AN ECONOMIC EVALUATION OF IRISH POTATO RESEARCH TECHNOLOGIES : A CASE STUDY OF NAKURU DISTRICT, KENYA.

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A Thesis submitted to the Graduate School in partial fulfilment of the requirements for a Master of Science degree in Agricultural Economics.

EGERTON UNIVERSITY

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DECLARATION

This thesis is my original work and has not been submitted in this or any other form for a degree in this or any other university.

Signed.....Muthoni.....

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This thesis has been submitted with our approval as the supervisors.

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DEDICATION

To my beloved Parents Mr and Mrs Martin Muriuki - For loving me unconditionally.

Abstract.

With dwindling donor funds, research resources are becoming increasingly scarce. These limited resources must be allocated in the most efficient way among several competing research programmes, including those seeking to raise potato productivity. To do this, it is necessary to know the potential payoffs of different potato research programmes. Yet little information on these is available for Kenya, or for Nakuru District, an important potato producing area in the country.

The objectives of this study thus are to determine the payoffs to different potato research programmes in Nakuru District and hence provide guidelines for planning and priority setting in potato research in Kenya. Three potato research programmes are evaluated: crop protection; certification of seeds; and development of improved varieties. The basic hypothesis guiding the study is that for these research technologies to be adopted they must be profitable The profitability of a technology is based on its impact on farm income The research thrust that raises farm incomes the most thus should be given highest priority.

Data were collected from a targeted survey of 72 small scale potato producers in Molo and Njoro Divisions of Nakuru District and used to construct detailed potato production budgets for representative farm types.

Analysis of these budgets indicate that research on crop protection has the highest impact on farm incomes and thus the greatest potential payoff followed by research on certified seeds. Given existing prices, research on recommended varieties may not significantly raise farm incomes and thus may have limited potential payoff.

Other results reinforce these conclusions. Thirty two percent of the sampled farmers are using none of these three technologies, while only six percent of these farmers are using all of the three technologies. Adoption of crop protection is highest, which is expected due to its high payoff. Adoption of certified seed is low, apparently due to its high cost.

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CHAPTER ONE

INTRODUCTION

1.1 Background Information.

In Kenya, a predominantly agrarian country, agricultural development is important for both economic growth and food supply. With increasing demand for food and the need for rapid economic growth, agricultural production must rise. To increase agricultural production with constrained resources, agricultural productivity must grow. It is therefore important that new investments be directed to areas that increase agricultural productivity. One of these areas is agricultural research.

Most agricultural research in Kenya is conducted by the Kenya Agriculture Research Institute (KARI) in the Ministry of Research, Technical Training and Technology (MoRTT). Others include universities, International Research Center and non-governmental organisations.

Some research funds come from the Government through the MoRTT's annual vote from the Treasury. However, the bulk of research resources come from foreign donors (KARI, 1991). Since 1991, donor funding for agricultural research has been dwindling (Government of Kenya (GoK), 1994 a). Efficiency in the allocation of increasingly limited funds has therefore become important. Research funds are allocated among several crops, potatoes being one of these. Allocations to potato research must be directed to the research thrusts likely to yield highest returns.

Potato is the fourth most important food crop in the world after wheat, rice and maize as indicated in table 1.1 (CIP, 1978; CIP, 1984; FAO and CIP, 1995).

Table 1.1: Ten major world food crops in terms of production, 1995

Food crops	*Production (Million Tonnes)*	*No of producing countries*
Rice	550	120
Wheat	541	132
Maize	515	166
Potatoes	281	151
Cassava	163	98
Barley	143	104
Sweet Potatoes	122	113
Sorghum	54	106
Oats	29	77
Millet	26	78

Source: FAO, 1996

This crop is eaten by over one billion people world-wide. Annually, about 22 million hectares (ha) of land are devoted to its production, yielding a total of between 260 and 270 million tonnes (Nganga, 1982; FAO, 1991, FAO and CIP, 1995). Yields vary by region (Table 1.2), from as high as 40 tonnes/hectare (t/ha) in some developed countries to as low as 4 t/ha in developing countries (FAO, 1991; FAO and CIP, 1995)

Table 1.2: Potato yields for some major potato producing countries in the world.

Region	*Country*	*Yields(t\ha)*
Developed countries		
Western Europe	Belgium	42
	France	35
	Germany	33
	Italy	22
	Netherlands	42
	Portugal	14
	Spain	19
	United Kingdom	40
Eastern Europe	Hungary	16
	Poland	17
	Romania	12
Former USSR	Belarus	14
	Russia	11
	Ukraine	12
Others	Australia	29
	Canada	27
	Japan	31
	South Africa	21
	U S A	36
Developing countries		
Asia	Bangladesh	10
	China	12
	India	16

	Indonesia	19
	Iran	12
	Korea	9
	Nepal	11
	Pakistan	18
	Syria	24
	Turkey	10
	Viet Nam	10
Africa	Algeria	21
	Egypt	7
	Morocco	4
	Rwanda	16
	Kenya	9
Latin America & Caribbean	Argentina	18
	Bolivia	6
	Brazil	14
	Chile	15
	Colombia	15
	Cuba	15
	Equador	7
	Mexico	17
	Peru	8

Source: FAO and CIP, 1995

In Africa, 806,000 ha of land are used annually on potato production with an average yield of 8.7 t/ha (FAO, 1991).

Currently, the world potato sector is in transition. As indicated in table 1.3, Europe and the former Soviet Union, formerly the world's leading potato producers, have registered declines in potato output, whereas output in developing countries has risen (FAO and CIP, 1995)

Table 1.3 : Annual growth rates in Potato production and area between 1961 and 1993

Region	*Average annual growth rate in production (%)*	*Average annual growth rate in area (%)*
Developed countries		
Western Europe	-1.8	-3.4
Eastern Europe	-1.2	-1.7
Former USSR	-0.1	-0.1
Australia	2.4	-0.1
USA	1.4	-0.1
Developing countries		
Asia	4.6	2.7
Africa	4.4	3.7
Latin America & Caribbean.	1.9	-0.1

Source : FAO and CIP, 1995

Should this trend continue, towards the end of this century most of the world's potatoes will come from developing nations. As a consequence, potato cultivation is becoming an increasingly important source of food, rural employment and income for the growing populations of the developing nations. Nutritionally, potatoes are an important source of calories as shown in table 1.4. In fact a poorly understood fact is that potatoes also provide a considerable amount of proteins (CIP, 1982; CIP, 1984)

Table 1.4: Comparative Nutritive Value of some selected Commodities

Item	*Biological Value*
Egg	96
Potato	76
Soybean	72
Maize	54
Wheat Flour	53
Peas	48
Beans	46

NB- Biological value is an index of the portion of absorbed nitrogen retained in the body for the growth or maintenance or both.

Source: CIP, 1982

Kenya is one of the most important potato producers in Africa (Mogire et al., 1994; CIP, 1982)(Table 1.5). Country-wide, between 75,000 ha and 100,000 ha are annually devoted to potato production (FAO, 1991) with an average yield of 7.5 T/ha (CIP, 1982).

Table 1.5 : Important Potato producers in Africa, 1995

Country	Area(000 ha)	Production(000T)
South Africa	56	1468
Egypt	70	1450
Morocco	54	774
Algeria	76	720
Malawi	50	376
Uganda	48	368
Ethiopia	44	350
Madagascar	40	270
Tanzania	35	240
Kenya	47	205
Tunisia	16	205
Rwanda	25	150
Libya	18	127
Mozambique	6	72
Angola	10	43
Burundi	14	42
Cameroon	17	40
Zaire	6	35

Source: FAO, 1996

Potatoes contribute between 7 and 10 percent of Kenya's total calorie supply and its production employs about 3 percent of the labour force (Durr and Lorenzl, 1980). This crop thus plays a major role in national food security, albeit smaller than that played by cereals, among which maize has been the most important (Kabira and Njoroge, 1982). However, frequent deficiencies in maize production threaten national and household food security. In recent years, production of other important cereals, such as wheat and rice, has grown less than has demand (GoK, 1994 b). Potatoes have a shorter growing period than do cereals. In some areas farmers can grow three crops of potatoes per year, producing seven times more kilograms per hectare than does maize (Mogire, et. al., 1994). Potatoes are also a substitute to cereals in the provision of starch. With increasing urbanisation, fried potatoes (chips and crisps) have become an important food for medium to low income urban dwellers (Majiso, 1982; Mogire, et.al., 1994). Potentially, therefore, potatoes are a steadier source of income and nutrients than are cereals and may contribute to a reduction in current dependence on cereals for food security, especially among smallholders.

Seventy five percent of potato producers in Kenya are smallholders cultivating less than two hectares (Mogire et. al., 1994). The main potato producing districts are Meru, Nyeri, Kiambu, Nyandarua, Murang'a, Laikipia, Narok and Nakuru (Mogire, et. al., 1994).

In Nakuru, potatoes are the fourth most important crop in terms of acreage allocated, next to maize, wheat and beans (GoK, 1994 c). The crop occupied an area of 6771 hectares in 1994/95 (Ministry of Agriculture Livestock and Marketing (MoALM), 1995 a). The main potato producers in this District are small scale farmers actually, sixty five percent of the farms are less than 2 ha in size (Durr and Lorenzl, 1980; GoK, 1994 c;). The average yield was 4.5 T/ha in 1976/77 (Durr and Lorenzl, 1980) and 13.3 in 1995 (MoALM, 1995 a). Although there has been a tremendous improvement in the yields, as is the case elsewhere in Kenya and in the developing world, these yields are still below the world average of 15.4 t/ha and 26.8 t/ha in developed countries (FAO, 1991). Nakuru thus is a good case study area for investigating potato production. Insights gained from this study could have wide-ranging applicability in Kenya.

Despite the increasing importance of potatoes as an income source for Kenyan smallholders, and as a food item for a large proportion of the population, there is little information available concerning the potential returns to increased productivity through research. Most important, little is known about the farm-level costs and returns to adoption of alternative improved technologies generated by research. Such information is crucial to future priority setting in potato research.

Several potato technologies have been recommended by researchers. Typically, these recommendations have included three components: use of recommended varieties; use of certified seeds; and use of recommended crop protection practices (CIP, 1984). If adopted using recommended rates and management techniques, these technologies can potentially raise yields significantly. However, in Nakuru and elsewhere in Kenya, farmers have adopted them only partially. This suggests that the farm level economic returns associated with the recommendations may provide insufficient incentives for adoption. An important question thus is: How profitable are the various recommended technologies? Research is continuing on improving these technologies and enhancing their adoption (National Potato Research Centre, 1993). However, without an understanding of the profitabilities associated with existing and future technologies, scarce research resources may be inefficiently allocated.

1.2 Statement of the Problem

With dwindling donor funding, research resources have become very limited. These limited resources must therefore be allocated in the most efficient way among several competing research programmes, including those seeking to raise potato productivity.

Potatoes are becoming increasingly important as production and consumption commodities in Kenya. The potential returns to greater potato productivity through research include increased output and profitability at the farm level, and lower food costs, especially for urban consumers. Yet little information on these likely gains is available for Kenya, or for Nakuru district, an important potato producing area. Such information is pivotal for planning and priority setting in potato research.

1.3 Objectives

i. To determine the potential payoffs of different potato research technologies in Nakuru District.

ii. To provide guidelines for priority setting and planning in potato research in Kenya.

1.4 Hypothesis

The different potato research technologies available to farmers in Nakuru district are not profitable.

1.5 Justification

Decision makers need the information on research payoffs in order to assess alternative uses of public, donor and private funds. This study is intended to generate and provide potato research planners with information on payoffs of some potato research technologies. The information may be used as they allocate limited potato research resources, leading to a more efficient allocation of these resources. This could lead to increased potato productivity, which would increase rural incomes, reduce food costs for the urban population and contribute to the achievement of food security objectives.

1.6 The study area.

Nakuru is one of the 14 Districts in the Rift Valley Province of Kenya as shown in Figure 1.1. It has an area of 72,000 square kilometers (sq km). It is located between longitudes 35° 28' and 36' East and Latitude 0° 3' North and 1° 10' South. The total inhabited area is 5762 sq km (GoK, 1994 c). It is divided into ten administrative divisions namely Bahati, Molo, Njoro, Naivasha, Gilgil, Olenguruone, Rongai, Mbogoini, Nakuru Municipality and Keringeti as shown in Table 1.6.

Table 1.6: Area of the District by divisions

Division	*Area (Sq Km)*
Nakuru Municipality	78
Bahati	613
Mbogoini	404
Naivasha	1707
Gilgil	1039
Njoro	504
Molo	306
Keringeti	439
Rongai	565
Olenguruone	108
Total	5762

Source : GOK, 1994 c

The population of Nakuru was 522,409 in 1979 and was estimated at 1,034,334 in 1993 and 1,937,716 in 1996 as shown in Table 1.7. The estimated growth rate is 5 percent. As of 1993, 49 percent of the population was below 14 years and 4 percent above 59 years. This implies that 53 percent of the population are dependants.

Table 1.7: Nakuru district population estimates.

Age cohort	*1979*	*1993*	*1994*	*1996*
0-4	100,929	199,833	209,824	231,331
5-9	87,503	175,443	184,215	203,908
10-14	69,249	138,809	145,215	160,829
15-19	56,840	113,935	119,632	131,894
20-24	46,939	93,588	98,267	108,340
25-29	38,361	76,995	80,844	89,131
30-34	29,531	58,694	61,628	67,945
35-39	22,459	44,518	46,744	51,535
40-44	17,279	34,636	36,367	40,095
45-49	13,390	26,840	28,127	31,076
50-54	11,001	22,051	23,154	25,527
55-59	8,533	17,104	17,690	19,800
60-64	5,880	11,784	12,367	13,644
65-69	5,594	11,213	11,774	12,980
70-74	2,484	6,984	7,333	8,804
75+	6,412	12,855	13,500	14,880
Total	522,409	1,034,334	1,086,051	1,197,716

Source: GOK, 1994 c

In 1979 the labour force was estimated to be 488,361 and estimated at 565,363 in 1996 and 573,424 in 1998. Sixty percent of this is estimated to be involved in agricultural activities.

There is considerable variation in climate throughout the district. The area can be divided into three broad climatic zones. Zone one covers areas above 2400 meters(m) above sea level and receive an average annual rainfall of 1270 millimeters (mm) per annum as shown in Table 1.8. This is a humid to semi-humid climate with a moisture index of less than 10. This Zone covers Mau-Narok, Molo, Olenguruone, Upper Subukia, Ndundori and parts of Bahati.

Zone two covers areas with an altitude between 1800m and 2400m above sea level. The average rainfall is between 760 mm and 1270 mm per annum. This is a dry sub-humid equatorial climate with a moisture index of 10-30. This Zone covers lower parts of Molo, Njoro, Bahati, and parts of Rongai.

Zone three covers the bottom of the valley with an altitude between 1520m and 1890m above sea level. This is a semi-arid Zone with a moisture index of 30-42 and covers Naivasha, Gigil, Longonot, Solai, Lanet and parts of Rongai (GoK, 1994 c)

Nakuru is a major potato producing District in the country. The major potato growing divisions are Bahati, Molo, Njoro, Olenguruone, and

Keringeti. The study covers Molo and Njoro Divisions which were purposefully selected. Molo division represents the high rainfall zones while Njoro division represents the lower rainfall zones.

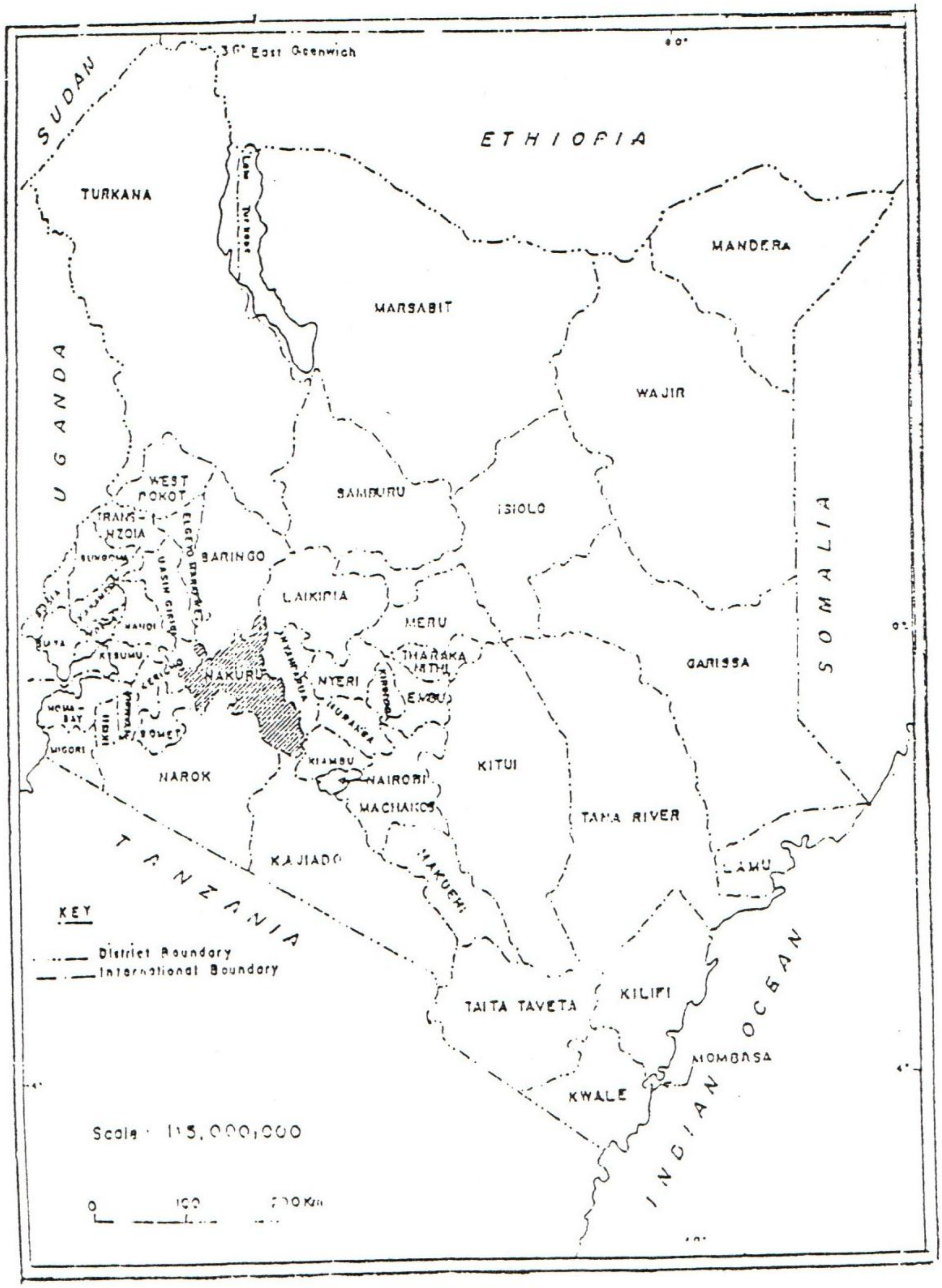
Table 1.8: Nakuru District average annual rainfall

Month	*1980*	*1984*	*1986*	*1989*	*1990*	*1992*	*1993*
Jan.	28.6	3.6	0.0	29.0	42.2	41.3	90.8
Feb.	0.9	6.1	1.1	80.1	74.1	4.7	112.2
March	36.4	11.2	20.8	69.5	153.6	13.3	9.2
April	102.3	65.3	171.8	110.0	207.0	134.4	38.9
May	342.5	32.0	94.3	82.0	125.9	127.8	76.9
June	85.2	67.0	163.3	59.4	30.3	52.1	80.4
July	29.3	87.4	115.5	112.4	54.5	142.0	63.1
Aug.	58.6	36.0	134.6	80.3	56.7	161.0	65.4
Sept.	18.2	69.4	76.4	175.2	46.8	76.2	38.8
Oct.	37.1	83.0	46.2	138.8	70.9	106.6	42.6
Nov.	87.4	62.1	40.9	93.5	64.1	44.9	56.8
Dec.	10.3	63.0	72.9	115.0	52.6	70.3	26.6
Total	836.8	586.1	937.8	1145.2	978.7	974.6	701.7

Source: GOK, 1994 c and GOK, 1995 d

Due to the variation in climate, this District serves as a good representative for potato producing Districts in the country. Both the high rainfall areas like Nyeri and Nyandarua and the lower rainfall areas like Laikipia and Narok are represented. The results gained from this study could thus have wide-ranging applicability.

Figure 1.1 : Location of Nakuru District



Source: GOK 1994 c

CHAPTER TWO

LITERATURE REVIEW

2.1 Methods of research evaluation.

Different methods for evaluating research benefits exist. Hertford and Schimitz, (1977); Linder and Jarret, (1978); Norton and Davis, (1981); Voon and Edward, (1991), all try to discuss and or develop the various methods used in evaluation of agricultural research benefits. There are two broad categories of evaluation: ex-ante evaluation and ex-post evaluation (Norton and Davis, 1981; Braha, 1985).

The ex-post categories comprises various approaches, which include economic surplus, production function, and the national income approach.

The economic surplus method for quantifying research impact measures the social benefit obtained from production and consumption of a good. The method assumes that the research shifts the supply (cost) curve, generating increased welfare by changes in producer and consumer surplus. The advantage of this method is that it requires less data and is able to capture the total societal welfare gains. The drawback of this method is the difficulty in estimating the supply shift. The shift can be divergent, parallel or convergent. All these will give different sizes of surpluses, (Linder and Jarret, 1978; Wise, 1978). This method can also be used in ex-ante studies.

The production function method also is widely used. Griliches, (1964); Bredalh and Peterson, (1976); Norton, (1981); and Karanja, (1993) used this method. This method seeks to capture the marginal effect of research on productivity. Research expenditure is included as an independent variable in an aggregate production function. The drawbacks of this method are the estimation of variables, the specification of the model, and significant data requirements.

The National Income approach was introduced by Tweeten and Hines (Norton, 1981). They employed the argument that National Income increased due to productivity in agriculture, which made possible the migration of human resources to the non-farm sector where the value of marginal product is higher. The larger the gap in earnings between farmers and non-farm workers, and the higher the migration rate off the farm, the higher the returns to agricultural research would be. The drawback of this method is that it does not provide concrete direction for research efforts.

The ex-ante methods for estimating returns to agricultural research include scoring models, cost-benefit analysis, and the simulation models (Norton and Davis, 1981; Braha, 1985). In the scoring method the strength and weaknesses in research program and future problems are identified. A simple score is then used to determine the extent to which a research problem area meet specified weighted criteria. Scientists use intuition and prior experience. This method, though relatively easy to apply, is open to criticism due to lack of rigour and susceptibility to biases introduced by researchers' subjective inclinations. This method has been used by KARI in the past (KARI, 1991)

In the cost-benefit method, future costs and benefits are estimated and discounted. Research recommendations are then ranked based on three key measures: the benefit cost ratio, the net present value, and the internal rate of return. Those with the highest expected returns are recommended for further development. The drawback of this method is that it is sensitive to assumptions about discount rates.

In the simulation method, the first step is to establish general goals, then identification of changes in product supply, input demand and farm consumption necessary to achieve these goals. Research problems and alternative technologies to solve them are then identified. Following this, the time costs and probabilities involved in research and farm adoption of the alternative technologies are estimated. Estimation of effects on farm consumption, product demand and input supply follows. Finally, specification of technology to be developed and scientists working objectives are established. The advantage of this approach is that it is flexible and can be constructed to incorporate optimising and ranking procedures. The major disadvantage is that it requires extensive data and time analysis. This is the current KARI approach to the evaluation of research impact (Howard and Crawford, 1997).

One method which is very important but has largely been overlooked by researchers is the farm income approach. This method can be both ex-ante and ex-post. Research impact is evaluated based on its effect on farm profits. The extent to which a research recommendation raises farm profits is determined. The research thrust raising the farm incomes most is given highest priority. This is the approach that is taken in this study.

The farm income method is very important especially in developing countries since one of their major national objectives is to raise farm incomes. The approach is appropriate for Kenya where about 70 percent of the population depends directly or indirectly on farm incomes. This method is likely to be more appropriate in the Kenyan situation than the current method KARI is using because of its ability to evaluate research at the farm level. Irrespective of the score in other aspects, if a research recommendation does not impact on farm incomes it would be difficult for it to be adopted and will thus have little impact to the economy.

An important drawback of this method is that it does not consider the amount invested in research. However, to the extent that it quantifies farm level research benefits, results from the current study may be coupled with those from other studies measuring research costs in making more comprehensive recommendations to guide agricultural research.

2.2 Empirical studies

Evaluation of returns to agriculture research is important for financial accountability to the donor, public and government funds, and also for identifying activities with the greatest impact and use this information in guiding research planning. This evaluation is especially important for the least developed countries due to their critical resource position (Kahlon, et. al., 1977).

The framework used in the estimation of agriculture research was introduced almost a century ago by Alfred Marshall (Hertfold and Schmitz, 1977) and since then economists have ventured into this area.

Griliches, (1964) studied the effect of research expenditure and education on production. He used the unrestricted Cobb-Douglas production function and included the education of workers as a variable. He found a coefficient of 0.403 for education and 0.59 for research and a marginal product of 1.3 for education and 16 for research.

Akino and Hayami, (1975), did a study on returns to rice breeding in Japan. They used the economic surplus model and found an annual benefit of

1.02 to 28.76 million Yen using 1934-1936 constant prices between the years 1932-1961.

Bredahl and Peterson, (1976) estimated the marginal products and internal rate of return to investment in agriculture research in commodity groups of cash grains, poultry, dairy and livestock in the United States. They used the Cobb-Douglas production function. They got a marginal product of 14.09 for cash grains, 19.58 for poultry, 25.93 for daily, 41.76 for livestock, and an internal rate of return of return of 36 percent, 47 percent, 43 percent and 46 percent respectively. They argued that a more efficient allocation of research resources could be achieved by a reallocation to the commodities with higher payoffs.

Kahlon, et. Al., (1977) studied the returns to agriculture research in India. This was an ex-post study and they used the production function of log linear type. The variables included in the production function were fertilizer, rainfall, male agriculture workers, literacy in rural males, draft bovines, tractor, total cropped area, gross irrigated area and gross research expenditure lagged 0-4 years. A rate of return of 11.61 rupees was obtained.

Norton, (1981) followed the Bredahl and Peterson study and included more variables, namely weather and spill-over effects. He also wanted to find out whether the impact of research had changed between 1969-1974. He used the Cobb-Douglas production function and found out that research coefficients of dairy, grains and livestock were significantly non different hence the impact of research had not changed within that period.

Schwartz, et. al., (1992) studied the impact of research of cowpea in Senegal. They used the cost benefit analysis and got a nominal rate of return of 31 percent. They concluded that research was successful and attributed this success on the ability of collaborative research to breed and maintain potentially successful cowpea varieties, to identify these varieties and complementary farming practices for this particular application, the ability of extension service to disseminate this information among the farm community, and the subsidised distribution of seed and complementary inputs. According to these researchers their results are consistent with the congruence rule which states that the optimal level of research investment should be proportional to the relative value of the commodity under consideration. The basis of this rule is the observation that research that generates benefits equal to a fixed proportion of the value of production will generate greater benefits when directed towards a commodity with a higher value of production. The results of their study indicate that research with a modest budget can be effective even if applied to a commodity of secondary importance.

Howard, et. al., (1993) estimated the impact of maize research in Zambia and got an internal rate of return of 99.7 using cost benefit analysis and 96.2 using economic surplus approach. These researchers pointed out the importance of institutional policies to enhance efficiency in research investment.

In Kenya, Karanja, (1993) studied the impact of maize research in the period between 1955-1988. He used the linear production function with a time lag of 10 years, the time taken to develop and release new varieties. He found out that an increase in maize research expenditure of ten percent increases maize yields by 2.5 percent. This estimated payoff was comparable to investment in agricultural activities elsewhere and thus confirm that investment made in maize research in this period was worthwhile. Also through institutional analysis, Karanja's study revealed the contribution of institutions to the success of maize research.

He noted significant roles made by the Kenya Seed Company and agricultural extension department. Karanja concluded that the aggressiveness of the seed and extension programmes enhanced the productivity of research as evident from the spread and adoption of different maize varieties countrywide. The other factors that led to successful development of the maize research were enumerated as: an effective railway and road network for facilitating farm inputs supply and produce marketing, an efficient marketing network of inputs through Kenya Farmers Association (KFA) and output through National Cereals and Produce Board (NCPB), provision of price guarantee and seasonal credit for maize, and the commitment of the government and political will to improve the quality and quantity of maize in Kenya as is evident from its systematic and procedural creation of institutions and formulation of supportive policies.

It is evident that a lot has been done on the evaluation of returns to research. From all these studies, the results show high payoffs. But is this the case for potato research in Kenya?

CHAPTER 3

METHODOLOGY

3.1 The Method

The farm income method seeks to determine the profitabilities of the different research programmes. Research impact is evaluated based on its effect on farm profits. The extent to which a research recommendation raises farm profits is determined, the research thrust raising the farm incomes most should be given highest priority. This is the approach taken in this study.

This has been done at farm level since one of the objectives of these programmes is to raise farm incomes. At farm levels these research programmes are in terms of technologies. Using this method, the impact each of these technologies has on farm profits has been determined. This has been done by getting the farm level profits of farmers not using a certain technology and the farm level profits of those using a certain technology and the difference gives the profits of using the technology. This has been taken as the potential payoff of the technology.

The budgetary approach has been taken for it allows for broader description and understanding of the farmers practices especially the choice of technical combinations of the technologies. It is also one of the methods that evaluates research at farm level. This is very important since the farmers are the consumers of agriculture research output.

The Budgets are based on measures of yield per acre (Y), output price (P), total revenue (TR), total costs (TC). The total profit (TP) from production has been calculated as follows:-

$$TP = TR - TC \qquad \ldots\ldots 1$$

TR has been taken as the total revenue earned due to production of one acre of the crop and has been calculated as follows:-

$$TR = Y\,P \qquad \ldots\ldots 2$$

TC has been taken as the total of all expenses incurred in producing one acre of potatoes and has been calculated as follows:-

$$TC = \sum_{i=1}^{n} X_i r_i \qquad \ldots\ldots 3$$

Where i = type of input

n = number of inputs

X = quantity of input

r = price of input

TP has been taken as the revenue above costs. It is a measure of how much the producer gains due to production. It has been calculated as:-

$$TP = TR - TC$$

$$= Y\,P - \sum_{i=1}^{n} X_i r_i \qquad \ldots\ldots 4$$

Average annual prices have been used in this study. 1995 is the year used since it was an average year without weather, market and political instabilities. The budgets show, output quantities and prices, input quantities and prices and the net farm profits. The unit of production used is an acre since most production units in Nakuru district are in acres.

There are two to three potato seasons in Nakuru district per year. In Nyankinyua and Mau-Narok clusters there are three Production seasons and two in other areas. The annual profits have been calculated using two production seasons since a majority of the farmers produce in two seasons.

The average yield per acre for the two seasons has been established. The unit used is the 130 Kilogram (Kg) bag, this is the extended potato bag. The average farm gate price for the 130 Kg bag for the two seasons for each group of varieties has been established. This has been calculated as:

$$\left\langle \frac{\sum_{i=1}^{n} Q_i^1 P_i^1}{\sum_{i=1}^{n} Q_i^1} + \frac{\sum_{i}^{n} Q_i^2 P_i^2}{\sum_{j=1}^{n} Q_i^2} \right\rangle / 2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots 5$$

Where 1 = season 1

2 = season 2

n = number of farmers

Q = quantity of potatoes in bags

P = price of Potatoes per bag

The varieties have been classified into two, the local and the recommended varieties. However there is a considerable group of farmers produce both local and recommended varieties. This brings into the picture a third group of farmers producing 'mixed varieties'. The different varieties register different prices. The prices for the different varieties have been estimated. The local varieties have slightly higher prices than the recommended varieties. The farmers producing both local and recommended varieties however are enjoying higher prices since they seem to pick the more preferred from both the local and recommended varieties. A price of Kenya Shillings (Ksh) 450 per bag has been estimated for the local varieties, Ksh 400 for the recommended varieties and Ksh 500 for the mixed varieties.

Only variable inputs are considered in this study. The only fixed input identified is the knapsack sprayer, however, this sprayer is used for all enterprises and especially spraying of animals, other vegetables and fruits. The cost of this item apportioned to potato production is thus negligible.

All inputs are thus variable input costs. Amounts used per acre per season have been established. Costs include: fertilizer, seed, agro-chemicals, plough hire and labour. The main fertilizer being used is Diammonium Phosphate (DAP) followed by Mono Ammonium Phosphate (MAP). The quantity used per acre per season has been established. Since a majority of the farmers use DAP the average farm-gate price of DAP has been used to cost this item. The price of DAP range between Ksh 1,200 and Ksh 1,500 per 50 Kg bag and an average transportation cost of Ksh 50 per 50 Kg bag. The average price was estimated at Ksh 1,450 per 50 Kg bag.

The quantity of agro-chemicals used has been established, the most common chemical used is Ridomil followed by Dithane. The farm gate price of Ridomil has been used to cost this item. Prices range from between Ksh 1200 and Ksh 1450 per liter. An average price was estimated at Ksh 1,300 per liter.

For labour costs, all activities performed for the potato crop have been established and the labour used in man hours determined. These activities are ridging, weeding, spraying, harvesting and sorting. The average labour requirements for these activities have been established. Both family and hired labour have been costed using the market price of labour which is Ksh 50 per man day.

Seeds have been classified into two; certified and the non certified seeds. The amounts in bags a farmer uses per acre have been established. The price of non-certified seed range from Ksh 400 to Ksh 900 for 130 Kg bag. The average price has been calculated as:

$$\left\langle \frac{\sum_{i=1}^{n} S_i^1 M_i^1}{\sum_{i=1}^{n} S_i^1} + \frac{\sum_{i}^{n} S_i^2 M_i^2}{\sum_{j=1}^{n} S_i^2} \right\rangle / 2 \qquad \ldots\ldots\ldots\ldots\ldots 6$$

Where 1 = season 1

2 = season 2

n = number of farmers

S = quantity of potato seeds in bags

M = price of Potatoes seeds per bag

This gives an average price of ksh 600. For certified seeds, the packaging is in 50 Kgs and priced at Ksh 820 for grade 1 and Ksh 615 for grade 2. All the sampled farmers are using grade 2, therefore a price of Ksh 615 has been used to cost this item. It has also been assumed that two and a half of the 50 Kg bags make the extended potato bag.

Most ploughing is done once a year using tractor, while harrowing is added only on virgin land. For the successive seasons, ridging is done immediately after harvesting. The plough hire price ranges between Ksh 900 to Ksh 1200 per acre. An average price of Ksh 1000 has been estimated and used to cost this item.

The working capital costs have been defined as the opportunity cost of holding capital. The amount of money the farmer holds for purchase of inputs and hiring of labour has been established. The opportunity cost has been taken as the amount the farmer would have gained had he invested this money in the bank for that duration of time. The market interest rate of 10 percent has been used as a proxy for opportunity cost since most bank interest rates for savings range between 8 and 15 percent.

For analysis, farmers have been grouped according to the technologies they are using. Six technology-mix groups have been identified. Budgets have been constructed for the different technology-mix groups. The profits of groups using a given technology have been compared with the profits of groups not using the technology. This gives the profit the farmer gets due to the use of the technology and is used as a proxy to estimate of the potential payoff of the technology.

The other measure of evaluation used to reinforce this is the ratio of differential benefits to costs. It is a measure to estimate the returns to the extra cost incurred by farmers by adopting these technologies.

This has been calculated as:

Benefits differential/Costs differential

The differences in costs and benefits for farmers using a certain technology and those not using have been determined. The ratio of these two differences is a measure of how much a farmer would gain after use of a certain technology. These two measures, the total profits and ratio of differential benefits to costs have been used to prioritise the technologies studied.

3.2 Population and sampling

Primary data are used in this study. The data are collected from a targeted survey of small scale farmers in Njoro and Molo divisions of Nakuru District. Njoro Division has a total of 22,860 farm families (MoALM, 1995 b) and Molo Division has a total of 33,324 farm families (MoALM, 1995 c). The Divisional Agriculture Office estimates that about 70 percent of these farmers at least produce some potatoes. From each division, the four major potato producing sublocations have been identified. By use of strategic random sampling, farmers producing between one-quarter and five acres of potatoes have been selected. Nine farmers have been selected from each cluster. Therefore the sample size used in this study is of 72 farmers.

Data collected include: quantities of output per acre, output prices, type of inputs required, quantities of inputs, prices of inputs and technology combinations.

3.3 Description of the technologies studied

The purpose of this study is to determine the potential payoffs of three potato research programmes. These are; use of certified seed; use of crop protection chemicals and use of recommended varieties. This has been done at farm level where these programmes are supposed to impact. At farm level, these are in terms of technologies.

Certified seeds have been taken as those seeds that have gone through the certification process. This process involves breeding of seed by Kenya Agriculture Research Institute (KARI) through National Potato Research Centre (NPRC) and multiplication of this seed through Agriculture Development Corporation (ADC) and certification by National Seed Quality Control Board (NSQCB). The seed is marketed by ADC to individual farmers and through Kenya Farmers Association (KFA).

Crop protection involves the application of agro-chemicals used to protect the potato against pests and diseases. The most common diseases are early blight, late blight and bacterial wilt. Protection against pests is minimal.

Recommended varieties have been taken as the varieties that have been developed by KARI through NPRC and are recommended for the use. All the other varieties have been considered as `local varieties'.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 The technology mixes.

The farmers were found to be using different combinations of technologies, the mixes identified are shown in Table 4.1

Table 4.1: Potato technology mixes

Abbreviation	*Description*
S_n C_n V_n	non-certified seeds, no crop protection, local varieties
S_n C V_n	non-certified seeds, crop protection, local varieties
S_n C_n V_m	non-certified seed, no crop protection, mixed varieties
S_n C V_m	non-certified seeds, crop protection, mixed varieties
S_n C V	non-certified s eeds, crop protection recommended varieties.
SCV	Certified seeds, crop protection, recommended varieties

Source: Author's own compilation

The first technical combination (S_n C_n V_n) is made up of farmers that use non-certified seeds, use no crop protection at all and use the local varieties. However this groups uses fertilizer but at a relatively lower rate. Unexpectedly, this is the largest group constituting of 32 percent of the sample farmers. This shows that a majority of the farmers do not use any of the studied potato research technologies.

The technical mix of (S_n C V_n) consists of the farmers who use non-certified and local varieties but they practice crop protection though not at recommended rates. This group has a higher seed rate of seven bags per acre and also a higher fertilizer rate than the first group. The chemical use is relatively lower than other groups using agro-chemicals. This group constitutes 17 percent of the sample farmers.

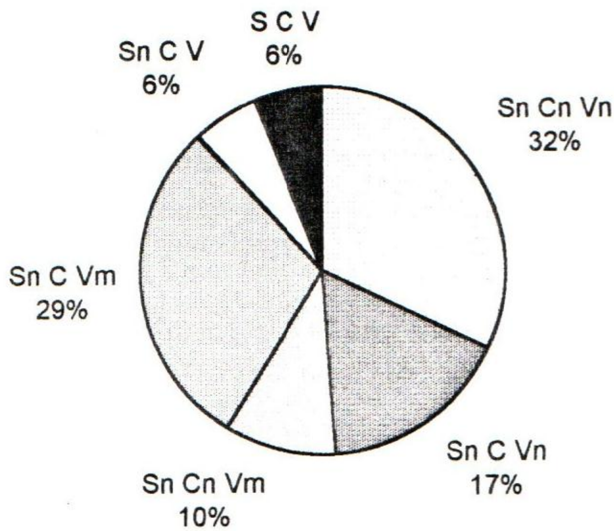
The combination (S_n C_n V_m) is of farmers using non-certified seeds and no crop protection but mixes both local and recommended varieties, probably to reap the benefits of both types of varieties. This is, however, a small group constituting ten percent of the sample. Their fertilizer rate is relatively high and the seed rate is low about six bags per acre.

The technical mix (S_n C V_m) is of farmers that use non-certified seeds, practice crop protection but use both local and recommended varieties. This is the second largest group constituting 29 percent of the sample. This group has a high fertilizer rate and also a high seed rate.

The other combination (S_n C V) is of certified seeds, practices crop protection and uses recommended varieties. The group has a high fertilizer rate and also a high seed rate. However the size of the group is small constituting six percent of the sample.

Finally the combination (S C V) consists of farmers that utilise all the three technologies of use of certified seeds, use of crop protection and recommended varieties. The fertilizer rates are high and so is the seeding rate. Its however not a large group, it constitutes of 6 percent of the sample.

Figure 4.1: Distribution of technology mixes in the farmer sample



Source: Author's own compilation

As indicated in Figure 4.1, the largest group is of farmers that use none of the technologies. This is probably linked to the fact that these technologies are expensive hence a majority of the farmers cannot afford to use them.

The second largest group is that which uses crop protection and mixes their varieties. This result confirm this studies view of that farmers are rational decision makers since this technology mix achieves the highest profits. These farmers pick the most profitable of the two types of varieties.

One of the smallest groups is that which uses all the three technologies. Though this group is achieving the highest yields, their costs are also the highest. This explains the small size of the group.

The other group which is small is the group that combines crop protection, recommended varieties with non-certified seeds. This group has unexpectedly the lowest profits probably because its fertilizer rates are very high. The response to high fertilizer and agro-chemical rates on non certified seeds could be low leading to relatively lower yields and high costs hence low profit levels. It is therefore no wonder that this technology mix group has few farmers.

The different groups have different input use and achieve different yields as shown in Table 4.2. At 5% level of significance, there are significant differences in fertilizer use and agro-chemical use. The difference in yields are also significant. The highest yields are achieved as expected with the technical combination of certified seeds, crop protection and recommended varieties while the lowest by the combination of non-certified seeds, no crop protection and local varieties.

It can be noted with concern that a majority of the farmers are in the mix of using none of these technologies and are achieving the low yields while a minority are using the three technologies and achieving high yields. as shown in figure 4.2.

Table 4.2 : Input use and yields of the different technology mix groups

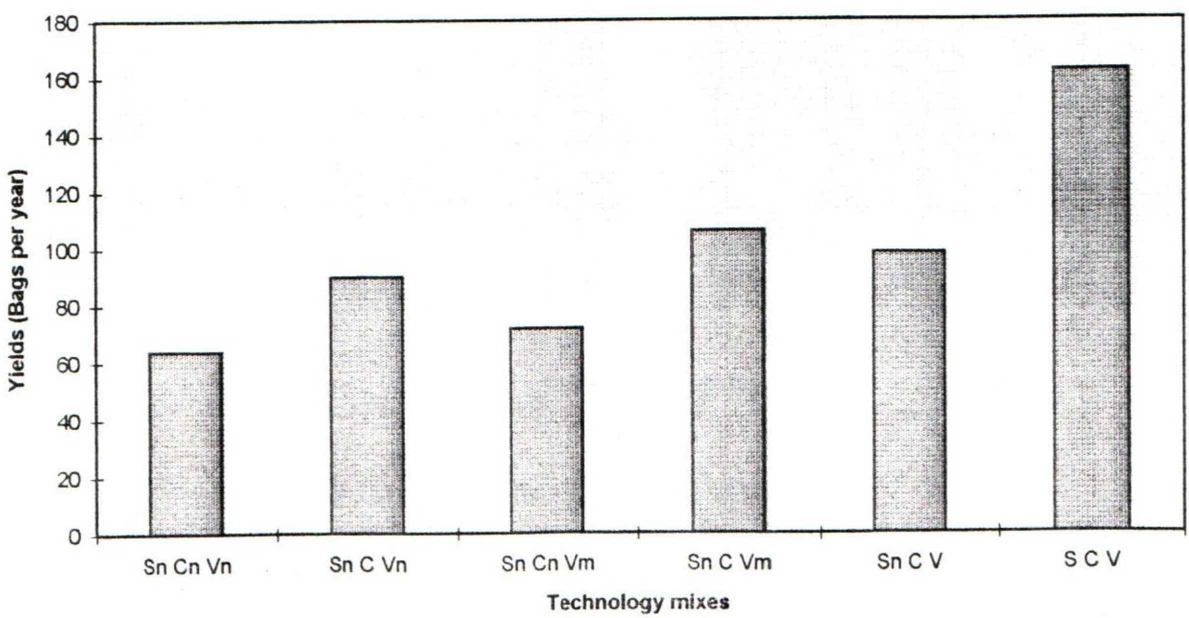
Tech mix	*Percent farmers*	*Avg fert rate(Kg/ ac/sn*	*Avg Agro chem rate Kg/ac/sn*	*Avg seed rate(Bag/a c/sn*	*Yields (Bag/ac/ Year*
S_n C_n V_n	32	38	0	6	64
S_n C V_n	17	56	1	7	90
S_n C_n V_m	10	84	0	6	72
S_n C V_m	29	79	2	7	106
S_n C V	6	110	1.5	7	98
S C V	6	94	2	8	162

NB: Tech - Technology; Avg - Average; fert - Fertilizer; Kg - Kilogram; ac -acre; sn - season; Agro chem - Agro-chemicals;

Source: Author's own compilation

This is likely to be linked to the fact that these technologies are expensive therefore farmers choose low yielding low costing practices.

Figure 4.2 : Yields of the different technology combinations.

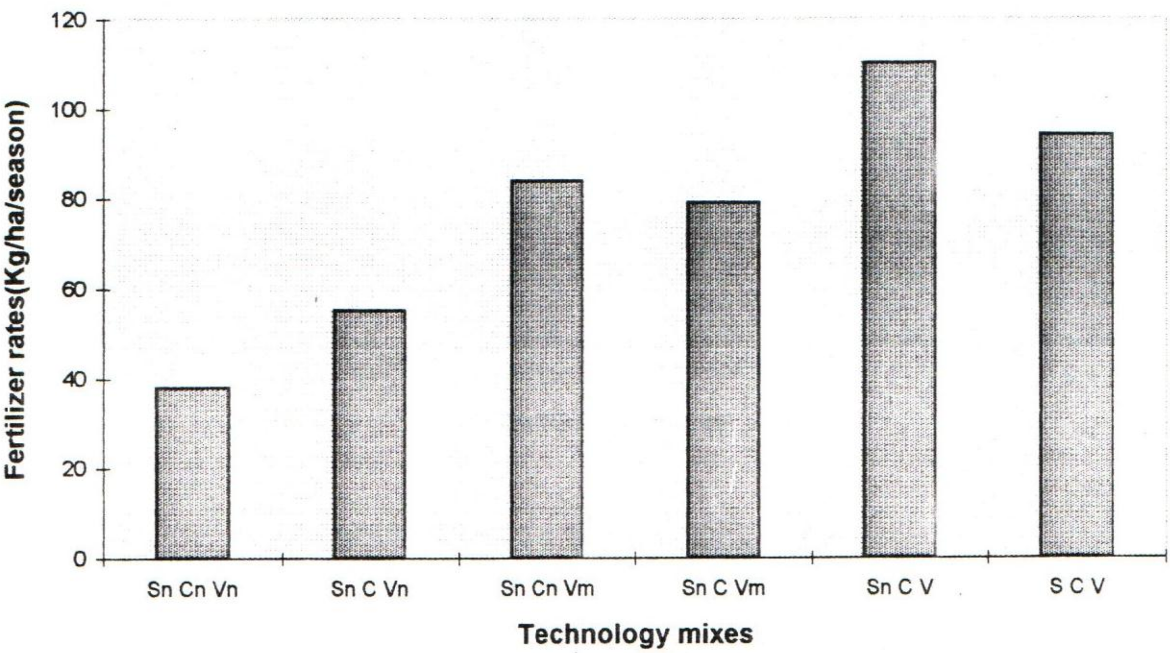


Source: Author's own compilation

It also evident that the technical combinations with crop protection achieve higher yields than those that do not. Those using certified seeds also record higher yields than those that do not as shown in Figure 4.2.

The data reveal other examples of farm-level adjustments in technical packages to fit the conditions under which farmers are operating. Farmers using local varieties were found to be using lower fertilizer dosages than those using either mixed or recommended varieties as shown in Figure 4.3.

Figure 4.3: Fertilizer application rates by different technology combinations.

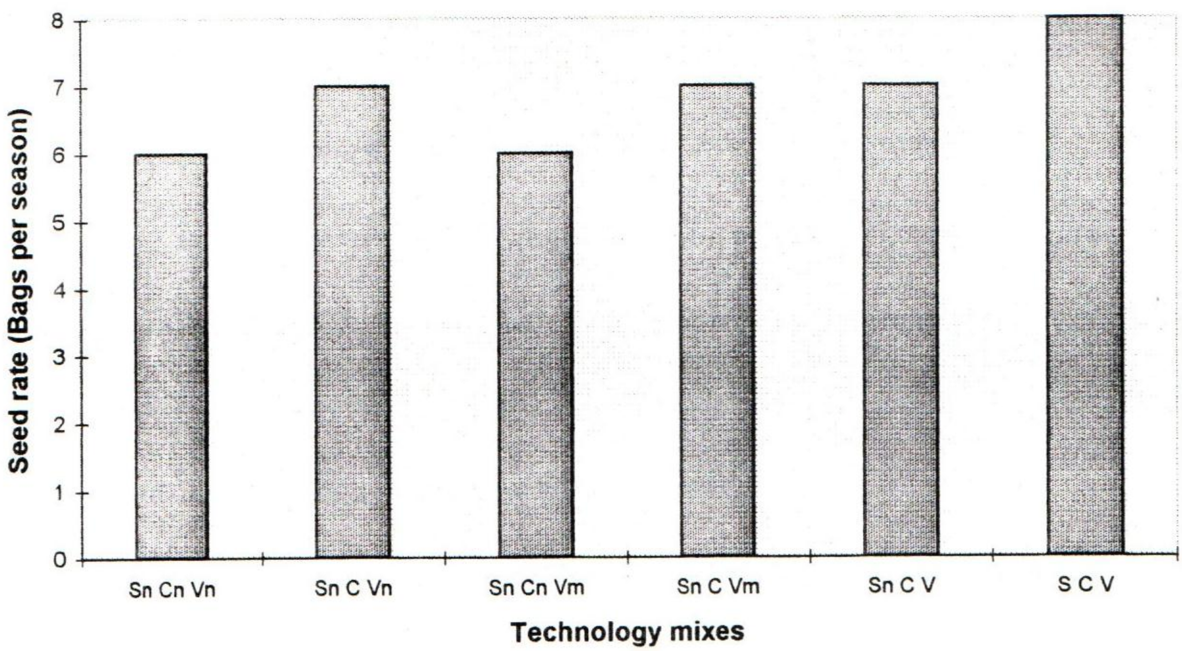


Source: Author's own compilation

This could be expected since local varieties are known to be less fertilizer responsive than are recommended varieties.

The seeding rate variability is not significant at 5% level of significance as shown in Figure 4.4. However, the absence of crop protection is associated with lower seeding rates than is the case with crop protection. This makes sense since only high seeding rates give high yields but the higher costs may require resources beyond the means of poor farmers.

Figure 4.4 : Seeding rates of the different technology combinations



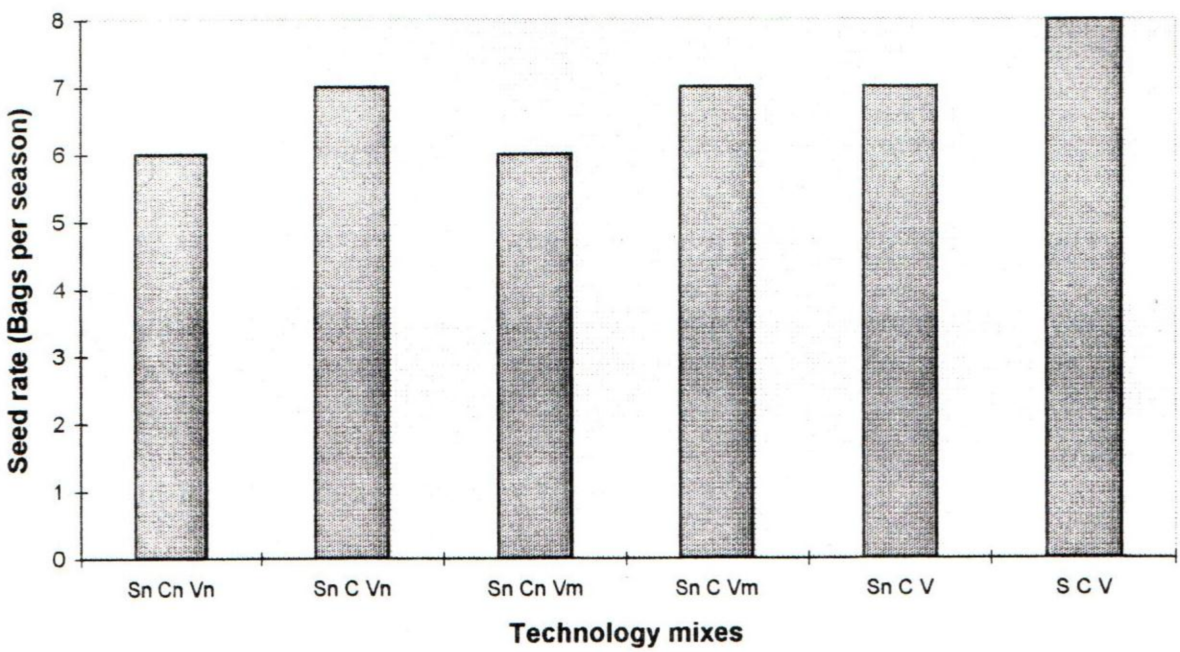
Source: Author's own compilation

Due to use of the different technical combinations of technologies, different revenues, costs and profits are achieved as shown in the Table 4.3.

At 5% level of significance, there are significant differences in revenues, costs and profits. revenues.

The seeding rate variability is not significant at 5% level of significance as shown in Figure 4.4. However, the absence of crop protection is associated with lower seeding rates than is the case with crop protection. This makes sense since only high seeding rates give high yields but the higher costs may require resources beyond the means of poor farmers.

Figure 4.4 : Seeding rates of the different technology combinations



Source: Author's own compilation

Due to use of the different technical combinations of technologies, different revenues, costs and profits are achieved as shown in the Table 4.3.

At 5% level of significance, there are significant differences in revenues, costs and profits. revenues.

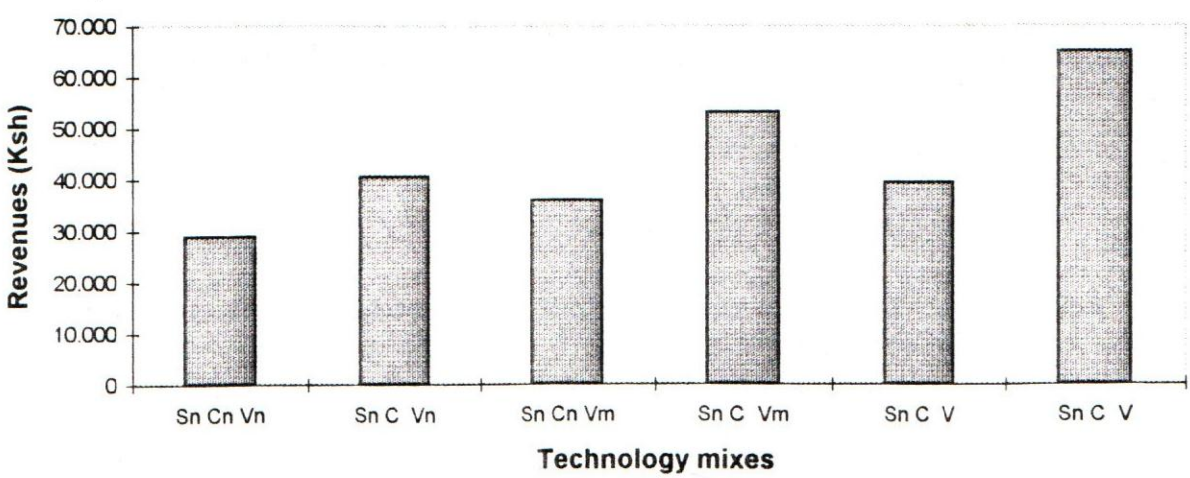
Table 4.3: Profit levels of the different technology mix groups

Technology mix	*Total revenue (Ksh)*	*Total costs (Ksh)*	*Profit (Ksh)*
S_n C_n V_n	28,800	19,474	9,326
S_n C V_n	40,500	26,013	14,487
S_n C_n V_m	36,000	22,629	13,371
S_n C V_m	53,000	30,780	22,220
S_n C V	39,200	31,328	7,872
S_n C V	64,800	51,207	13,593

Source: Author's own compilation

As is expected, the technical combination of non-certified seeds, no crop protection and local varieties register the lowest revenue. while the combination of certified seed, crop protection and recommended varieties achieve the highest revenue as shown in Figure 4.5. This can be attributed to the low and high yields achieved by these groups.

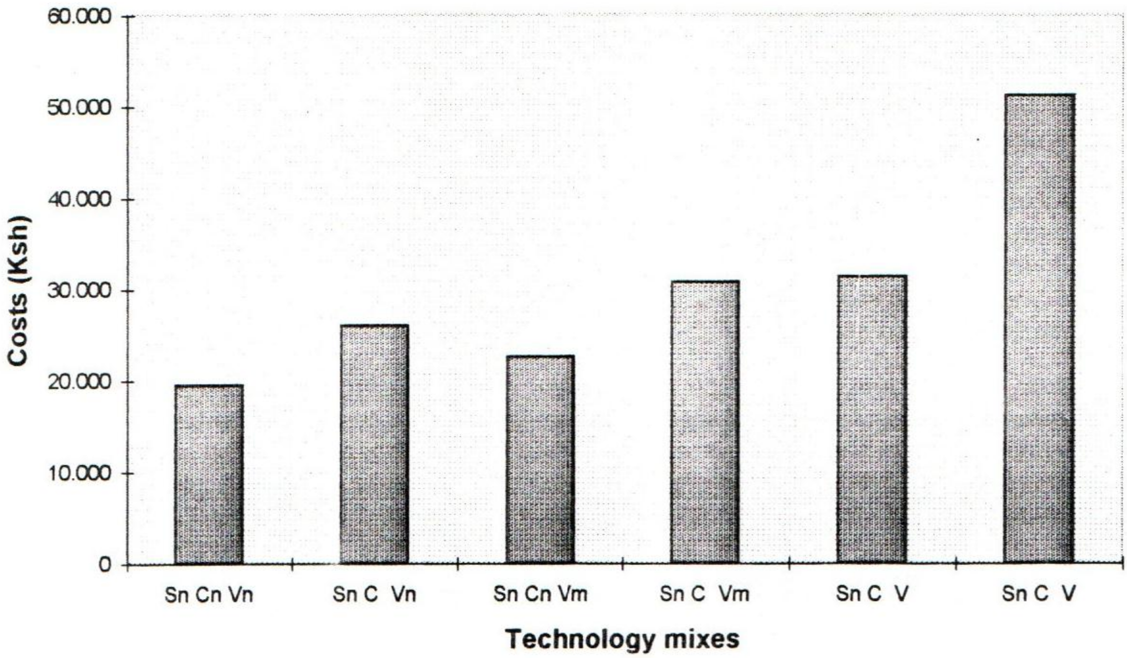
Figure 4.5: Revenues earned by different technology combinations



Source: Author's own compilation

The costs, as expected are highest for the combination that includes all the three technologies and lowest for the combination that use none of the technologies as shown in Figure 4.6.

Figure 4.6: Costs incurred by use of different technology combinations

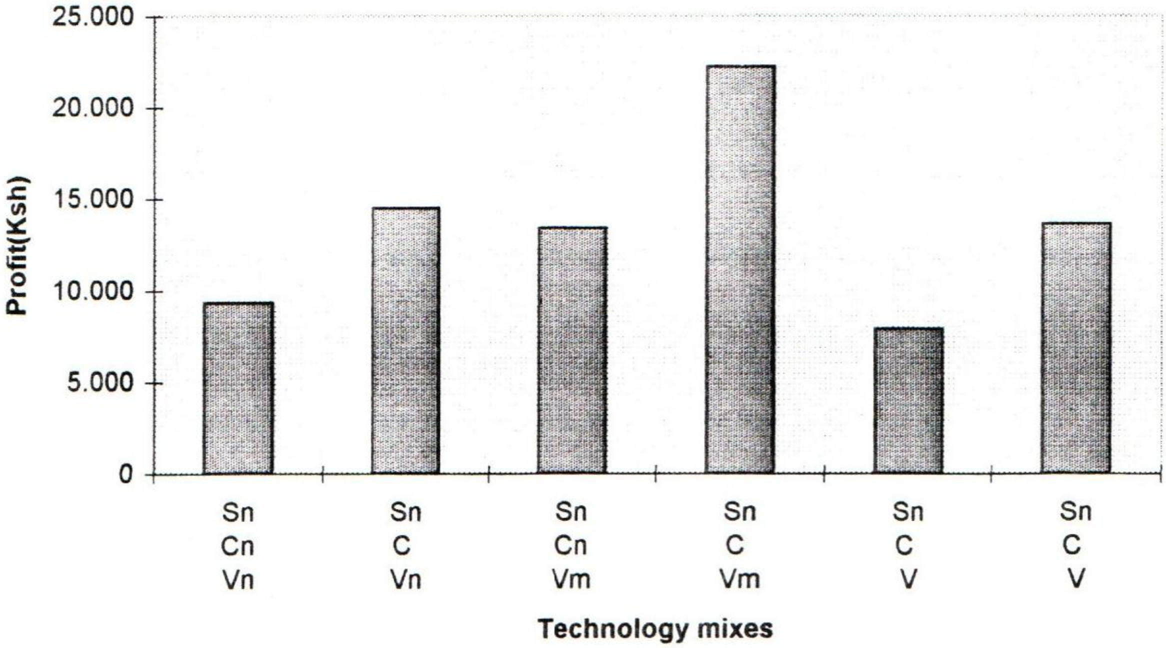


Source: Author's own compilation

The technical combinations that include crop protection incur higher costs than those that do not and those which have certified seeds have higher costs than those that do not. This shows that these technologies have a cost to the farmers.

For the profits as shown in Figure 4.7, the technical combination of using non certified seeds, crop protection and mixed varieties register the highest profits contrary to the expectation that the combination of certified seed, crop protection and recommended varieties would earn the highest profits. This is because though the group (SCV) has a higher revenue but the costs are also very high that the profits are lower. With the technical combination of non-certified seeds, crop protection and recommended varieties, lowest profits are earned.

Figure 4.7: Profit levels of different technology combinations



Source: Author's own compilation

This probably is as a result of the low revenues resulting from lower yields coupled with high costs.

Using the difference in profit levels of these technologies mixes, it is possible to get estimated profitabilities of each separate technology as is the aim of this study.

4.2 The Profitabilities of different technologies

The purpose of this study is to determine the potential payoffs of the different potato technologies. Due to use of different technology mixes, the profits are different. This means that the different technologies have different impacts on farm incomes. The level to which each of these technologies raises farm incomes is taken as the potential payoff of the technology.

(a) Crop protection

The income impact by crop protection can be determined from two sets of combinations. One set is of the combination of non-certified seeds and non recommended varieties but one set uses crop protection and the other does not. The other set is of the combination of non-certified seeds and mixed varieties with one using crop protection and the other one not.

Table 4.4: Profitability of crop protection for farmers using non-certified seeds and non recommended varieties.

Technology mix	*Annual Yield (bags/year)*	*Net profit (Ksh)*
S_n C V_n	90	14,487
S_n C_n V_n	64	9,326
Difference	26	5,161

Source: Author's own compilation

There is a difference in profits and also in yields between the use and non-use of crop protection as shown in Table 4.4. For the farmers using local varieties and non-certified seeds there is a difference in yield of 26 bags per year and a difference in profit level of Ksh 5,161.

Table 4.5: The ratio of differential benefits to costs of crop protection for farmers using non-certified seeds and non recommended varieties

Cost Differential	6539
Benefit Differential	11,700
Ratio of differential benefits to costs.	1.78

Source: Author's own compilation

The ratio of differential benefits to costs 1.78 as shown in Table 4.5. This means that for every extra unit a farmer puts in this technology, he gains 78% more.

Table 4.6: Profitability of crop protection for farmers using non-certified seeds and mixed varieties.

Technology mix	*Annual Yield (bags/year)*	*Net profit (Ksh)*
S_n C V_m	106	22,220
S_n C_n V_m	72	13,371
Difference	34	8,849

Source: Author's own compilation

For the farmers who use mixed varieties and non-certified seeds, there is a difference in yields of 34 bags and a difference in profits of Ksh 8,849 due to the use of crop protection as shown in Table 4.6.

Table 4.7: Ratio of differential benefits to costs of crop protection for farmers using non-certified seeds and mixed varieties.

Costs Differential	8,151
Benefits Differential	17,000
Ratio of differential benefits to costs	2.09

Source: Author's own compilation

The ratio of differential benefits to costs 2.09 as shown in Table 4.7. This means that the farmer using an extra shilling in adopting this technology gains Ksh 1.09 units.

From the above results, it is evident that that the use of crop protection is profitable at farm level, raising farm incomes by between Ksh 5,161 and Ksh 8,849. The Marginal benefit is approximately 2. This means that for every extra unit cost the farmer incurs in adopting this technology, he achieves twice the benefits.

(b) Recommended varieties

The income impact by recommended varieties can be determined from two sets of combinations. One set is of the combination of non-certified and crop protection and local varieties while the other uses non-certified and crop protection and recommended varieties

Table 4.8: Profitability of recommended varieties for farmers using non-certified seed and crop protection.

Technology mix	*Annual Yield (bags/year)*	*Net Profit (Ksh)*
S_n C V	98	7,872
S_n C V_n	90	14487
Difference	8	-6615

Source: Author's own compilation

There is an unexpected decrease in income due to use of recommended varieties and a minor increase in yield of 8 bags as shown in Table 4.8. The decrease in income is of Ksh 6,615. This suggests that the increase in yield resulting from use of recommended varieties is not high enough to cover the costs.

Table 4.9: Ratio of differential benefits to costs of recommended varieties for farmers using non-certified seed and crop protection.

Costs Differential	5,315
Benefits Differential	-1,300
Ratio of differential benefits to costs	-0.24

Source: Author's own compilation

The ratio of differential benefits to costs is - 0.24 as shown in Table 4.9. This means that for every extra unit cost a farmer incurs in this technology he looses 24% of his investment. It is therefore evident that recommended varieties do not fit with most farmers motives of raising farm incomes.

(c) Certified seeds

The impact on incomes by use of certified seed can be determined using the technical combinations of crop protection and recommended varieties but one includes certified seed while the other does not.

Table 4.10: The profitability of certified seed for farmers using crop protection and recommended varieties.

Technology mix	*Annual Yield (bags/year)*	*Net profit (Ksh)*
S C V	162	13,593
S_n C V	98	7,872
Difference	64	5,721

Source: Author's own compilation

There is a tremendous difference in yields and some positive difference in profit levels between the use of certified seed and non use. There is a difference in yields of 64 bags and a difference in profit levels of Ksh 5,721 as shown in Table 4.10.

The ratio of differential benefits to costs is 1.29 as shown in Table 4.11. This means that for every extra unit a farmer invests in this technology there is 29% gains.

Table 4.11: Ratio of benefits to costs of certified seed for farmers using crop protection and recommended varieties.

Costs Differential	19,879
Benefits Differential	25,600
Ratio of differential benefits to costs	1.29

Source: Author's own compilation

It is therefore evident that certified seed technology increases both income and yields. The impact on yields is quite high but the impact on income relatively low. This is because of the high cost of this technology as is reflected by the low ratio of differential benefits to costs of 1.29.

From the results, crop protection is having the greatest impact on farm incomes followed by use of certified seeds as shown in Table 4.12. The use of recommended varieties has no impact on farm incomes. Crop protection is thus the most profitable to the farmers. It therefore has the greatest potential payoff to research.

Use of certified seed has a positive impact on farm incomes, however, lower than that of crop protection. This is low compared with the extra costs required as reflected by the low ratio of differential benefit to costs.

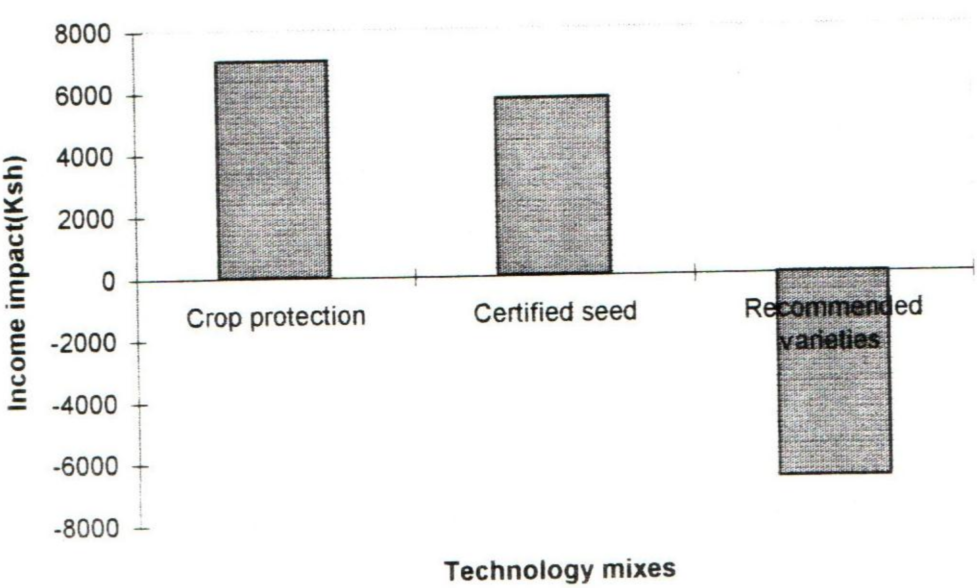
Table 4.12: Income impact of the different technologies.

Technology	*Income impact (Ksh)*	*Ratio of differential benefits to costs*
Crop protection	5,161 - 8,849	1 78 - 2 09
Certified seed	5,721	1 29
Recommended varieties	-6,615	-0 24

Source: Author's own compilation

The use of recommended varieties has no impact on farm incomes, the farmers are actually loosing by using it as shown in Figure 4 8. This technology thus has a limited potential payoff.

4.8 Income impact of different technologies



Source: Author's own compilation

4.3 The effect of product price changes on the profitabilities of technologies.

The results of this study were based on prevailing market prices of potatoes in 1995 Product prices usually fluctuate It would therefore be important to determine what would happen as the product prices fluctuate Rather as market prices change, does the impact on incomes by these technologies change? Two price levels will be used for this, the lower level of Ksh 200 and an upper level of Ksh 1000 per 130 Kg bag These are usually the lowest and the highest potato product prices. This is done with the assumption that input prices are constant. This is not usually the case, however, the input prices are more constant while output prices fluctuate a lot in the short run.

With low product prices, for all the technical combinations of technologies, farmers are making losses as shown in Table 4.13. The income impact of crop protection on farmers who use local varieties and non-certified seeds is Ksh -701 and for farmers who use mixed varieties and non-certified seeds is Ksh -1,351.

The impact on incomes by use of certified seeds for farmers using crop protection and recommended varieties is Ksh -7079 The impact on income by use of recommended varieties for farmers using non certified seeds and crop protection is Ksh -4353 With low product prices, non of the technologies is worthwhile

Table 4.13: Profit levels of different technology mixes with Product price of Ksh 200 per bag.

Technology mix	*Total revenue (Ksh)*	*Total costs (Ksh)*	*Net profit (Ksh)*
S_n C_n V_n	12,800	19,474	-6,674
S_n C V_n	18,000	25,375	-7,375
S_n C_n V_m	14,400	22,629	-8,229
S_n C V_m	21,200	30,780	-9,580
S_n C V	19,600	31,328	-11,728
S C V	32,400	51,207	-18,807

Source Author's own compilation

When prices are high all technology combinations are making profits as shown in Table 4.14. The income impact of crop protection on farm incomes for farmers that use non-certified seeds and local varieties is Ksh 19,461 and Ksh 25,849 for farmers that use non-certified seeds and mixed varieties.

The impact on income by use of certified seed for farmers that use recommended varieties and crop protection is Ksh 44,121 and the impact on farm incomes by use of recommended varieties on farmers that use non-certified seed and crop protection is Ksh 2,685

Table 4. 14: Profit levels of different technology mixes with Product price of Ksh 1,000 per bag.

Technology mix	*Total income (Ksh)*	*Total costs (Ksh)*	*Net profit (Ksh)*
S_n C_n V_n	64,000	19,474	44,523
S_n C V_n	90,000	25,375	64,625
S_n C_n V_m	72,000	22,629	49,371
S_n C V_m	106,000	30,780	75,220
S_n C V	98,000	31,328	66,672
S C V	162,400	51,207	110,793

Source: Author's own compilation

When product prices are high all the technologies have a positive income impact. Use of certified seeds has the greatest income impact followed by crop protection. When prices are high the use of certified seed would be highly recommended.

4.4 Summary of the results

The farmers are combining the technologies studied in six different ways. The revenues, costs, and profits vary significantly between the groups. Since different applications of the technologies by farmers achieve different levels of profits, a change in the technical combination of technologies could be used to raise farm income.

The technical combination of use of the three technologies is achieving the greatest revenue as is expected. This is because the yields are also high. The farmers using none of the technologies are earning the lowest revenues due to the low yields. The use of the three technologies result to the highest costs while the use of none of the technologies result in the lowest costs. This suggests that these technologies have a cost to the farmers.

Most unexpectedly, the use of the three technologies does not result to the highest profits. Though this combination gives the highest yields, the extra cost in achieving these yield is high, resulting to low profits. This suggests that the extra cost of increasing the yields by use of these technologies are high relative to the value of the extra yields achieved.

The results indicate that crop protection has the highest impact on farm incomes followed by the use of certified seed. The use of recommended varieties at prevailing market prices does not impact on the farm incomes, however when this is combined with other interventions there is a positive impact especially on yields. This calls for a combined technical package of technologies.

From this study it is evident that farmers are rational decision makers. Majority of the farmers are choosing low cost low profits technical combinations.

This is probably due to their limited incomes. A large percentage of the sampled farmers are in the combination that is achieving the highest profits. This shows that farmers are able to pick and combine the technologies in the most profitable way

CHAPTER FIVE

GUIDELINES FOR POTATO RESEARCH IN KENYA, RECOMMENDATIONS AND CONCLUSIONS.

5.1 Guidelines for potato research

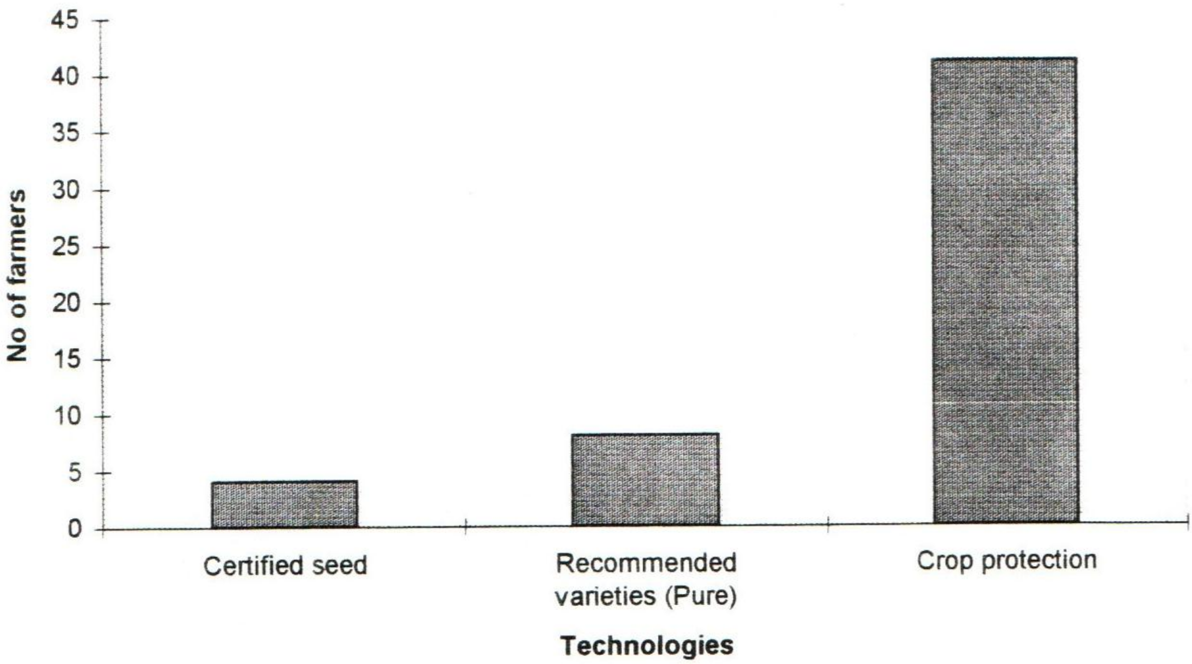
In Kenya one of the avenues that remains to be exploited in increasing agricultural growth is increasing land productivity. Small scale farmers due to their numbers as well as the overall large tracts of land they farm, are an important target group in efforts to increase agricultural production (Maina, 1996). Also one of the national objectives is to raise farm incomes (GoK, 1994 a). This therefore is an important group as far as research technologies are concerned.

But is the use of these technologies raising smallholders' farming incomes? This would be an important question for research planners who are faced with limited research resources to be allocated between several research programmes. The answer to this question probably would guide these planners in their decisions on allocation of these resources.

This study was designed to determine the potential payoffs of some research programmes and hence formulate guidelines for potato research. These programmes were evaluated based on their impacts on farm incomes. Three programmes were studied: the use of certified seeds; crop protection; and use of recommended varieties.

From the results crop protection has the greatest impact on farm incomes. The use of this technology raises farm incomes by between Ksh 5161 and Ksh 8849. This technology has the highest adoption as expected as shown in Figure 5.1.

Figure 5.1: Adoption of technologies in the farmer sample

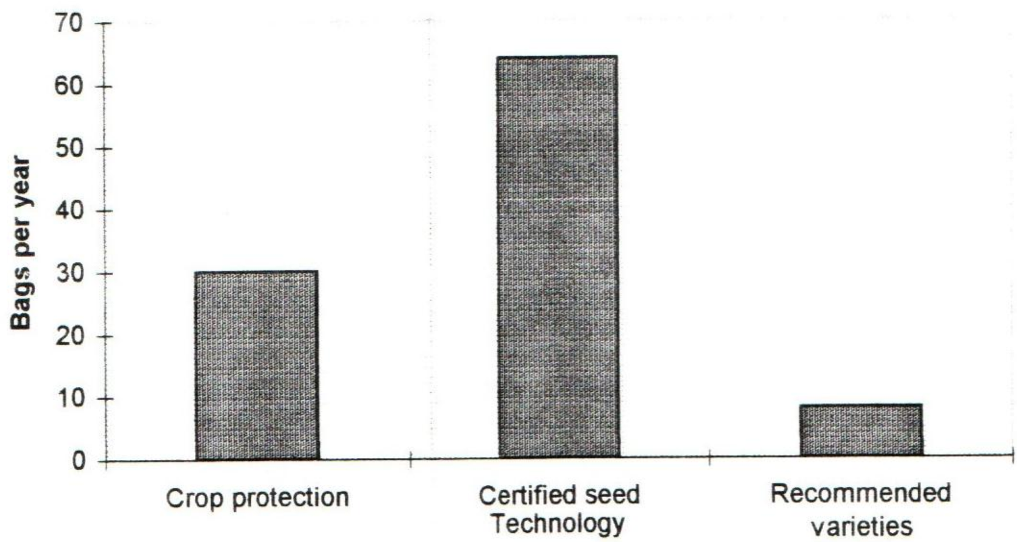


Source: Author's own compilation

If about 40 percent of all the potato producers have adopted this technology and are able to earn an extra income of between Ksh 5,161 and Ksh 8,849 per year, then this research technology is not only profitable to the farmers but to the nation as a whole. This technology is thus contributing positively to national economic growth. Researchers therefore should give this technology high research priority.

The use of certified seed has a positive impact on farm incomes albeit lower than that of crop protection. However, the potential impact on potato yields is almost double that due to crop protection as expected as shown in Figure 5.2. This implies that the cost of this technology is high as actually confirmed through this study, indicated by the lower ratio of differential benefits to costs.

Figure 5.2: Potential impact of different technologies on yields



Source: Author's own compilation

The adoption of the certified seed technology is low evident on only six percent of the sample farmers. This could even be lower for a bias was noted in the sample. All the six percent farmers were concentrated in Molo where the certified seed distribution center is. It was zero percent in Njoro, suggesting that the adoption of the technology country wide may be much lower than six percent. Although the certified seed technology has a positive impact on farm income its adoption too low. This can be explained by the high cost as indicated by the lower ratio of differential benefits to costs of 1.29. This technology is thus contributing little nationally due to its very low adoption. However, this certified seed technology has a high potential due to its high impact on yields. This is a technology that could raise potato production in Kenya but its potential is limited by its high cost. High research priority thus should be given to finding ways to reduce these costs while retaining the positive impact on yields.

The use of recommended varieties has a negative impact on farm incomes at prevailing prices, however, the results indicate that when recommended varieties are combined with the rest of the technologies, there is a great positive impact on farm incomes. This means that the recommended varieties are of no major importance to the farmers if used without combining them with certified seeds and crop protection. This technology has a significant adoption of about 11 percent. However half of these adopters are combining recommended varieties with certification of seeds and hence they may not be losing. Nevertheless, the negative benefits could have serious implications on farmers and also nationally. If about five percent of all potato producers lose about Ksh 7000 every year due to use of recommended varieties, then it means that this technology may be contributing negatively to economic growth. The researchers should therefore not introduce recommended varieties where it is not possible to combine them with other interventions.

5.2 Policy Recommendations.

5.2.1 Price Policies

Howard, et. al., (1993) in their study of maize research in Zambia, found out that one of the factors that led to the success of the maize research program was implementation of marketing and pricing policies. Karanja, (1993) in a similar study of maize research in Kenya noted that its success was due to guaranteed maize prices among others. Similar price policies may raise returns to potato research in Kenya. The potato prices fluctuate widely across seasons. The results of this study indicate that low harvest time prices that reduce the ratio of differential of differential benefits to costs may be an impediment to adopting the studied technologies. A floor price may reduce these effects.

Byerlee, (1992), in their study on maize research in Sub-Saharan Africa, indicate that adoption of technologies that depend upon the use of purchased inputs such as seed and fertilizer is strongly conditioned by policy environment with respect to inputs prices. Howard, et. al. (1993), found out that the success of maize research in Zambia was due to heavy fertilizer subsidy among others. As indicated by the results of this study one of the factors hindering adoption of these technologies is the cost. It is no wonder that the majority of the farmers are choosing low costing but low profit combinations. This would be solved if these inputs were made cheaper. Ceiling prices for key inputs would ensure that potato producers are making profits after using the technologies.

However, in the era of market liberalisation, such price policy interventions are unlikely. An alternative approach would be to reduce the costs of using improved technologies by investment in improved rural infrastructure, which could reduce the unit cost of key inputs.

5.2.2 Institutional policies

As Howard, et. al., (1993), put it, to overcome the gaps in technology adoption in developing countries, improved technology must be adjusted to better fit the infrastructural and institutional development in the developing countries.

Akino and Hayami, (1979) noted an increased efficiency in research due to an institutional innovation. The high maize research payoff in Kenya was attributed to good seed and extension programmes and seasonal credit by Karanja, (1993). From these researchers, there seems to be an enhanced research payoff from institutional organisation.

These also seem necessary to enhance research payoff for potatoes in Kenya. From this study it has been found out that one of the reasons that probably hinder adoption of the technologies is the cost. This calls for an institutional policy of integrating research with agriculture credit institutions to avail credit to the farmers.

The other probable reason for low adoption of certified seed technology could be poor seed distribution. From this study it was noted that 100 percent of the farmers using this technology are located in Molo where the center for certified seed distribution is situated. There was no adoption in Njoro division. This points to poor distribution of certified seeds. This calls for institutional policies enhancing production and distribution certified potato seed.

5.3 General recommendations

Through this study several issues came up which should be addressed to make potato research more productive.

i. Consideration of farmer preference in development of varieties.

The development of varieties by research are due to biological aspects, that is disease resistance, storability and yields. Farmers as found out through this study look for other factors as market preference, risk and cooking qualities. A variety like Nyayo is preferred because of its low yield variance. Farmers being risk averse prefer this variety because, irrespective of the environmental conditions there would still be some harvest. A variety like

'Meru' is preferred because of its high market demand irrespective of its low yield. Development of varieties should therefore not limit itself only on biological aspects but should also consider farmer preference otherwise research will continue to develop varieties that will not be adopted by the farmers. This could be done by certifying the varieties the farmers already prefer especially the Nyayo variety.

ii. Dissemination of technology

Transfer of information on technology should also be a part of research package. About 40 percent of the farmers indicated that they were not aware of the certified seed technology. Researchers may continue to produce a technology but as long as the farmers have no knowledge about it then it may not be adopted. Research should therefore not only concentrate on production of the technology but also on ensuring that this technology reaches the intended group. This perhaps calls for corroboration between researchers and extension agents.

(iii) Evaluation of research impact.

There should be a continuos evaluation of the impact of agriculture research. When researchers are developing a technology, they should have clear objectives, and then evaluate its impact continuously. This will help them determine whether they are wasting resources developing technologies that do not impact the farmers in any way or the economic growth of the country.

5.4 Further research

There is need to determine why it is not profitable to use research recommended potato varieties. It is expected that recommended varieties would perform better than local varieties especially when coupled with crop protection but that is contrary to the findings of this study. There is therefore a pressing need to uncover this quandary to avoid recommending to farmers a technology that is reducing their incomes.

5.5 Summary and Conclusions

Research, whether public or private, employs resources that have alternative uses and thus entails an opportunity cost to the society. The society foregoes other products as it commits resources to be invested in research. The only justification of such a cost would be a large enough return to lower the opportunity cost (Paulson and Kaldor, 1968).

In Kenya, where there is much need for investments in all areas the opportunity cost to research investment is high. All the same, substantial resources have been committed to agricultural research. Are they justified?

From this study that covers only three research programmes and one crop, it has become evident that some programmes are justifiable in that they raise the farm incomes significantly and hence have been adopted by a large number of farmers this contributing significantly to national economic development. There are others that raise farm income significantly but the adoption is so low that they do not impact on national development. Others reduce farm incomes and hence contribute negatively to national development. This calls for a serious and continuous evaluation of research investments to ensure that they contribute positively to national economic growth.

From this study that covered only three technologies on potatoes in Nakuru District, crop protection was found to have the highest potential payoff and a high adoption rate and therefore needs high research priority. Certified seed was found to have a lower income impact but a higher yield impact. The adoption of this technology is hindered by high costs. It is suggested that this technology has a high potential and a way of reducing its costs to the farmers should be searched for.

Recommended varieties have no impact on farm incomes at prevailing prices. It has been recommended that this technology should be introduced if it is to be combined with others. It is hoped that these findings will assist the research planners as they allocate limited research resources.

The other important issue that has come up from this study is the need for product and input price policies. Floor prices for products and a ceiling price for inputs would be required to ensure that farmers make profits after adopting the technologies.

Institutional policies would also be required to ensure availability of credit and efficient seed distribution. This perhaps would call for integrating agriculture research with agricultural credit institutions and other institutions like Kenya Farmers Association and Agriculture Development Corporation. Should these be followed, then potato productivity would increase, farm incomes would be raised and this would hopefully reduce over dependence on cereals, especially maize.

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Appendix 1

Budgets for different technology mix groups

Non-certified seeds, no crop protection, local varieties

	Units	Quantity	Price	Frequency	Total
Output	Bags	32	450	2	28800
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	16	50	2	1600
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	6	600	2	7200
DAP fertilizer	Kgs	38	29	2	2204
working capital					1770,4
Total costs					19474,4
Total annual profits					9325,6

Certified seeds, crop protection, local varieties

	Units	Quantity	Price	Frequency	Total
Output	Bags	45	450	2	40500
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	4	50	2	400
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	23	50	2	2300
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	7	600	2	8400
Agro chemical	Kgs	1	1300	2	2600
DAP fertilizer	Kgs	56	29	2	3248
working capital					2364,8
Total costs					26012,8
Total annual profits					14487,2

Appendix 1

Budgets for different technology mix groups

Non-certified seeds, no crop protection, mixed varieties

	Units	Quantity	Price	Frequency	Total
Output	Bags	36	500	2	36000
Inputs					
Labour inputs	Mandays	12	50	2	1200
Ridging	,,	10	50	2	1000
Planting	,,	20	50	2	2000
Weeding	,,	15	50	2	1500
Earthing	,,	18	50	2	1800
Harvesting & sorting	,,				
Intermediate inputs		1	1000	1	1000
Plough hire		6	600	2	7200
Uncertified potato seed	Bags	84	29	2	4872
DAP fertilizer	Kgs				2057.2
working capital					
Total costs					22629.2
Total annual profits					13370.8

Non-certified seeds, crop protection, mixed varieties

	Units	Quantity	Price	Frequency	Total
Output	Bags	53	500	2	53000
Inputs :					
Labour inputs	Mandays	12	50	2	1200
Ridging	,,	10	50	2	1000
Planting	,,	20	50	2	2000
Weeding	,,	4	50	2	400
Spraying	,,	15	50	2	1500
Earthing	,,	27	50	2	2700
Harvesting & sorting	,,				
Intermediate inputs		1	1000	1	1000
Plough hire		7	600	2	8400
Uncertified potato seed	Bags	2	1300	2	5200
Agro chemical	Kgs	79	29	2	4582
DAP fertilizer	Kgs				2798.2
working capital					
Total costs					30780.2
Total annual profits					22219.8

Appendix 1
Budgets for different technology mix groups

	Non-certified seeds, crop protection, recommended varieties				
	Units	Quantity	Price	Frequency	Total
Output	Bags	49	400	2	39200
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	6	50	2	600
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	25	50	2	2500
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	7	600	2	8400
Agro chemical	Kgs	1.5	1300	2	3900
DAP fertilizer	Kgs	110	29	2	6380
working capital					2848
Total costs					31328
Total annual profits					7872

	Certified seeds, crop protection, recommended varieties				
	Units	Quantity	Price	Frequency	Total
Output	Bags	81	400	2	64800
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	6	50	2	600
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	40	50	2	4000
Intermediate inputs					
Plough hire		1	1000	1	1000
Certified potato seed	Bags	8	1537.5	2	24600
Agro chemical	Kgs	2	1300	2	5200
DAP fertilizer	Kgs	94	29	2	5452
working capital					4655.2
Total costs					51207.2
Total annual profits					13592.8

Appendix 2
Low product prices (200 Ksh)

	Non-certified seeds, no crop protection, local varieties				
	Units	Quantity	Price	Frequency	Total
Output	Bags	32	200	2	12800
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	16	50	2	1600
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	6	600	2	7200
DAP fertilizer	Kgs	38	29	2	2204
working capital					1770.4
Total costs					19474.4
Total annual profits					-6674.4

	Non-certified seeds, crop protection, local varieties				
	Units	Quantity	Price	Frequency	Total
Output	Bags	45	200	2	18000
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	4	50	2	400
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	23	50	2	2300
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	7	600	2	8400
Agro chemical	Kgs	1	1300	2	2600
DAP fertilizer	Kgs	56	29	2	3248
working capital					2364.8
Total costs					26012.8
Total annual profits					-8012.8

Appendix 2

Low product prices (200 Ksh)

	Non-certified seeds. no crop protection. mixed varieties					
		Units	Quantity	Price	Frequency	Total
Output		Bags	36	200	2	14400
Inputs :						
Labour inputs		Mandays				
Ridging		,,	12	50	2	1200
Planting		,,	10	50	2	1000
Weeding		,,	20	50	2	2000
Earthing		,,	15	50	2	1500
Harvesting & sorting		,,	18	50	2	1800
Intermediate inputs						
Plough hire			1	1000	1	1000
Uncertified potato seed		Bags	6	600	2	7200
DAP fertilizer		Kgs	84	29	2	4872
working capital						2057.2
Total costs						22629.2
Total annual profits						-8229.2

	Non-certified seeds. crop protection. mixed varieties					
		Units	Quantity	Price	Frequency	Total
Output		Bags	53	200	2	21200
Inputs :						
Labour inputs		Mandays				
Ridging		,,	12	50	2	1200
Planting		,,	10	50	2	1000
Weeding		,,	20	50	2	2000
Spraying		,,	4	50	2	400
Earthing		,,	15	50	2	1500
Harvesting & sorting		,,	27	50	2	2700
Intermediate inputs						
Plough hire			1	1000	1	1000
Uncertified potato seed		Bags	7	600	2	8400
Agro chemical		Kgs	2	1300	2	5200
DAP fertilizer		Kgs	79	29	2	4582
working capital						2798.2
Total costs						30780.2
Total annual profits						-9580.2

Appendix 2
Low product prices (200 Ksh)

	Units	Quantity	Price	Frequency	Total
Non-certified seeds, crop protection, recommended varieties					
Output	Bags	49	200	2	19600
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	6	50	2	600
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	25	50	2	2500
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	7	600	2	8400
Agro chemical	Kgs	1,5	1300	2	3900
DAP fertilizer	Kgs	110	29	2	6380
working capital					2848
Total costs					31328
Total annual profits					-11728

	Units	Quantity	Price	Frequency	Total
Certified seeds, crop protection, recommended varieties					
Output	Bags	81	200	2	32400
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	6	50	2	600
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	40	50	2	4000
Intermediate inputs					
Plough hire		1	1000	1	1000
Certified potato seed	Bags	8	1537,5	2	24600
Agro chemical	Kgs	2	1300	2	5200
DAP fertilizer	Kgs	94	29	2	5452
working capital					4655.2
Total costs					51207.2
Total annual profits					-18807.2

Appendix 3
High product prices (Ksh 1000)

Non-certified seeds, no crop protection, local varieties

	Units	Quantity	Price	Frequency	Total
Output	Bags	32	1000	2	64000
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	16	50	2	1600
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	6	600	2	7200
DAP fertilizer	Kgs	38	29	2	2204
working capital					1770.4
Total costs					19474.4
Total annual profits					44525.6

Non-certified seeds, crop protection, local varieties

	Units	Quantity	Price	Frequency	Total
Output	Bags	45	1000	2	90000
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	4	50	2	400
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	23	50	2	2300
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	7	600	2	8400
Agro chemical	Kgs	1	1300	2	2600
DAP fertilizer	Kgs	56	29	2	3248
working capital					2364.8
Total costs					26012.8
Total annual profits					63987.2

Appendix 3
High product prices (Ksh 1000)

		Non-certified seeds. no crop protection. mixed varieties						
			Units	Quantity	Price	Frequency		Total
Output			Bags	36	1000	2		72000
Inputs :								
Labour inputs			Mandays					
Ridging			,,	12	50	2		1200
Planting			,,	10	50	2		1000
Weeding			,,	20	50	2		2000
Earthing			,,	15	50	2		1500
Harvesting & sorting			,,	18	50	2		1800
Intermediate inputs								
Plough hire				1	1000	1		1000
Uncertified potato seed			Bags	6	600	2		7200
DAP fertilizer			Kgs	84	29	2		4872
working capital								2057.2
Total costs								22629.2
Total annual profits								49370.8
		Non-certified seeds. crop protection. mixed varieties						
			Units	Quantity	Price	Frequency		Total
Output			Bags	53	1000	2		106000
Inputs :								
Labour inputs			Mandays					
Ridging			,,	12	50	2		1200
Planting			,,	10	50	2		1000
Weeding			,,	20	50	2		2000
Spraying			,,	4	50	2		400
Earthing			,,	15	50	2		1500
Harvesting & sorting			,,	27	50	2		2700
Intermediate inputs								
Plough hire				1	1000	1		1000
Uncertified potato seed			Bags	7	600	2		8400
Agro chemical			Kgs	2	1300	2		5200
DAP fertilizer			Kgs	79	29	2		4582
working capital								2798.2
Total costs								30780.2
Total annual profits								75219.8

Appendix 3

High product prices (Ksh 1000)

Non-certified seeds. crop protection. recommended varieties					
	Units	Quantity	Price	Frequency	Total
Output	Bags	49	1000	2	98000
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	6	50	2	600
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	25	50	2	2500
Intermediate inputs					
Plough hire		1	1000	1	1000
Uncertified potato seed	Bags	7	600	2	8400
Agro chemical	Kgs	1.5	1300	2	3900
DAP fertilizer	Kgs	110	29	2	6380
working capital					2848
Total costs					31328
Total annual profits					66672

Certified seeds. crop protection. recommended varieties					
	Units	Quantity	Price	Frequency	Total
Output	Bags	81	1000	2	162000
Inputs :					
Labour inputs	Mandays				
Ridging	,,	12	50	2	1200
Planting	,,	10	50	2	1000
Weeding	,,	20	50	2	2000
Spraying	,,	6	50	2	600
Earthing	,,	15	50	2	1500
Harvesting & sorting	,,	40	50	2	4000
Intermediate inputs					
Plough hire		1	1000	1	1000
Certified potato seed	Bags	8	1537.5	2	24600
Agro chemical	Kgs	2	1300	2	5200
DAP fertilizer	Kgs	94	29	2	5452
working capital					4655.2
Total costs					51207.2
Total annual profits					110792.8