ASSESSING THE FINANCIAL VIABILITY OF INVESTING IN SMALL-SCALE IRRIGATION TECHNOLOGY FOR POTATO PRODUCTION IN DEDZA AND NTCHEU DISTRICTS OF CENTRAL MALAWI

By

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To my wife, Chrissie and my two sons, Chris and Peter for their love

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LIST OF ABBREVIATIONS

BCR	Benefit Cost Ratio
FAO	Food and Agricultural Organization
GDP	Gross Domestic Product
IRR	Internal Rate of Return
KOV	Key Output Variables
MoAFS	Ministry of Agriculture and Food Security
MP	Motorized Pumps
MK	Malawi Kwacha
NFCI	Net Farm Cash Income
NFI	Net Farm Income
NPV	Net Present Value
ODI	Overseas Development Institute
PBP	Pay Back Period
PDF	Probability Density Function
TP	Treadle Pumps
UNDP	United Nations Development Programme

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Over 50% of small scale farmers in Malawi leave on less than $1.00 a day and are food insecure. This stems from scarcity and seasonality of rainfall, lack of access to fertile arable land suitable for sustained rain-fed farming and lack of crop diversification. In response to this the Malawi Government developed a National Irrigation Policy and Development Strategy in June 2000. The Policy Document highlights financial viability of investing in small scale irrigation as one of the research needs.

This study examines and analyzes the financial viability of investing in small-scale irrigation technologies for potato production in Central Malawi. The study identified seven irrigation scenarios: motorized pump-furrow, motorized pump-sprinkler, motorized pump-drip, treadle pump-furrow, treadle pump-basin, treadle pump-canal and drum drip kits. The financial viability of investing in the seven scenarios was assessed using net present values, benefit cost ratio and probability of generating positive net farm cash incomes.

With the help of risk analysis software Simetar©, a distribution of 500 iterations for the three key output variables for each irrigation technology was generated. The results

show that the individual irrigation scenarios are financially viable. Each scenario gives a positive net present value and the benefit cost ratio for each scenario is greater than one. The scenarios also have a probability of at least 80% of generating positive net farm cash incomes.

The motorized pump-furrow scenarios and treadle pump-furrow scenarios provided the highest mean net present value. The drip scenarios yielded the lowest mean net present value. The probability of generating positive net farm cash income increased with the passage of time. After three years of operations, the probability of generating positive net farm cash income rose to 100%.

CHAPTER 1
INTRODUCTION, PROBEM STATEMENT AND OBJECTIVES

Introduction

Malawi is one of the poorest countries in the world with per capita gross domestic product (GDP) of $190, 30% of under-five children being malnourished and the infant mortality rate of 229 per 1,000 live births and a life expectancy at birth of 42 years (World Bank, 2001). Poverty levels have remained relatively high despite the Malawi government instituting several poverty alleviation programmes over the decades. The 1998 Integrated Household Survey and the 2004 Integrated Household Survey show that while poverty rate was estimated at 54.1% in 1994, the figure went down to only 52.4% in 2004 (Malawi Government/World Bank, 2006).

The economy is heavily dependent on agriculture, which accounts for over 80% of employment and foreign exchange earnings, and nearly 40% of GDP (UNDP, 2005). The agricultural sector is divided into two subsectors: the estate subsector and smallholder subsector. The estate subsector has a small number of large-scale farmers covering about 17% of the cultivated land and is the major contributor to growth and employment; with the major export crops being tobacco, sugar and tea (Overseas Development Institute, 2005). The smallholder subsector covers the rest of the cultivated land. It dominates food production providing livelihood to over 2.4 million households (Academy for Educational Development, 2007).

The main crops grown by the smallholder farmers are maize, tobacco, cassava, groundnuts, potatoes, cotton, sorghum and millet. Of these crops maize occupies 75% of the cultivated land and is cultivated by over 95% of the farmers (Academy for Educational Development, 2007). According to the Academy for Educational

Development, for most Malawians, maize is synonymous with food and a sense of food security at the household level. However, maize production has been declining over the recent years and demand for food has been increasing steadily. Malawi is not able to meet its food requirements. Kundell (2008) identified the following as the major reasons

a) the failure of food production to keep pace with increases in the human population;

b) lack of water (droughts) and inability to use it for agricultural production;

c) declining soil fertility, combined with shrinking average farm holdings;

d) inappropriate and outdated agricultural technologies; and

e) the perception by many that maize is the only food even if other crops that are more adapted to drought are available.

Thus Vulnerability to shocks such as climatic hazards-dry spells, seasonal droughts, intense rainfall and flash floods (Malawi Governmnet, 2006) has led to a decline in productivity. This is aggravated by mounting land pressure, declining soil fertility, lack of diversification in the agricultural sector and reliance on rain-fed agriculture (Overseas Development Institute, 2005).

Potatoes and Food Security

It has been argued that crop diversification, rather than increased maize production, is the way off the poverty treadmill (Rubey, 2003). One of the crops that is becoming important as a food security crop is the potato. Globally the potato is an integral part of the food system (FAO, 2009). According to FAO, the potato is

a) the world's number one non-grain food commodity and its consumption is expanding strongly in developing countries; where its ease of cultivation and high energy content have made it a valuable cash crop for millions of farmers.

b) a highly recommended food security crop that can help low-income farmers and vulnerable consumers ride out the turmoil in world food supply and demand because, unlike major cereals, the potato is not a globally traded commodity, and its prices are determined usually by local production costs, not by the vagaries of international markets.

Roots and tubers are a major source of sustenance in Sub-Saharan Africa (International Food Policy Research Institute (IFPR), 2001). A high demand and production scenario shows that the total use of roots and tubers in developing countries is likely to increase by 74% between 1993 and 2020; with more than half of the increase attributable to faster growth in the use of potato (IFPR, 2001). Roots and tubers also serve as sources of cash income for low-income farm households and raw material for processed products for both rural and urban consumption.

In Malawi, roots and tubers play an important role in food security and providing income to rural farm households. During the 2001 food crisis which recorded a 32% reduction in national maize production, the Ministry of Agriculture and Irrigation believed that the high production of roots and tubers (cassava, sweet potatoes, Irish potatoes) in the same year offset the dip in maize production and provide adequate, if not surplus, food for the country (UNDP, 2008). In addition a pilot phase of a tripartite partnership among Universal Industries Limited (the largest confectionary manufacturer in Malawi), International Potato Centre (a leading research institution) and Concern Universal working with communities and the Government of Malawi to improve potato production and to bring about improved incomes of smallholder farmers shows that improved potato production brings about increased income for smallholder farmers (Concern Universal, 2008). The crop is deemed important enough today to warrant a program of research and extension by the national government in cooperation with international organizations, notably the International Potato Center (Nsanjama, 1984).

Irrigation and Food Security

A study by GTZ (2006) noted that population pressure in many countries, including Malawi, has exhausted the access to fertile arable land suitable for sustained rain-fed cultivation. This has forced millions of subsistence farmers to toil land that has minor potential to meet their household food requirements. According to GTZ, these physical constraints are often compounded by harsh climatic conditions with scarce rainfall and a more pronounced seasonality of the rains. As a result there is an increasing need for developing small scale irrigation schemes for smallholder farmers. According to NEPAD/FAO (2005), the development of irrigation is critical to offering real prospects for boosting productivity, diversifying production and mitigating against the effects of drought. Postel (1999) noted that irrigated plots in developing countries commonly yield twice as much as rain-fed plots do. Postel argues that with irrigation, farmers can choose to invest in high-yielding seeds, grow higher-value crops, have a normal harvest even during periods of scarce rainfall, and harvest two or more crops from same piece of land in a year.

Malawi is gifted with large water resources-lakes, rivers and the traditional dambos (wetlands). Almost one fifth of the country is covered by water. However, despite the huge water resources, agriculture is rain-fed. Irrigated land comprises only 0.6% of total arable land in Malawi. The existing potential for irrigation is far from utilized, especially in the area of low-cost water harvesting measures (Carr, 1997).

Problem Statement

More than 50% of smallholder farmers in Malawi are poor and food insecure. This stems from increased pressure on land due to rapid population growth, weather shocks, reliance on rain-fed agriculture and lack of crop diversification. All this is happening while there is potential for diversifying from maize and developing small-scale irrigation for smallholder farmers. NEPAD/FAO (2005) noted that irrigation resources are underutilized and there has been no recent detailed study to identify and evaluate the potential to utilize the groundwater resources for small-scale wet season supplementary irrigation and dry season irrigation of high value crops. Furthermore there is limited information among farmers, investors and policy makers on the viability of small-scale irrigation systems for potato production in Malawi.

Hypothesis

Investment in small-scale irrigation (SSI) for potato production is a financially viable investment option.

Objectives

The overall objective of this study is to assess the financial viability of investing in small-scale irrigation technology for potato production in Dedza and Ntcheu Districts of Central Malawi. The specific objective of the study is to develop a model which, under a given set of assumptions, should be able to

a) determine initial investment and operating costs of different irrigation technologies,

b) determine the projected net cash flows per hectare for each irrigation technology,

c) determine net present value (NPV) and benefit cost ratio (BCR) for each irrigation technology, and

d) determine the probability of generating positive cash flows from each irrigation technology.

It is the aim of this study to become a tool for potato farmers for analyzing investments in irrigation. The study should be of interest to farmers, government departments and other stakeholders in the agricultural sector. The study should give them a tool for decision making.

CHAPTER 2
LITERATURE REVIEW

Introduction

The purpose of this chapter is to provide a review of work already done on determining financial viability of investments. The chapter also reviews some work on potato production and irrigation technologies.

Financial Viability

In June 2000, the Malawi Government developed a National Irrigation Policy and Development Strategy. Article 7.3.6 of the Policy Document highlights *“Financial Issues (e.g. financial viability from a farmers’ perspective)”* as one of the research needs in the Irrigation Sub-sector. Financial viability is the extent to which project can be justified financially. A financially viable project is the one that is a sound business proposition capable of earning a rate of return that satisfies the investors and which generates cash-flows sufficient enough to keep it going.

Financial viability of an irrigation system is important to farmers. Investing in an irrigation technology involves committing huge sums of money. This has huge implications on farmers’ future profits and cash-flows. The benefits of such commitments extend into the future and once the commitment is made the expenditure is irreversible (Seo et al, 2006).

A large body of literature exists regarding techniques that are used to determine financial viability of investment projects. These methods range from the traditional payback period (PBP) to advanced methods such as net present value (NPV) and internal rate of return (IRR). The traditional techniques rank projects based on accounting profits and do not take into account the time value of money while the advanced techniques, apart from taking into account the overall profitability and returns of projects, also base the analysis on net cash-flows (Akalu, 2003), and take into account the time value of money. These techniques are discussed further in Chapter 3.

There are a number of studies analyzing the viability of investing in different irrigation technologies.

Mloza-Banda (2006) and Kadyampakeni (2004) used gross margin analysis to analyze the viability of different irrigation technologies based on a bean crop. They found that there were variations in viability across different technologies. Farmers who used motorized pumps realized negative gross margins while those who used treadle pumps, watering cans, gravity irrigation and residual moisture realized positive gross margins.

Another study by Mangisoni (2006) used net farm income (NFI) to analyze the impact of treadle pumps on poverty and food security in Malawi. Mangisoni found that adopters of treadle pump irrigation technology had higher NFI than non-adopters. The NFI of adopters of the technology was five times higher than that of non-adopters. Mangisoni found that, in Blantyre district, the adopters got an average NFI of MK122,855 while the non-adopters got NFI of MK15,987. Similar results were found for Mchinji district.

Postel, S., et al (2001) focused on innovations that are designed to provide smallholder farmers with appropriate, affordable and highly efficient technologies. Postel et al. reported that farmers who adopted low-cost drip irrigation technology had reported yield increases of between 50% and 100%. According to Postel et al., the adopters of the technology also had a decrease in water use of between 40% and 80%. Postel et al.

also analyzed farmers who adopted treadle pumps. It was found that the adopters of the treadle pump got extra income that enabled them to graduate to higher levels of mechanization.

Malik and Luhach (2002) used NPV, IRR and BCR to determine the viability of drip irrigation for fruit production. They found that investment in drip irrigation for fruit production was sound and economically viable. Senkondo et al (2004) also used NPV, IRR and BCR to analyze investments in rainwater harvesting for dry season irrigation for maize, rice and onions. They found that investing in rainwater harvesting for maize, rice and onions is financially viable. To determine how sensitive the investment was to changes in variables, Senkondo et al increased input costs by 20% and reduced selling prices by 20% and found that the NPV was positive, IRR was above cost of capital and BCR was greater than 1 for maize and onions production only.

There are some similarities between this study and the studies discussed above. The focus of all the studies is analyzing the viability of irrigation technologies. This study draws some lessons from the studies discussed above. However, to accomplish its purpose, this study has several marked differences in approach from the above studies.

a) The studies discussed above, except for Mloza-Banda (2006) and Kadyampakeni (2004), analyze one irrigation technology only (for example drip only) or compare two different irrigation technologies (such drip versus furrow). This study analyzes and compares the viability of three different irrigation technologies (motorized pump, treadle pump and drip) that lift water from the water source to the field and five technologies (basin, canal, furrow, sprinkler and drip) that convey water from the field to the plant. This is done to enable farmers to have a wider basis for decision-making when it comes to investing in irrigation technologies.

b) There are some differences between the methods used in this study and the some of the methods used in the studies above. The use of gross margins and NFI were justifiable for the studies conducted by Mloza-Banda, Kadyampakeni and Mangisoni respectively. Gross margin is the difference between revenues and cost of sales. Gross margin analysis ignores some costs (such as marketing costs) which affect a farm’s cash earning capacity. NFI, on the other hand, is an accounting profit which is based on accrual accounting. NFI includes both cash and non-cash receipts and costs. This study uses net farm cash income (NFCI) and capital budgeting techniques as measures of financial viability. NFCI is used because the ability to generate cash goes a long way in determining the survival of entities including farms and capital budgeting techniques are used because they take into account the time value of money.

c) The other marked difference taken by this study is the use of simulation analysis. While using measures such as NPV, IRR, BCR and PBR; this study recognizes that these measures are deterministic. To account for the stochastic nature of the variables involved, a simulation analysis is carried out so that the farmers have a complete distribution of possible outcomes.

d) While this study focuses on potato production, none of the studies above does so. Potatoes have been chosen because they are becoming a major part of the global food system as discussed in the next section.

Potato Production

Potatoes were brought to East and Central Africa in the 19th century by missionaries and European colonialists, but the crop did not become important to Malawians until the 1960s, when production was estimated at 60,000 tonnes a year (FAO, 2009). The crop is deemed important enough today to warrant a program of research and extension by the national government in cooperation with international organizations, notably the International Potato Center (CIP) (Nsanjama, 1984).

Now Malawi is sub-Saharan Africa’s biggest potato producer. In 2007 Malawi was the second highest producer of potatoes in Africa with a harvest of 2.2 million tonnes. Although only a tiny proportion of Malawi’s potatoes is exported, annual consumption of the potato had more than tripled between the years of 1994 and 2009 to 88 kg per capita (FAO, 2009).

The potato is grown mainly in highland areas in the country’s southern and central regions. The most suitable areas are those at altitudes of between 1,000 and 2,000 m above sea level which receive more than 750 mm of annual rainfall (Gondwe, 1980). In the central region potato production is concentrated in the districts of Dedza and Ntcheu near the eastern border with Mozambique (Gondwe, 1980). While in the southern region, production is mainly around the districts of Blantyre and Mwanza (Gondwe, 1980). Although potato production appears to be relatively unimportant in the Northern region, suitable areas have been identified, particularly the Nyika Plateau and the northern border with Tanzania (Malunga, 1982).

McDonagh (2002) studied “Crop-based farming livelihoods and policies in Malawi.**”** McDonagh found that potato farming is the most common new crop across all income groups. In his paper, McDonagh states that “vegetable production (irish potatoes, particularly) are a somewhat less risky option as they can be sold at local markets.” This view is supported by FAO (2009). According to FAO (2009) the potato is a highly recommended food security crop that can help low-income farmers and vulnerable consumers ride out the turmoil in world food supply and demand. FAO argues that, unlike major cereals, the potato is not a globally traded commodity, and its prices are determined usually by local production costs, not by the vagaries of international markets.

Potatoes are also becoming a major part of the global system because they can be used for a variety of purposes. According to FAO (2009)

a) potatoes are eaten fresh, frozen or dehydrated.

b) potato starch is used as an adhesive, binder, texture agent and filler. FAO states that “Potato starch is a 100% biodegradable substitute for polystyrene and other plastics and used, for example, in disposable plates, dishes and knives.”

c) potatoes are used for feeding animals. Studies show that pigs fatten quickly on 6kg of boiled potatoes.

d) peels and other potato wastes can be fermented to produce ethanol. A study shows that 440,000 tonnes of processing waste can produce between 4 to 5 million litres of ethanol.

FAO estimates that less than 50% of potatoes grown worldwide are consumed fresh and the rest are processed into potato food products and food ingredients, fed to cattle, pigs and chickens, processed into starch for industry, and re-used as seed tubers for growing the next season's potato crop.

In Malawi, the potato is also becoming very important. FAO statistics indicate that, in terms of the value of production, potatoes are among the top three crops produced in Malawi. In 2005, potatoes ranked first with a value of $261,090,000 and were seconded by maize at a value of $203,350,000 (FAO Statistics, 2009).

The above and other statistics may indicate that potato production is a financially viable farming option that could help to improve incomes of smallholder farmers in Malawi. For this reason this study carries out an analysis to determine if potato production is financially viable from the perspective of the smallholder farmer.

Irrigation Technologies

The unpredictability of weather patterns (especially erratic rainfall) has made agricultural production more risky. Weldon et al. (1984) state that "new crop varieties, pesticides and irrigation are examples of technologies that have reduced risk and increased income". In their paper, Weldon et al. stress that irrigation cannot eliminate the risk altogether but can reduce the risk of low yields on soils with low available water holding capacity. Thus this study focuses on investing in irrigation as one of the measures for reducing risk, not eliminating it.

Several studies on irrigation have been conducted in Malawi. The most notable of these are "Smallholder Flood Plain Development Program-Irrigation Technologies

Diagnostic Study" (Makoko, 2000), "The Impact of Treadle Pump on Small-Scale Farmers in Malawi" (Itamura & Shinohara, 2004), "Comparative Analysis of Different Irrigation Technologies and Water Management Techniques for Dry Season Cultivation of Beans in Chingale Agricultural Development Program" (Kadyampakeni, 2004), and "Experiences with Micro agricultural Water Management Technologies: Malawi" (Mloza-Banda, 2006).

All the above studies show that there is potential for irrigation farming in Malawi and Mloza-Banda identified irrigation technologies that need amplification. The five technologies identified include:

a) treadle pump irrigation
b) river diversion irrigation (canalization)
c) residual moisture cultivation
d) small earth dams, and
e) river impounding/weirs.

Apart from the studies carried out in Malawi mentioned above, there are also studies completed in other countries. The most notable is the FAO (1997) proceedings of a subregional workshop in Harare on "Irrigation Technology Transfer in Support of Food Security." A report by Perry (1997) from the proceedings discusses low-cost irrigation technologies for food security in sub-Saharan Africa. Perry classifies the technologies into "improved manual irrigational technologies" and "mechanized technologies for small-scale irrigation." The improved manual irrigation technologies include the traditional rope and bucket method, the motorized pump and the treadle pump; while the mechanized technologies include high capacity-mechanized pumps inserted in hand-dug wells. Perry indicates that the mechanized technologies assist in water lifting, groundwater development and water distribution.

Considering that the target group is smallholder farmers, this study, focuses on both manual and mechanized technologies. The particular focus is the treadle pump, drip technology, motorized pump, basin, furrow, canal and sprinkler systems as shown in the Figure 2-1.

Chapter Summary

Studies show that there are several types of irrigation technologies that smallholder farmers can adopt. This study applies these technologies to potato production as literature suggests that potatoes are becoming important to increasing smallholder incomes. Chapter 3 lays out the methodology for determining the financial viability of the technologies.

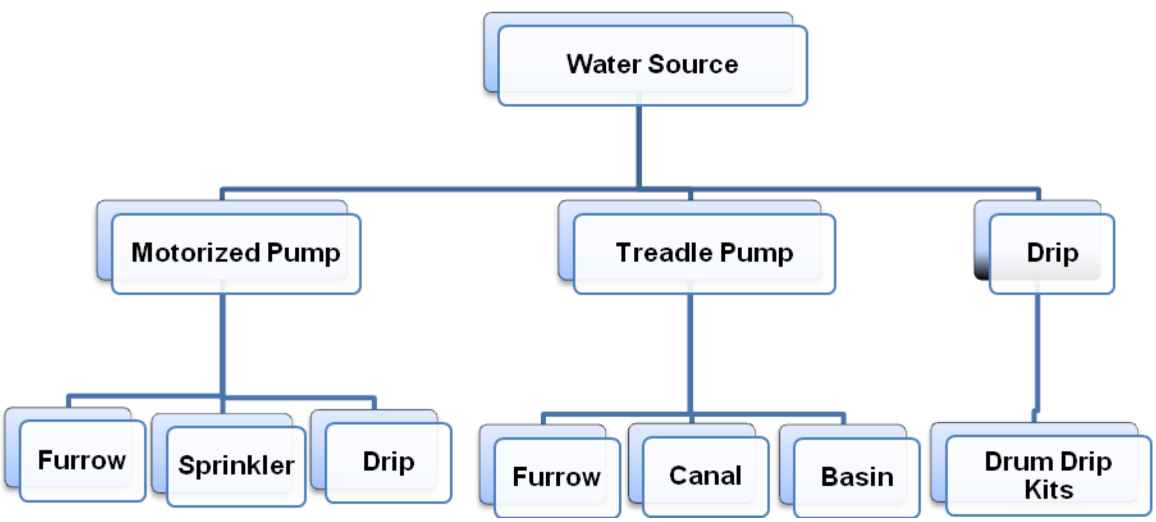

Figure 2-1. Irrigation technology scenarios.

CHAPTER 3
METHODOLOGY

Introduction

This study uses secondary data. Data is collected through field visits to selected Malawi Government Irrigation Schemes, and to Concern Universal's Food Security and Sustainable Livelihoods Project. The government schemes are chosen because they are the oldest and largest irrigation schemes in Malawi. Concern Universal's Food Security and Sustainable Livelihoods Project is chosen because Concern Universal's two components of integrated sustainable livelihoods that are getting increasing attention are crop diversification and the development of small-scale irrigation schemes. Concern Universal is working with communities in Dedza and Ntcheu districts of Central Malawi to improve potato production and bring about improved incomes for smallholder farmers.

Other data is collected from Malawi's Ministry of Agriculture and Food Security, FAO website, University of Florida and University of Malawi libraries. The data collected includes:

a) initial investment costs for each irrigation technology
b) operating costs for each irrigation technology
c) historical potato yields, prices and costs of production, and
d) energy (diesel) costs

Methods

This study evaluates financial viability of investing in different irrigation technologies using net present value (NPV), benefit-cost ratio (BCR) and probability of generating positive net farm cash incomes (NFCI).

Net Present Value (NPV) Method

The NPV of an investment is the sum of discounted future cash-flows matched with the initial investment. Under the NPV method, an investment is worth undertaking if the discounted cash-flows over the project's life are equal or greater than the initial outlay. Thus the decision rule is to accept projects with positive NPV and reject those with negative NPV (Brigham & Ehrhardt, 2008).

Future net cash flows are discounted to present values based on the modification of Barry et al. (1995) formula.

$$NPV = -I + NCFI_1/(1+i)^1 + NCFI_2/(1+i)^2 + \ldots + NCFI_n/(1+i)^n \qquad (3\text{-}1)$$

Where: I is the initial cost of investing in an irrigation technology, $NCFI_1$, $NFCI_2$… $NFCI_n$ are net farm cash incomes for each year, i is the interest or discount rate, and n is the life span of the irrigation technology.

Net farm cash incomes (NFCI) for each year are computed by deducting total operating cash payments from total cash receipts. Thus

$$NFCI = Q.p - TOC \qquad (3\text{-}2)$$

Where: Q is yield per hectare, p is unit price, and TOC is total cash costs.

Benefit Cost Ratio (BCR) Method

The benefit cost ratio (BCR) method compares the sum of discounted benefits to the sum of discounted costs. BCR of greater than 1 indicates that the project is profitable. The decision rule is to accept project with BCR of greater than 1 and reject those with BCR of less than 1. From Equation 3-2, BCR is given by:

$$BCR = \sum Q.p_d / \sum TOC_d \quad (3\text{-}3)$$

Where $\sum Q.p_d$ is the sum of discounted cash receipts and $\sum TOC_d$ is the sum of discounted cash costs.

In doing the analyses using the methods above, consideration is made explicitly about the discount rate. Enters (1998) noted that there is a long debate about what the discount rate should be. According to Enters, normally market rates are used when analyzing agricultural projects and most investment calculations use rates between 5% and 15%. In Malawi, the Reserve Bank sets the base lending rate for commercial banks and currently the rate is set at 15%. Therefore, this study uses a rate of 15%.

Probability Positive Net Cash Farm Income (NFCI)

NPV and BCR may not be the only key output variables (KOVs) that may be of concern to farmers. Other KOVs exit. One example of such KOVs is the probability that the farmer will generate positive net farm cash incomes (NFCI). This study, therefore, also determines the probability that farmers will generate positive NFCI under each of the irrigation technology scenario.

Annuities

The different irrigation technologies have different life spans. As such, the NPV calculations made are based on those different time horizons. If farmers are to decide between technologies that have different life spans, a direct comparison of the NPV generated by each technology would not be valid. A farmer who decides to invest in a technology with a shorter life has the opportunity to invest in a new technology sooner than if the farmer invested in a longer term technology. This has to be taken into account when analyzing the different technologies so that a direct comparison can be made between technologies with unequal lives. To overcome this problem, the NPV are converted to annuities.

Annuities are constant cash flows from year to year. By converting the NPV for each technology to an annuity, a comparison was made between the NPV of technologies with different time spans. This enables the farmers to look at annual streams of cash. The NPV are converted to annuities using Equation 3-4:

$$NPV \cdot i \,/\, (1 - (1+i)^{-n}) \qquad (3\text{-}4)$$

Where NPV is the net present value for a technology as determined using Equation 3-1; i is the discount factor; and n is the life span of the technology.

Simulation Analysis

The values estimated using the above procedures are single values. However a range of probable outcomes exist because of risk. This study uses simulation technique to capture the riskiness of investing in the different technologies. Under this technique a forecasting model is used to forecast Q, p and TOC in Equations 3-1, 3-2 and 3-3. The study builds two scenarios (non-irrigated operation and irrigated operation) during the simulation process using input values for the project’s key uncertain variables. Software Simetar© (Simulation for Excel to Analyze Risk) is used to carry out the simulation analysis.

Figure 3-1 shows modification of the risk analysis process developed by Savvides (1994) which is used in this study to generate a risk profile of investing in irrigation technology for potato production.

Developing a Forecasting Model

The first stage of the stochastic model involves the identification of critical variables that have an impact on the success or failure of investing in the irrigation technologies. It also involves developing mathematical relationships between the variables. This study identifies several risk variables. The variables identified include labor costs, energy (diesel) prices, pests and disease incidences, prices of inputs, levels of production, inflation and type of irrigation technology. Figure 3-2 shows the model used to define the mathematical formulae for processing input variables to arrive at the key output variables (KOVs). This study uses NPV, BCR and Probability Positive Net Cash Flow as KOVs.

Probability Distributions

The next step involves developing probability distributions for the risk variables as was discussed by Savvides (1994), Poulinquen (1970), and Jones (1972). Several probability distributions are identified for each risk variable. The probability distributions used in this study include the empirical, GRKS and triangle.

The empirical distribution is used where the risk variable ccan take on continuous values, or where there are limited obsevations for the risk variable such that it is difficult to estimate the the parameters of the true probabability density function (PDF) (Richardson 2006).

The GRKS distribution and triangle distribution are used where only three pieces of information such as minimum, mode and maximum can be identified (Richardson, 2006). Richardson suggests that the three values (minimum, mode and maximum) should be used to define a subjective distribution that can be used until something better is developed.

Correlation Conditions

Two or more risk variables may be associated. Such associations may bias the results of risk analysis. To avoid the bias, software Simetar© is used to test correlations among the variables. This is done to restrict the random selection of values for correlated variables to the direction and limits of their expected dependency (Savvides, 1994). The correlations are determined using Equation 3-5 below.

$$\rho_{i,j} = \frac{\sigma_{ij}}{\sigma_i \sigma_j} \qquad (3\text{-}5)$$

Where $\rho_{i,j}$ is the correlation between risk variables i and j, σ_{ij} is the standard deviation existing between risk variables i and j, σ_i is the standard deviation of risk variable i, and σ_j is the standarddeviation of risk variable j.

Simulation Runs

The values of the risk variables are drawn from the specified probability distributions repeatedly by Simetar© simulation engine. This study uses a sample of 500 iterations. The stochastic results of the model (i.e. net present value, benefit-cost ratio and probability of positive cash flows) are computed and stored following each run.

Analysis of Simulation Output

The last part of analyzing the risk involves statistical analysis and interpretation of the results from the simulation runs. Probability distribution functions (PDFs) graphs are constructed from the 500 iterations to compare risk profiles of the investment for the various perspectives. To arrive at a decision the following guide is used:

a) If the minimum point of the PDF of the NPV for an irrigation technology is greater than zero, the technology is accepted (Figure 3-3). If the maximum point of PDF of the NPV for an irrigation technology is less than zero, the technology is rejected (Figure 3-4).

b) If the minimum of the PDF of the NPV ofor an irrigation technology is less than zero and maximum point is greater than zero, the technology is neither accepted nor rejected. Assuming other factors remain constant, the decision will depend on risk preference of the farmer (Figure 3-5).

c) If the PDFs of theNPV for the different irrigation technologies do not intersect when plot together, the technology whose CDF is on the far right is chosen (Figure 3-6). If PDFs of the NPV for the different irrigation technologies intersect, the choice will depend on the individual farmer’s risk preference (Figure 3-7).

d) If the benefit cost ratio (BCR) of the irrigation technology is greater than zero, accept the technology.

Summary

This chapter describes the outline of the research methodology. The study uses secondary data. Capital budgeting techniques (NPV, BCR and probability positice cash flows) are used to analyze and determine the viability of investing in irrigation technology for potato production. Simulation analysis is carried out to take account for risk.

Stage 1 Forecasting Model (Preparation of a model capable of predicting reality)
Stage 2 Probability Distributions (Definition and allocation of probability weights to a range of values)
Stage 3 Correlation Conditions (Setting relationships for correlated variables)
Stage 4 Simulation Runs (Generation of random scenarios based on a set of assumptions)
Stage 5 Analysis of Simulation Output

Figure 3-1. Risk analysis process.

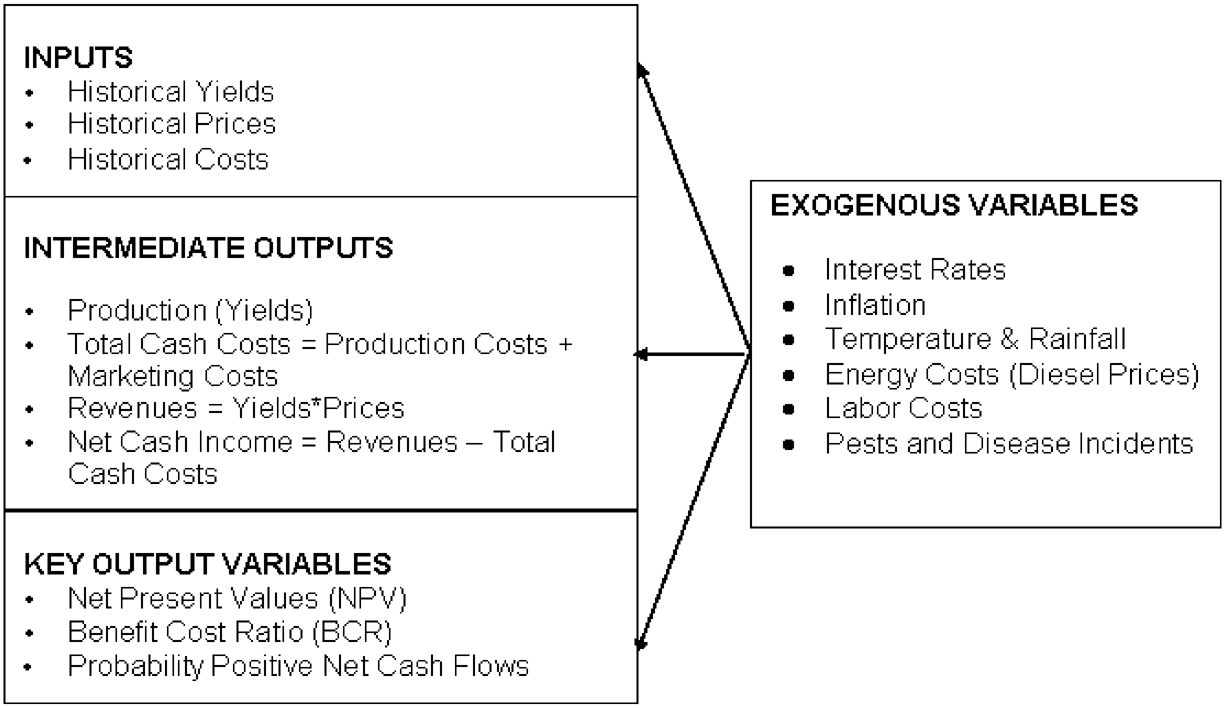

Figure 3-2. Forecasting model.

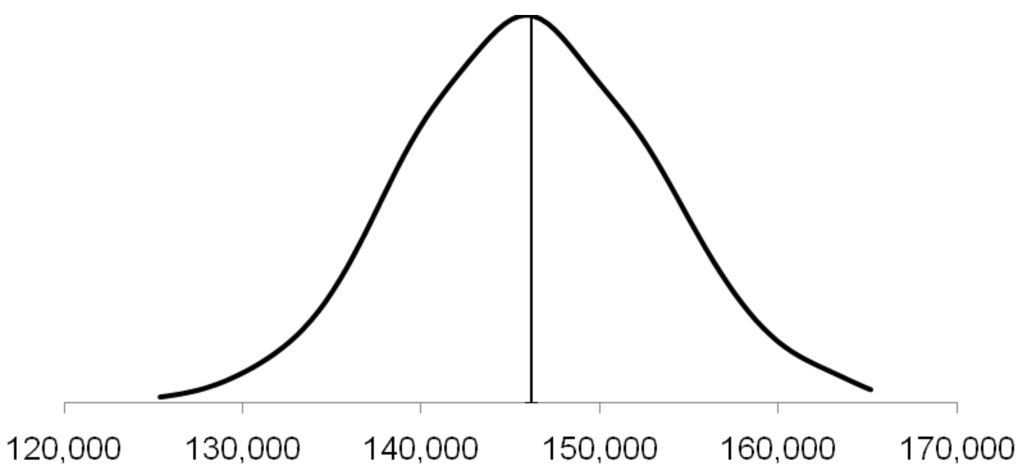

Figure 3-3. Minimum NPV greater than zero.

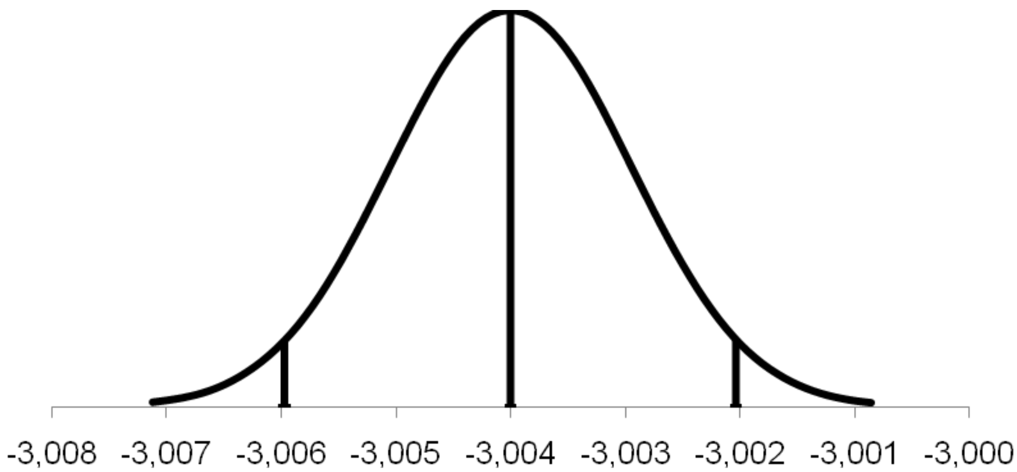

Figure 3-4. Minimum NPV less than zero.

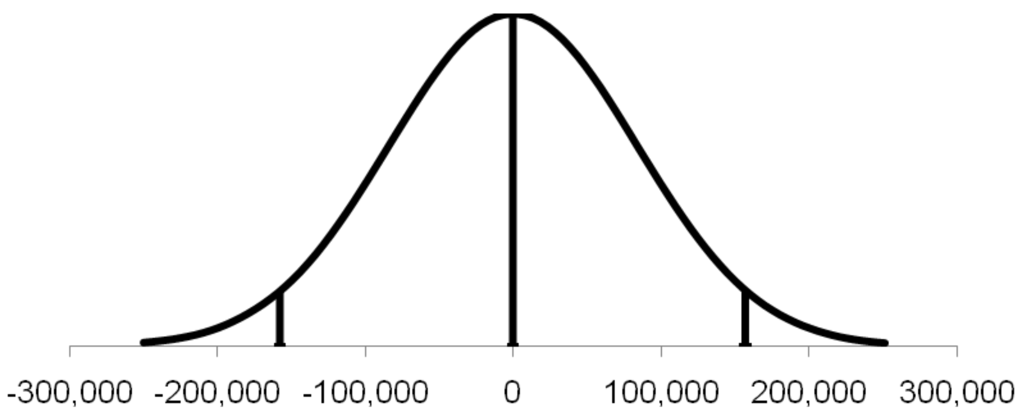

Figure 3-5. NPV between less than zero and greater than zero.

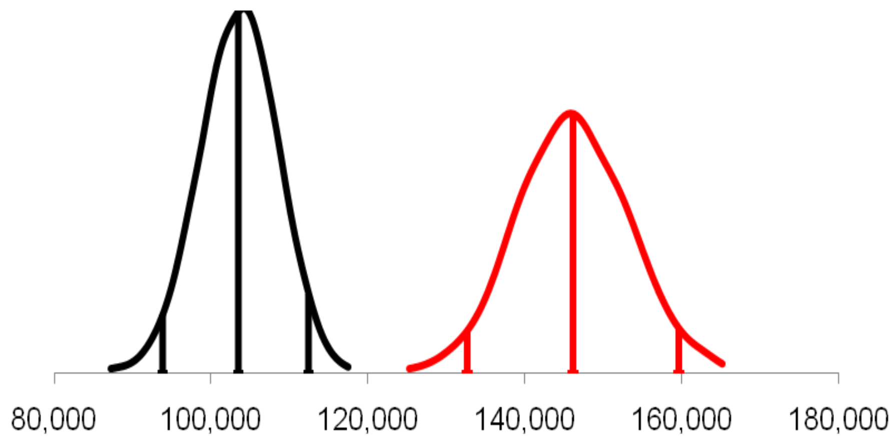

Figure 3-6. Non-overlapping PDFs.

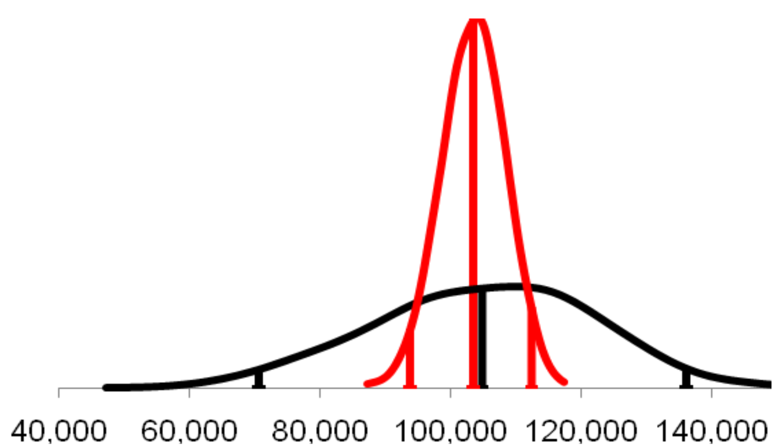

Figure 3-7. Overlapping PDFs.

CHAPTER 4
DATA COLLECTED

Introduction

This study uses secondary data. Data were collected from Bunda College of Agriculture, Ministry of Agriculture and Food Security (MoAFS), Concern Universal's Sustainable Livelihoods Project, British Petroleum (BP) Malawi, Sino-Link, Lilongwe Mechanical Development and some online sources. The data collected include: historical potato yields, historical potato prices, potato production costs, energy (diesel) costs, inflation, initial investment costs for each irrigation technology and operating costs for each irrigation technology.

Data on historical potato production costs were collected from Concern Universal's Sustainable Livelihoods Project. Data on historical potato yields were collected from MoAFS and Concern Universal's Sustainable Livelihoods Project. Historical data on inflation was collected from the National Statistical Office website. Finally data on initial investment costs and operating costs for each irrigation technology were obtained from two irrigation equipment traders in Lilongwe: Sino-Link and Lilongwe Mechanical Development.

Historical Prices

Most small scale potato farmers sell their potatoes at the farm gate. They sell the potatoes in bags weighing between 200kg and 400 kg. At the time of this study each bag was selling at MK15,000 which translates to an average of MK50.00/kg.

A fourteen year time series of prices was obtained from Bunda College of Agriculture stores bin cards and from farmers of Namphantha village in Dedza district. These prices were used to forecast future prices using trend analysis.

The prices showed an upward trend (Figure 4-1). From the trend line in Figure 4-1, the equation for forecasting future prices was determined and is given as

$$\text{Future Price} = -2774.10 + 1.40x \qquad (4.1)$$

Where x is the year for which the price is to be forecast.

The mean price per kilogram for the observed data was MK17.52 with a minimum of MK7.00 and maximum of MK28.57 (Table 4-1).

Historical Potato Yields

A fourteen year time series was also collected on potato yields. This was collected from MoAFS and Concern Universal's Food Security and Sustainable Livelihoods Project. The trend and its related equation for these data are shown in Figure 4-2. The minimum observed yield per hectare was 6,300kg and the maximum was 14,500kg. The mean yield was 10,258kg per hectare with a standard deviation of 2,617kg (Table 4-1).

Initial Investment Costs

The irrigation technologies were split into two main categories: those that lift water from water source to the field; and those that convey water from the field to the actual growing plant. These technologies were summarized in the Figure 2-1. Seven scenarios, over which KOVs were computed and compared, were identified. The seven scenarios included: (1) treadle pump (TP)-basin, (2) treadle pump (TP)-canal, (3) treadle pump (TP)-furrow, (4) motorized pump (MP)-furrow, (5) motorized pump (MP)-sprinkler, (6) motorized pump (MP)-drip, and (7) drum drip kits.

Data on initial investment cost was collected for the seven scenarios (Table 4-2). MP-drip scenario showed the highest initial investment cost of MK333,900 while TP-furrow showed the lowest initial investment cost of MK50,000.

Treadle Pumps (TP)

Treadle pumps (TP) were introduced in Malawi in 1994. By 2005 the number of treadles pumps in Malawi was estimated at 64,000 (Mangisoni, 2006). Currently there are two types of treadle pumps: the standard and the superlite. Commercial traders sell the standard treadle pump at MK19,000 and the superlite at MK26,000. Although the standard pump is cheaper than the superlite, most farmers prefer the superlite. The superlite treadle pump is lighter and easier (requires less energy) to propel than the standard one. Therefore, the analysis of treadle pumps in this study was based on the superlite treadle pump.

Commercial traders sell the pumps without suction and delivery pipes. The pipes are sold separately at MK375/meter. This study assumes that farmers require 50 meters of pipes to deliver water to canals, basins and furrows. Thus the total cost for the pipes is estimated at MK18,750.

This study also assumes that treadle pumps have a life period of 5 years (Palanisami 1997). Accordingly all the KOVs for treadle pump technology were calculated based on cash flows for 5 years.

Irrigation water from the treadle pump is delivered to the actual growing plant through canals, basins or furrows. This leads to three treadle pump (TP) scenarios: TP-canal, TP-basin and TP-furrow. The initial investment costs of the three scenarios were determined to be MK75,000, MK60,000 and MK50,000 (Table 4-2) respectively.

Motorized Pumps (MP)

Motorized pumps (MP) come in different sizes depending on horsepower (HP). This study assumes a 5-HP pump. The pump including suction and delivery pipes cost MK202,500 at SinoLink Limited and Lilongwe Mechanical Development (LMD). Like the treadle pump technology, motorized pumps are also combined with other technologies to deliver water to the plant, which leads to three motorized pump (MP) scenarios: MP-furrow, MP-sprinkler and MP-drip. MP-furrow costs MK206,750; MP-sprinkler costs MK262,500; and MP-drip costs MK333,900 (Table 4-2).

Based on Palanisami (1997), the motorized pumps are assumed to have a life span of 10 years.

Drip Technology

Drip irrigation applies water through small emitters to the soil surface at or near the plant to be irrigated. At the time of this study, drip technology was relatively new in Malawi and was in a trial phase. As a result, the costs used in this study were obtained from comparable technologies from Zimbabwe. Palanisami determined that the drip system costs about 1,150 USD per hectare. This translates to about MK168,900 at an exchange rate of MK147.00 to 1.00 USD. If motorized pumps are used to convey water to the drips, the total initial cost of both the pump and the drips is MK333,900 (Table 4-2).

Annual Operating Costs of Irrigation Technologies

This study identified labor, energy (diesel) and repairs as annual operating costs of the irrigation technologies. The operating costs are high under the motorized pump technology as compared to the other two technologies, treadle pump and drip technologies. The reason for this is that unlike the other two technologies, the motorized pump requires energy (diesel) to operate. Drip technologies exhibit the lowest annual operating costs because drip irrigation requires less labor and cost less to maintain as compared to motorized pumps and traditional furrow, basin or canal technologies.

Irish Potato Production Costs

Potato production costs were obtained from Concern Universal's Food Security and Sustainable Livelihoods Project in Ntcheu and from Bunda College of Agriculture. These costs are shown in Table 4-3 and represent costs that a representative potato farmer would incur per hectare of potato production.

Land preparation costs include costs incurred on land clearing, ploughing, harrowing and ridging. The cost of seed is included in planting costs. Harvesting and marketing costs depend on yield. There is a harvesting and marketing cost of MK5.64/kg which includes MK2.41/kg for actual harvesting, MK2.03/kg for packaging and MK1.20/kg for transportation.

Non-irrigated and Irrigated Operations assumptions

Given that the purpose of this study was to determine the viability of irrigation, a non-irrigated operation is used as a base and is compared to an irrigated operation. However, no yield data was available for an irrigated operation. As such, some modifications and assumptions were made.

a) The historical yield data is used to forecast future yields and an empirical distribution with trend is used to model the risk of yield on a single representative non-irrigated operation.

b) Deterministic forecast yields are used to represent an irrigated operation. The assumption is that irrigation reduces yield variability to zero.

c) Risk from pests and diseases is introduced into the model to relax the yield variability assumption. Since very limited information is available, we assume that this risk follows a triangle distribution (Table 4-4). Three points (minimum, median and maximum yield loss) are identified for both the non-irrigated and irrigated operations. We also assume that there is higher pest prevalence during the rainy season than the dry season. Hence higher pests and disease incidences for the non-irrigated operation than the irrigated operation.

d) Other sources of risk for the irrigated operation are identified as risks emanating from repairs and energy costs. We assume that repairs follow a GRKS distribution

(Table 4-4). We also assume that the cost of diesel is and follows an empirical distribution. A fourteen year time series data for diesel prices were collected and are used in an empirical distribution with trend to model the risks of energy prices.

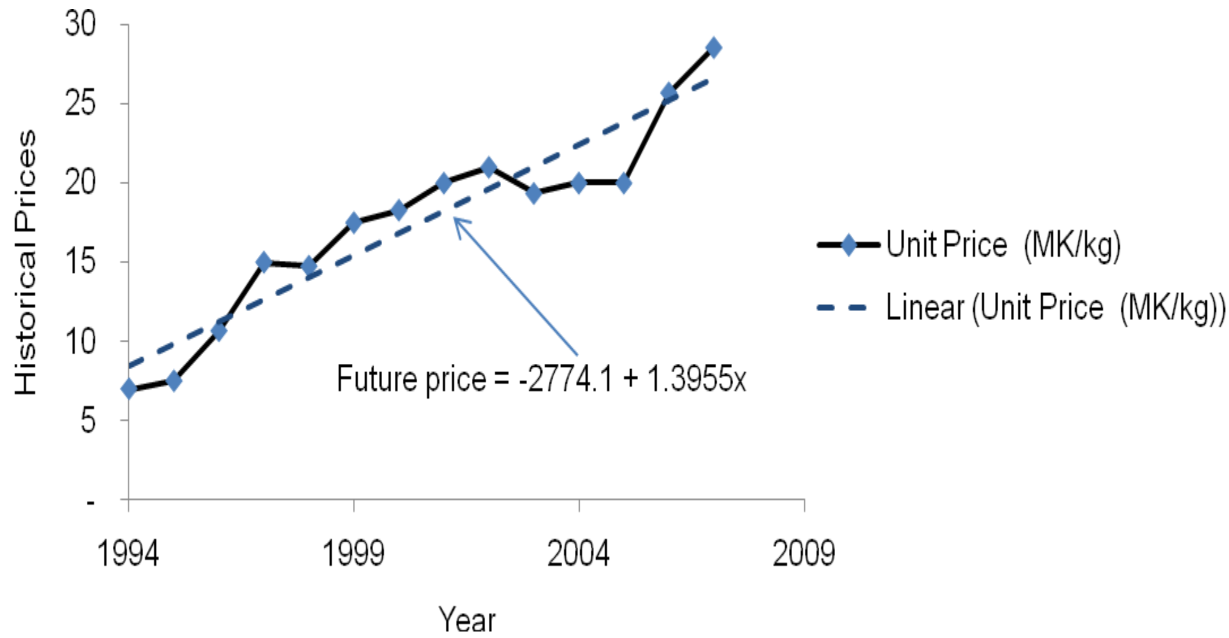

Figure 4-1. Historical prices time series.

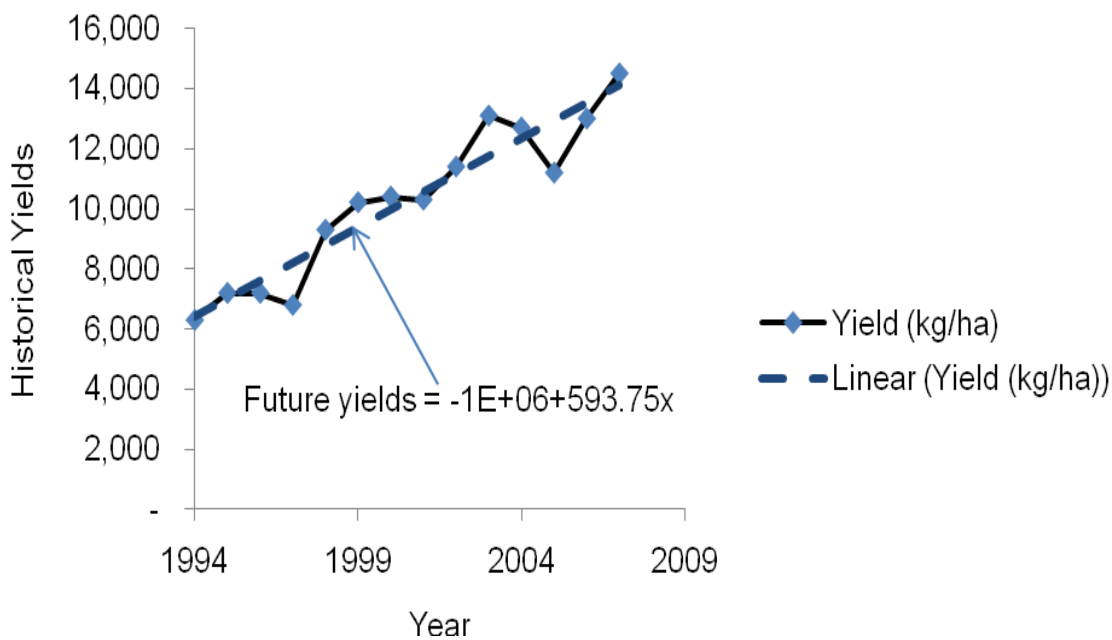

Figure 4-2. Historical yields time series.

Table 4-1. Summary statistics for yields and prices

	Yield (kg/ha)	Unit Price (MK/kg)
Mean	10,258.21	17.52
Standard Deviation	2,616.70	6.18
95 % LCI	8,503.16	13.38
95 % UCI	12,013.27	21.67
CV	25.51	35.24
Min	6,300.00	7.00
Median	10,350.00	18.82
Max	14,500.00	28.57
Skewness	(0.12)	(0.21)
Kurtosis	(1.11)	(0.11)

Table 4-2. Initial investment costs

	Initial Investment Cost (MK)	Useful Life (Years)
Treadle pump-canal	70,000	5
Treadle pump-basin	60,000	5
Treadle pump-furrow	50,000	5
Motorized pump-furrow	206,750	10
Motorized pump-sprinkler	262,500	10
Motorized pump-drip	333,900	10
Drum drip kits	295,000	8

Table 4-3. Potato production costs per hectare

	MK
Land Preparation	21,000
Planting	125,250
Fertilizers	75,500
Pest & Disease Control	16,800
Weed Control	6,000
Total Cost	244,550

Table 4-4. Labor, repairs and pests assumptions.

Repairs assumptions (% of investment cost)							
Minimum	3.0%						
Median	7.0%						
Maximum	10.0%						
Loss of yields due to pests and diseases							
	Irrigated	Non irrigated					
Minimum	3%	5%					
Mode	5%	10%					
Maximum	7%	15%					
	MP-furrow	MP-sprinkler	MP-drip	TP-canal	TP-basin	TP-furrow	Drum drip kits
Irrigation labor assumptions							
Minimum	7,500.00	4,500.00	3,000.00	15,000.00	15,000.00	15,000.00	10,000.00
Median	12,500.00	8,500.00	4,500.00	20,000.00	23,200.00	27,500.00	17,500.00
Maximum	15,650.00	11,250.00	7,500.00	37,500.00	32,500.00	40,000.00	26,520.00

CHAPTER 5
RESULTS AND DISCUSSION

Introduction

Based on the methods described in Chapter 3 and the data collected in Chapter 4, a simulation model was built and simulation analysis carried out to measure the importance of irrigation. We present results of the simulation analysis in this chapter. Yields, prices, energy costs, labor, repairs, pest and diseases were identified as the risk variables that affect the key output variables (KOVs).

Non-Irrigated Scenario

Results for the non-irrigated scenario are linked to the three main KOVs: net present values (NPV), benefit cost ratio (BCR) and probability of generating positive cash flows. Each KOV for the non-irrigated scenario is discussed in the next sections.

Net Present Values (NPV)

Net present values (NPV) were converted to annuities so that valid comparisons could be made between different time horizons. Three time horizons (5 years, 8 years and 10 years) were identified depending on the irrigation technology to be considered. A summary of simulation results for the non-irrigated scenario are shown in Table 5-1.

If the time horizon is 10 years, the mean NPV is MK173,407 with a standard deviation of MK16,652 and a coefficient of variation of 9.6. Where the time horizon is 5 years, the mean NPV is MK104,872 with a standard deviation of MK17,058 and a coefficient of variation of 16.27. The mean NPV for a time horizon of 8 years is MK147,665 and its standard deviation and coefficient of variation are MK16,841and 11.4 respectively. PDF graphs for the NPVs for the non-irrigated scenarios can be seen in Figures 5-1, 5-2 and 5-3.

Benefit Cost Ratios (BCR)

Summary statistics for benefit cost ratios (BCR) from the simulation of the three time horizons are presented in Table 5-2. The mean BCR for a 10-year time horizon is 1.43 with a standard deviation of 0.046. The mean BCR for a 5-year horizon is 1.26 and its standard deviation is 0.04 while the mean BCR for an 8-year span is 1.37 with a standard deviation of 0.037. The simulation results show that the minimum BCR is obtained under the 5-year life span while the maximum BCR is obtained under the 10-year period.

Probability of Positive Net Cash Flows

While NPV and BCR are good indicators of financial viability, other farmers may be interested in the ability to generate positive cash flows. Table 5-3 shows an extract of the probability of farmers generating positive cash flows during the first 5 years of operations. The simulation results show that the probability of generating positive cash flows is 87.8% during the first year, 99.6% during the second year and 100% during the third year and thereafter. These results are same for the three time horizons.

Irrigation Scenarios without Pests Prevalence

Like the non-irrigated scenario, results for the irrigated scenario without pests' prevalence were determined. The three main KOVs, NPV, BCR and probability of generating positive cash flows were computed.

Motorized Pump (MP) Scenario

Simulation results for the motorized pump (MP) scenario were split into MP-furrow, MP-sprinkler and MP-drip depending on the technology that delivers water to the actual plant (Figure 2-1). Simulation results of the three MP scenarios are given in Table 5-9.

The mean NPV for the three MP scenarios (MP-furrow, MP-sprinkler and MP-drip) are MK135,177, MK115,479 and MK95,695 respectively. MP-furrow scenario gives the highest maximum NPV of MK151,818 while the MP-drip gives the lowest maximum NPV of MK118,235. The standard deviations and the related coefficients for the three MP scenarios are MK4,808 and 3.56 for MP-furrow scenario, MK5,989 and 5.19 for MP-sprinkler scenario and MK7,082 and 7.4 for MP-drip scenario.

Summary statistics for BCR the three MP scenarios are shown in Table 5-7. A similar pattern as that of NPV is obtained for BCR. MP-furrow has the highest mean BCR of 1.38 while MP-drip has the lowest mean BCR of 1.33. MP-furrow shows both the smallest standard deviation and coefficient of variation as compared to MP-sprinkler and MP-drip (Table 5-7).

An extract of the simulation results of the probability of generating positive cash flows for the MP scenarios is shown in Table 5-10. While the simulation results show that there is a 100% probability of generating positive cash flows under the MP-furrow scenario during the first two years of operations, the probabilities of MP-sprinkler are 97.4% and 100% during the same period and those for MP-drip are 93.8% and 100%.

Treadle Pump (TP) Scenarios

Results were generated for the three treadle pump (TP) scenarios: TP-canal, TP-basin and TP-furrow. These results are shown in Tables 5-4 and 5-7.

Firstly, the mean NPV of the TP-canal scenario is MK100,806 with a standard deviation of MK6,459. The minimum NPV for TP-canal obtained during any single iteration is MK78,221 while the maximum is MK111,462. PDF graphs for NPV for this scenario can be seen in Figure 5-2. The mean BCR for this scenario is 1.276 with a standard deviation of 0.02.

The mean NPV of the TP-basin scenario is MK103,511 and its standard deviation is MK4,841. The NPV for the TP-basin scenario during any single iteration range between MK878,247 and MK117,440. Figure 5-2 shows a PDF graph for NPV of the TP scenarios. BCR simulation results for this scenario are shown in Table 5-7.

Finally the mean NPV of TP-furrow were also determined. The mean NPV is MK146,179 with a standard deviation of MK6,901. The maximum NPV is MK165,213 while the minimum NPV is MK125,353. Like for the other TP scenarios PDF graphs for this scenario can be seen in Figure 5-2.

Drum Drip Kits Scenario

The mean NPV of the drum drip kits scenario is MK77,579 with a standard deviation of MK6,020 (Table 5-4). A PDF graph of NPV for this scenario is shown in Figure 5-3. The minimum NPV for the drum drip kits scenario is MK61,126 while the maximum is MK95, 857. Table 5-7 shows the BCR results. The mean BCR of the drum drip kits scenario is 1.49 and its standard deviation is 0.26 with a coefficient of variation of 1.78.

Irrigation Scenarios with Pests Prevalence

Pests and diseases were introduced into the model to relax the yield variability assumptions made under the irrigation scenarios. The simulation results for the pest prevalence were determined. These results are presented in Tables 5-5, 5-6 and 5-8. After introducing pests, PDF graphs of the irrigated scenarios are shown in Figures 5-4 and 5-5.

The highest mean NPV of MK123,959 is obtained under the TP-furrow scenario while the lowest mean NPV of MK36,343 is obtained under the drum drip kits. MP-drip gives the highest standard deviation of MK8,896 where as TP-basin gives the lowest standard deviation of MK6,194.

After introducing pests, the mean BCR for the scenarios range from 1.23 (TP-basin) to 1.44 (drum drip kits).

Discussion of Results

Motorized Pumps (MP)

Both NPV and BCR suggest that investing in all the three motorized pump (MP) scenarios (MP-furrow, MP-sprinkler and MP-drip) is financially viable. Thus a farmer can invest in any one of them. However, when the three MP scenarios are considered together, a question arises as to which one a farmer should invest in.

Results show that MP-furrow scenario provides the lowest risk as shown by its standard deviation. Apart from providing the lowest risk, the results also show that MP-furrow scenario has the highest maximum NPV of MK131,074 and the lowest minimum NPV of MK91,016. This leads us to believe that, holding other factors constant; MP-furrow scenario is superior to the other MP scenarios. This is true if we compare MP-furrow and MP-drip scenarios only, it may not be the case when we compare MP-furrow and MP-sprinkler scenarios. While the maximum NPV (MK118,235) of MP-drip scenario is below the minimum NPV (MK122,804) of MP-furrow scenario, the maximum NPV for MP-sprinkler of MK135,835 is above the minimum NPV of MP-furrow .

A further analysis was done to identify why TP-furrow was superior to the other technologies. We found that farmers were more familiar with this method. We also found that furrow irrigation is most appropriate to shallow rooted crops. Thus potato is best suited to furrow irrigation as it cannot stand in very wet soils for a long period.

Treadle Pumps (MP)

Results for treadle pump (TP) scenarios suggest that investing in the individual scenarios, TP-canal, TP-basin and TP-furrow, is financially viable. This is supported by the positive NPV and BCR of greater than one (Table 5-4 and Table 5-7).

The results also suggest that, other things being equal, TP-furrow is more superior to the other two TP scenarios. The minimum NPV of TP-furrow scenario obtained during each iteration (MK125,353) is greater than the maximum NPV of both TP-canal (MK111,462) and TP-basin (MK117,440). As a consequence, regardless of risk preference of the farmers and holding other factors constant, TP-furrow is the most preferred.

Drum Drip Kits

Table 5-4 shows that the NPV obtained under the drum drip kits is positive and Table 5-7 shows that the BCR is greater than one. These results suggest that investing in drum drip kits irrigation technology is financially viable.

Probability of Generating Positive Cash Flows

The results suggest farmers have a high probability of generating positive cash flows both under the irrigated and non-irrigated scenarios. The lowest probability of generating positive cash flows for the non-irrigated scenario is 88% with a standard deviation of 33% (Table 5-3) while the lowest probability for the irrigated scenario is 94% with a standard deviation of 24% (Table 5-10). After the first two years of operations the probability of generating positive cash flows increases to 100% for all the scenarios. This may suggest farmers gain more experience with the passage of time such that the chance of getting loses decreases.

Pests Prevalence

Introducing pest into the model, shown in Figures 5-4 and 5-5, does not affect our results significantly. Still investing in any of the irrigation scenarios is financially viable. There is only a slight shift in the results. Pests reduce the mean NPV of all the irrigation scenarios while increasing the risk at the same time (Tables 5-5 and 5-6).

Table 5-1. NPV simulation results for non-irrigated operations

	10 year life span	5 year life span	8 year life span
Mean (MK)	173,407	104,872	147,665
Std. Dev	16,652	17,058	16,841
CV	9.60	16.27	11.40
Min (MK)	117,260	47,311	96,050
Max (MK)	228,286	151,586	198,292

Table 5-2. BCR simulation results for non-irrigated operations

	10 year life span	5 year life span	8 year life span
Mean	1.43	1.261	1.366
Std. Dev	0.046	0.040	0.037
CV	2.52	3.16	2.68
Min	1.33	1.12	1.26
Max	1.53	1.38	1.46

Table 5-3. Extract of probability positive cash flows (Non-irrigated Scenario)

	2010	2011	2012	2013	2014
Mean	87.8%	99.6%	100%	100%	100%
Std. Dev	32.8%	6.3%	0%	0%	0%
CV	37.3	6.3	0	0	0
Min	0%	0%	100%	100%	100%
Max	100%	100%	100%	100%	100%

Table 5-4. NPV simulation results for TP and drip (without pests)

	TP-canal	TP-basin	TP-furrow	Drum drip kits
Mean (MK)	100,806	103,511	146,179	77,579
Std. Dev	6,459	4,841	6,901	6,020
CV	6.41	4.68	4.72	7.76
Min (MK)	78,221	87,247	125,353	61,126
Max (MK)	111,462	117,440	165,213	95,857

Table 5-5. NPV simulation results for MP (with pests)

	MP-furrow	MP-sprinkler	MP-drip
Mean (MK)	109,397	89,699	69,914
Std. Dev	6,993	8,023	8,896
CV	6.39	8.94	12.72
Min (MK)	91,016	66,849	46,015
Max (MK)	131,074	117,353	99,374

Table 5-6. NPV simulation results for TP and Drip (with pests)

	TP-canal	TP-basin	TP-furrow	Drum drip kits
Mean (MK)	78,586	81,291	123,959	58,192
Std. Dev	7,804	6,194	7,879	7,066
CV	9.93	7.62	6.36	12.14
Min (MK)	49,270	63,348	99,073	36,343
Max (MK)	94,602	97,720	146,233	79,695

Table 5-7. BCR simulation results for irrigated operations (without pests)

	MP-furrow	MP-sprinkler	MP-drip	TP-canal	TP-basin	TP-furrow	Drum drip kits
Mean	1.379	1.354	1.339	1.276	1.275	1.401	1.489
Std. Dev	0.015	0.018	0.021	0.019	0.014	0.024	0.026
CV	1.076	1.326	1.539	1.487	1.094	1.708	1.779
Min	1.333	1.290	1.279	1.200	1.233	1.327	1.422
Max	1.429	1.407	1.401	1.314	1.316	1.473	1.585

Table 5-8. BCR simulation results for irrigated operations (with pests)

	MP-furrow	MP-sprinkler	MP-drip	TP-canal	TP-basin	TP-furrow	Drum drip kits
Mean	1.327	1.303	1.288	1.228	1.227	1.350	1.435
Std. Dev	0.018	0.021	0.022	0.021	0.016	0.025	0.028
CV	1.338	1.583	1.739	1.676	1.327	1.850	1.974
Min	1.275	1.243	1.212	1.147	1.176	1.274	1.353
Max	1.384	1.361	1.351	1.284	1.270	1.419	1.544

Table 5-9. NPV simulation results for MP (without pests)

	MP-furrow	MP-sprinkler	MP-drip
Mean (MK)	135,177	115,479	95,695
Std. Dev	4,808	5,989	7,082
CV	3.56	5.19	7.40
Min (MK)	122,804	96,485	75,415
Max (MK)	151,818	135,835	118,235

Table 5-10. Extract of probability positive cash flows (MP Scenarios)

	MP-Furrow		MP-Sprinkler		MP-Drip	
	2010	2011	2010	2011	2010	2011
Mean	100.0%	100.0%	97.4%	100.0%	93.8%	100.0%
Std. Dev	0.0%	0.0%	15.9%	0.0%	24.1%	0.0%
CV	0.0	0.0	16.4	0.0	25.7	0.0
Min	100%	100%	0%	100%	0%	100%
Max	100%	100%	100%	100%	100%	100%

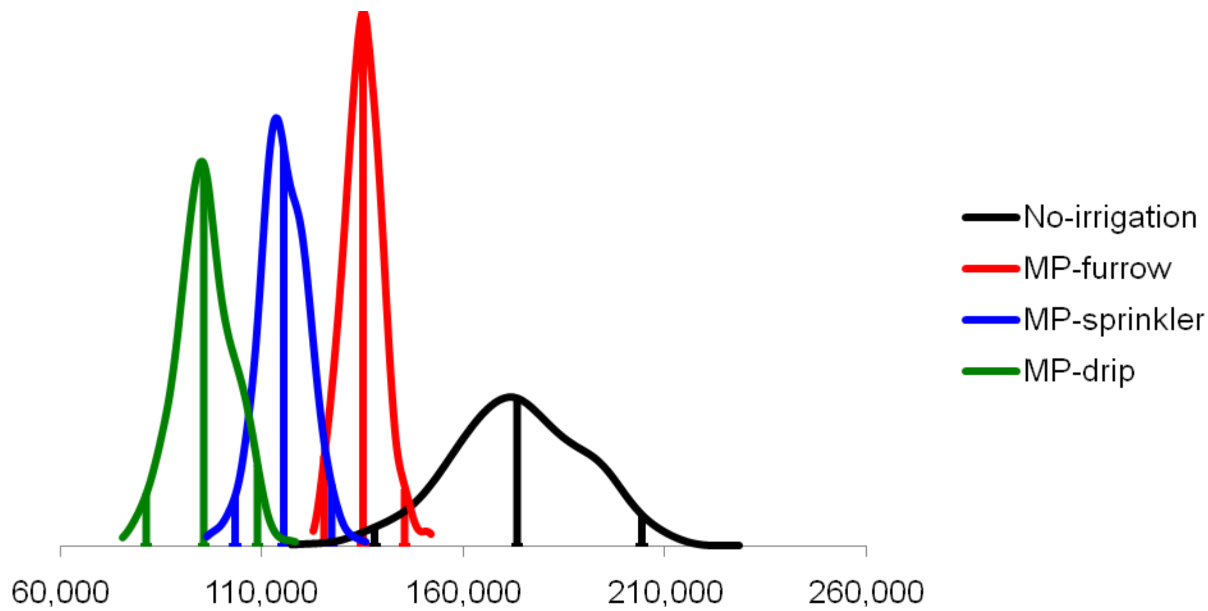

Figure 5-1. PDF of NPVs for motorized pumps (without pest prevalence).

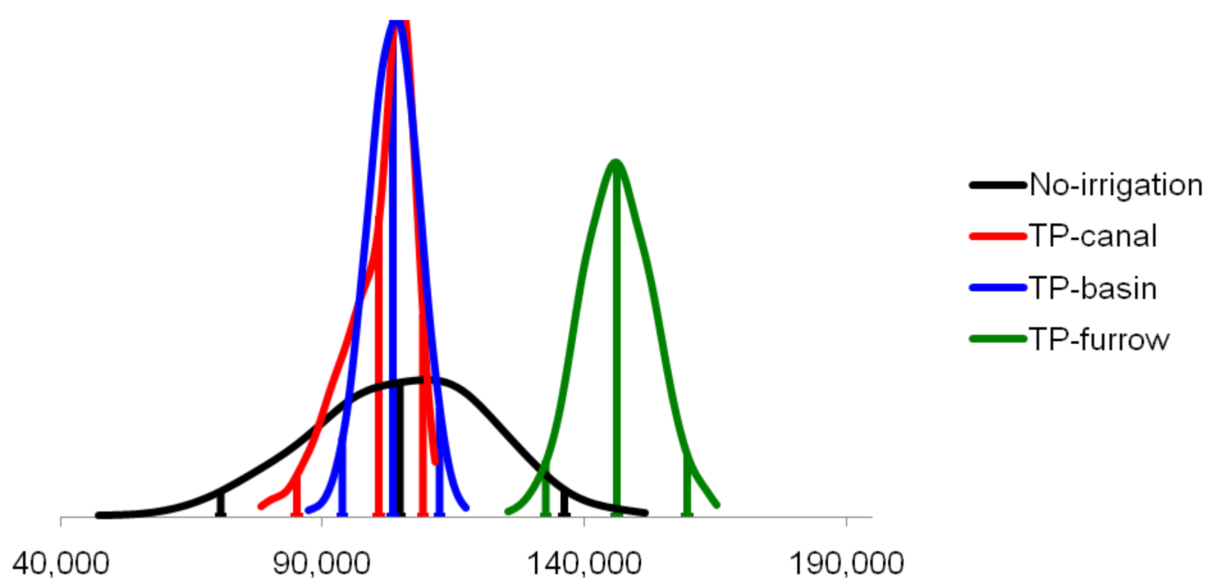

Figure 5-2. PDF of NPVs for treadle pumps (without pest prevalence).

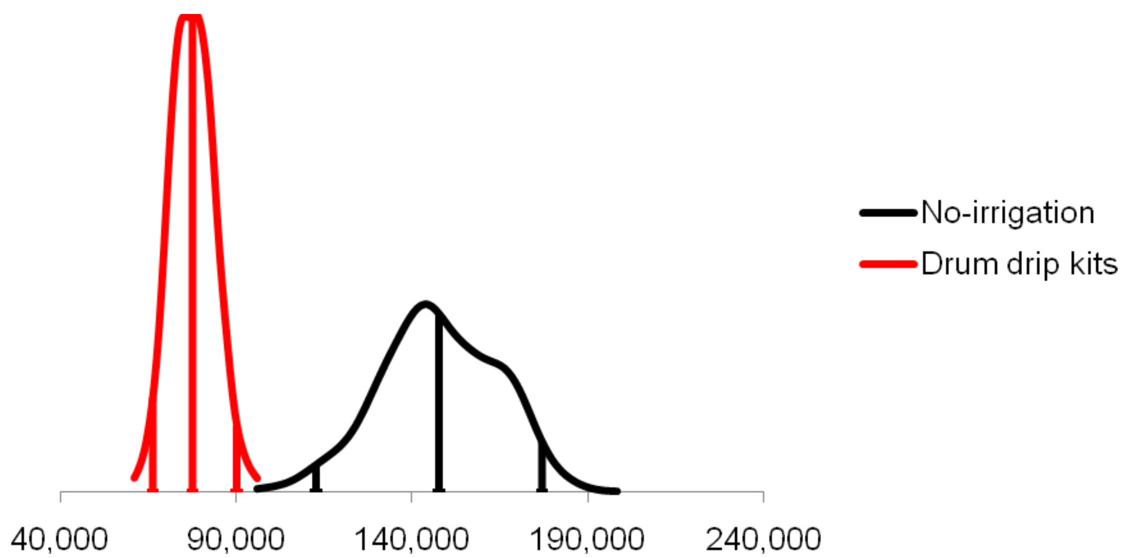

Figure 5-3. PDF of NPVs for drum drip kits (without pest prevalence).

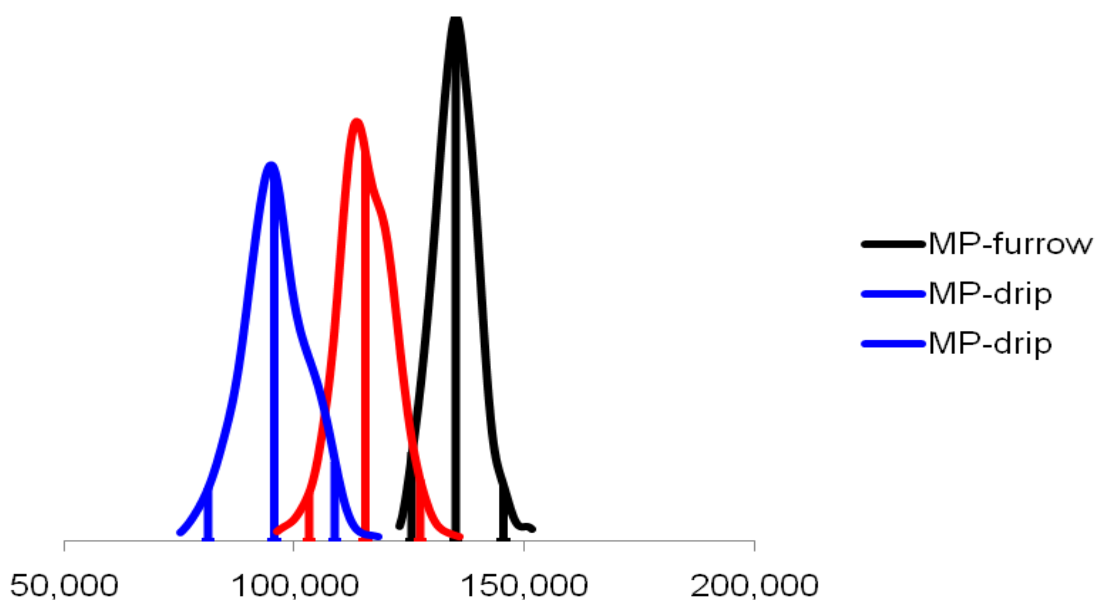

Figure 5-4. PDF of NPVs for motorized pumps (with pest prevalence).

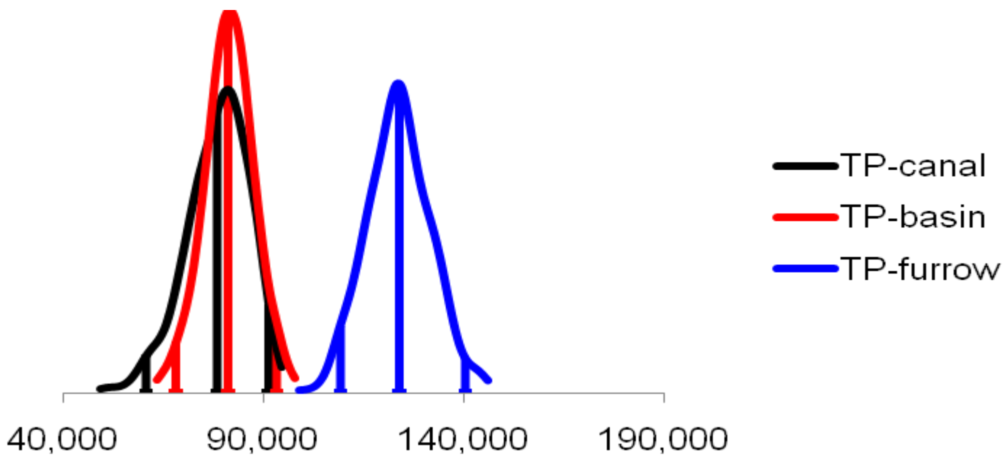

Figure 5-5. PDF of NPVs for treadle pumps (with pest prevalence).

CHAPTER 6
CONCLUSIONS

Introduction

More than 50% of smallholder farmers in Malawi are poor and food insecure because of lack of crop diversification and reliance on rain-fed agriculture. Customarily farmers rely on maize for food and grow their crops during the rainy season which runs from November of one year to April of the following year. There is potential for farmers to engage in crop diversification and invest in irrigation technologies. Crops other than maize are becoming more important in food security; and one such crop is the potato. Additionally, the Government of Malawi is advocating the adoption of irrigation technologies by smallholder farmers.

A simulation model was developed to determine the financial viability of investing in small-scale irrigation technologies for potato production. The first objective of this study was to determine initial investment and operating costs of different irrigation technologies. The second was to determine projected net cash flows per hectare of irrigation. Third, was to determine the net present value (NPV) and benefit cost ratio (BCR) of each irrigation technology. The final objective was to estimate the probability of generating positive cash flows from each irrigation technology.

Contributions of the Research

Currently, there is inadequate information on the financial viability of investing in irrigation technologies in Malawi. The National Irrigation Policy and Development Strategy (Malawi Government, 2000) identified financial viability from a farmer's perspective as one of the research needs in the irrigation sub-sector. The analyses in this study provide relevant information about initial costs of investing in irrigation technologies for potato production and the benefits of undertaking such investments. In addition, the model used in this study gives a framework that may be useful to other crops.

To date, studies analyzing financial viability of irrigation technologies in Malawi have been based on deterministic results. This study uses stochastic stimulation and as such provides entire probability distributions. This enables the reporting of risk outcomes and provides farmers and other decision makers with more sensible information.

Summary

The overall objective of this study was to determine the financial viability of investing in small-scale irrigation technologies for potato production in Dedza and Ntcheu districts of Central Malawi. The study identified motorized pumps (MP), treadle pumps (TP) and drip as the three technologies that take water from water sources to the field. The study also identified furrow, sprinkler, drip, canal and basins as the technologies that take water from the field to the actual growing plant. A combination of the technologies resulted in seven irrigation technology scenarios: MP-furrow, MP-sprinkler, MP-drip, TP-furrow, TP-canal, TP-basin and drum drip kits (Figure 2-1).

Financial viability of investing in the irrigation technologies was evaluated using three key output variables (KOV); net present values (NPV), benefit cost ratios (BCR) and probability of generating positive cash flows. To achieve this, a stochastic simulation model was developed. Times series data on potato yields, prices and costs were input into the model to estimate future production costs and revenues from which net farm cash incomes (NFCI) were calculated. Software Simetar© was used to carry out simulation analysis. Distributions of probable outcomes were generated for each KOV from which tables and PDF graphs were constructed.

Data on initial investment costs and operating costs for the irrigation technologies was collected from irrigation equipment suppliers. This data was analyzed under a certain set of assumptions to satisfy the first objective.

Stochastic yields and prices were used to estimate revenues generated per hectare of irrigation. The revenues were matched with stochastic cash costs to obtain net farm cash income (NFCI) per hectare of irrigation so as to satisfy the second objective.

To satisfy the third and fourth objectives a simulation model was run. In the model;

a) the sum of discounted future NCFI were matched with the initial investment costs to obtain NPV from each irrigation scenario,

b) the sum of the discounted future revenues were matched with the sum of discounted future cash costs to determine BCR from each irrigation and

c) probabilities of generating positive cash flows were determined.

The procedure used in this study and the results of the simulation analysis allowed us to test the hypothesis: “investment in small-scale irrigation (SSI) for potato production is a financially viable investment option”. All the irrigation scenarios have positive NPV, BCR of greater than one and probability of generating positive cash flows of at least 80%. This leads us to fail to reject the hypothesis.

Limitations of the Study Further Research Needs

There are a number of limitations of this study. First, the study assumes that the farmers have enough funds to invest in the technologies. Alternative financing options were ignored because, at the time of this study, it transpired that smallholder farmers find it difficult to access credit from financing institutions. The financing institutions demand collateral which most smallholder farmers cannot afford.

Second, this study assumed that the different irrigation scenarios have the same level efficiency. This would not be case; the different scenarios have different efficiency levels and this has a direct impact on the yields achieved by each scenario. There may be variations in yields from scenario to scenario due to operational and water use efficiencies of the technologies.

Third, this study assumed that the only factor that determines whether a farmer should invest in an irrigation technology or not is the farmer’s risk preference. However, the choice of investing in a technology also depends on other factors such as familiarity with the technology, cost of the technology, slope of the farm and water source.

Lastly, there is very limited times series data on yields and prices in Malawi. Most farmers do not keep farm records. The information that farmers provide is from recall and personal experiences.

Further Research Needs

Based on the limitations outlined in the preceding section, there are four areas that need further research. First, a study should be conducted to determine the exact role that banks and other money lending institutions play in providing financing to farmers. The results of that study should be incorporated into the model used in this study so that the risk that farmers may face by getting credit is accounted for. Second, the model proposed in this study should be expanded to take into account the different efficiency levels of the different irrigation technology scenarios. Third, the techniques and proposed model used in this study should be applied to other crops in an attempt to answer the Malawi Government’s call of looking at financial viability from the farmers’ perspective in the irrigation sub-sector. Lastly, a study should be carried to document historical yields, costs and prices for the different crops grown in Malawi so that the hitch of obtaining farm time series data is overcome.

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BIOGRAPHICAL SKETCH

Bonet Chikhawo Kamwana was born on 20 May 1976 in Lilongwe, Malawi. He obtained his Bachelor of Accountancy degree from University of Malawi in March 2001 and began his professional career as a Finance Assistant with University of Malawi's Chancellor College in April 2001 before he moved to Malawi College of Accountancy in October 2002 to teach accounting and finance. He rejoined University of Malawi's Bunda College of Agriculture in January 2004 as a Teaching Staff Associate in Financial and Managerial Accounting in the Agribusiness Management Department.

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Bonet Chikhawo Kamwana is married to Chrissie Chisomo Chinkolenji and has two sons, Chris and Peter.