(1)Describe your weekly expenditure and the amount purchased per item

Item	Amount per item	Last Week (7 days)
Food purchase		
1.salt		
2.onions		
3.sugar		
4.vegetables		
5.grains (rice/maize/sorghum		
6.meat/poultry/fish		
7.cooking oil		
8.Beer and refreshments		
Total		

H: HOUSEHOLD CHARACTERISTICS AND ASSETS

(1)What kind of roofing does the household have: 1 = Modern (tiles, iron sheets) ( ), 2 = Poor(mud/grass) ( ) 3 = concrete ( )

(2) What are the walls made of: 1= bricks ( ) 2 = mud ( )

(3) What are the floors made of: 1 = concrete ( ) 2 = earth ( )

(4) Indicate the if you own the following assets:

Item	Number	Item	Number
Hoe		Radio	
Machete		TV	
Wheelbarrow		Cell phone/land line	
Sprayer		Stove (gas/electric)	
Bicycle		Fridge	
Car			
Tractor		Land (acres)	
Sickles		Livestock	
Ox-carts		-cattle (cows etc)	
Ox-ploughs		-sheep	
Axe		-Goats	
Other (specify)		-Donkeys	
		-Pigs	
Radio		-Chicken	
TV		Others (specify)	

Thanks for your cooperation