FINANCIAL EVALUATION OF PRIVATE SMALLHOLDER PUMPED IRRIGATION PROJECTS IN KIAMBU DISTRICT, KENYA.

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DECLARATION

I declare that this thesis is my original work and has not been submitted for a degree in any other University.

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16TH APRIL, 1992

DATE

This thesis has been submitted to the University of Nairobi with my approval as University Supervisor.

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DATE

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ABBREVIATIONS

A.I.C.	Agricultural Imformation Centre, Kenya
AEZ	Agro-Ecological Zone.
D.A.O.	District Agricultural Officer.
F.A.O.	Food and Agricultural Organisation of the United Nations.
GOK	Government of Kenya
IDB	Irrigation and Drainage Branch, Ministry of Agriculture, Kenya.
Ksh.	Kenya Shilling
LH2	Lower Highland 2
M.O.A.	Ministry of Agriculture, Kenya.
N.I.A.	Net Irrigated Area
RowTTL	Row Totals
TARDA	Tana and Athi River Development Authority
UM5	Upper Midland 5
USAID	United States Agency for International Development
-	Nil or negligible
- -	Figures nor available
$\bar{X}$	Mean
(38)	Negative value

ABSTRACT

Farmers develop irrigation facilities to ensure that the demands of their crop water requirements are satisfied. By doing this, they anticipate to enhance their net farm incomes and to safeguard themselves from the risks and uncertainities of the weather.

This study was conducted to evaluate the financial viability of Smallholder, pumped, splinkler irrigation farms, that are privately operated by individuals, in Kiambu district.

Investment, operating and production data were collected from a purposive sample of 34 irrigation and 14 rainfed farmers. This data was used to develop six representative irrigation farm models based on the cropping pattern, agro-ecological zone, type of prime mover and the net irrigated area.

The "With" and "Without" irrigation project approach of financial analysis was adopted. The discounted measures of project worth were used to evaluate the financial viability of the irrigation farms.

The results obtained showed that individually operated, private, smallholder, pumped sprinkler irrigation farms, in Kiambu District were financially viable. However, the availability of marketing and transport infrastructure was a major factor that influenced the farmers' incremental net benefit.

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1. INTRODUCTION

This study was conducted to evaluate the financial viability of the individually organised, private, smallholder, pumped irrigation farms. A smallholder was defined as a farmer with a total farm area equal to or less than 8 ha.

The study was carried out in Kiambu District, one of the districts in the Central Province of Kenya. The District forms the uppermost catchment of the Athi river and has many springs and streams that are used by farmers for irrigation. The streams occur in steep valleys necessitating the use of water lifting devices for irrigation.

The choice of this topic of study was inspired by a number of factors:

(i) The author's long association with irrigation projects;

(ii) The shift in the Government of Kenya's irrigation development strategy from large scale irrigation systems (Republic of Kenya, 1986);

(iii) The stated objective of the Ministry of agriculture Kenya, to promote private smallholder irrigation systems in areas where high-cost, high value, labour intensive crops can be grown and to encourage lending institutions to look for investment opportunities in the irrigation subsector, particularly in the development of high cost, high return irrigation systems, which are operated on an individual, private, smallholder basis (IDB, 1987).

(iv) The normal requirement by the lending agencies for a detailed evaluation of the proposed agricultural development, to assist them in determining whether it is economically viable (Thompson, 1983).

(v) The realisation that, whereas gravity flow is the cheapest and most reliable form of irrigation water abstraction, there are areas with great irrigation potential, such as around Lake Victoria, which cannot be developed by gravity irrigation systems. USAID (1987) estimates that 70% of irrigated agriculture in Africa will depend on pumping.

To facilitate the financial analysis of the smallholder pumped irrigation farms, the data collected from individual farmers was used to develop six farm models based on cropping pattern,, agro-ecological zone, type of prime mover and the net irrigated areas. A with and without irrigation financial analysis approach was adopted as recommended by Gittinger (1982).

2. OBJECTIVES

The objective of the study was to evaluate the financial performance of the individually organised private, smallholder pumped irrigation projects. The study set out to answer the following questions:-

(a) Why do the farmers undertake irrigation development instead of rainfed agriculture?

(b) What are the costs associated with private smallholder irrigation investment?

(c) What are the financial benefits associated with private smallholder irrigation investment?

(d) What sources of credit are available to farmers for irrigation development?

(e) What other agricultural services (e.g. input supply; marketing; irrigation planning and design, machinery repairs and servicing etc) are available to the farmers?

3. BACKGROUND INFORMATION

3.1 LOCATION

Kiambu district is one of the five districts that comprise the Central Province of Kenya. The district borders Nyandarua and Murang'a districts to the north, Nakuru and Kajiado districts of Rift Valley province to the west; Nairobi Province to the south and Machakos District of Eastern Province to the East.

The district has seven administrative divisions; Thika, Gatundu, Githunguri, Kiambaa, Kikuyu, Limuru and Lari.

3.2 CLIMATE

3.2.1 Rainfall

Rainfall is bimodal; long rains occur in the months of March to June and Short rains in the months of October to December.

The average annual rainfall varies from 600 mm to 2000 mm; it is lowest in Thika division in the East and in parts of Kikuyu and Limuru Divisions bordering the Rift Valley escarpment in the west. The average annual rainfall is highest in the north(Jaetzold & Schmidt,1983).

3.2.2 Temperature

The annual mean temperature varies from 21.9°C to 13.5°C (Jaetzold & Schmidt,1983).The highest temperatures occur in the eastern and western parts of the district, the same areas receive the least rainfall. The temperature pattern takes a north-south axis, decreasing towards the north, as the altitude increases.

3.2.3 Evapotranspiration

The average reference crop evapotranspiration for the dry months of January, February, August and September as derived from the average crop water requirement data given by M.O.A. (1987) is 5 mm/day for the Thika area in the east, and 4.5 mm/day for the rest of the ditrict.

3.3 Soils

Jaetzold and Schmidt (1983) quoting Kenya Soil Survey reported that soils developed on tertiary basic igneous rocks, nitosols, are the major ones. They occur in about two thirds of the district covering the central region.

Pellic vertisols occur on the eastern part of the district, in Thika division. Phaeozems occur along the western edge, and the andosols on the north western part.

Except for those soils in the eastern part of the district, and along the western boundary, which are of low to variable fertility; the other soils are of moderate to high fertility (Jaetzold and Schmidt, 1983).

3.4 Drainage

The district forms the uppermost catchment of the Athi river. Many springs and streams originate here and flow South eastwards joining up to form major streams such as: Nairobi, Mathare, Karura, Rui Ruaka, Ruiru, Thiririka, Ndarugu and Komu rivers (Fig. 1).

Chania river which forms the boundary between Murang'a and Kiambu districts, flows South eastwards to join Thika river, a tributary of the Tana. The Southwestern part of the district, in Kikuyu and Limuru divisions, is dry and has no surface water sources (Fig. 1).

3.5 Land and Population

Based on the 1979 population census, the district is very densely populated; 686,290 people living on 244,800 ha.; a population density of 280 people per 100 ha (Jaetzold & Schmidt,1983).

The total rural area, excluding the grazing areas in the south west of the district, is 193,500 ha. About 73 per cent or 142,200 ha. of this total rural area is suitable for agriculture. Based on the 1979, census, an average household of 4.80 people had 1.13 ha. of agricultural land available. In Kikuyu division the average agricultural land per household was 0.58 ha.;in Limuru 1.01 ha. and in Thika division 3.01 ha (Jaetzold and Schmidt, 1983).

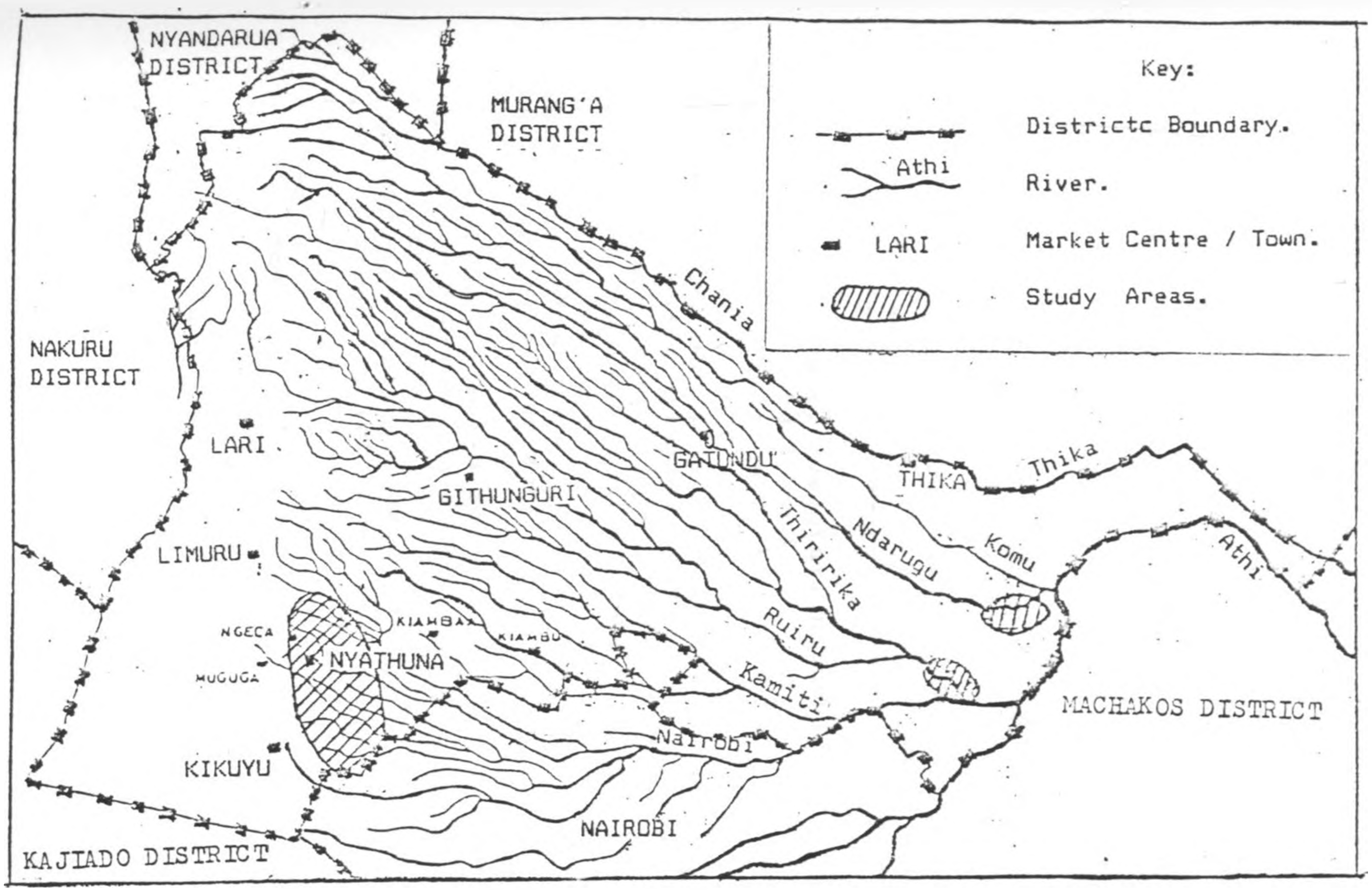

Fig. 1: Kiambu District - drainage and study areas.
Scale: 1:500,000

Source: East Africa: Nairobi SA-37-5
Nyeri SA-37-1

3.6 Agro-Ecological Zones

As reported by Jaetzold and Schmidt (1983) the agro-ecological zones found in the district are shown in Table 3.1.

Table 3.1 Agro-ecological Zones found in Kiambu District.

Agro-ecological zone		% of agric. land
UHO	Forest zone	-
UH1	Sheep and dairy (vegetation zone)	2.7
UH2	Pyrethrum - wheat zone	2.9
UH3	Wheat- barley zone	0.2
LH1	Tea - Dairy zone	12.8
LH2	Wheat/maize - pyrethrum zone	6.5
LH3	Wheat/maize - barley zone	7.8
LH4	Cattle - Sheep - barley zone	1.2
LH5	Lower highland ranching zone	1.9
UM1	Coffee-Tea zone	8.4
UM2	Main coffee zone	21.4
UM3	Marginal coffee zone	12.6
UM3-4		1.1
UM4	Sunflower - maize zone	10.2
UM5	Livestock-sorghum zone	10.3
UM6	Ranching zone	-
LM4	Marginal cotton zone	-
LM5	Livestock-millet zone	-
LM6	Lower midland ranching zone	-

3.7 Agriculture

Maize, beans and Irish potatoes are the major food crops grown in the district, 15,700 ha., 14,990 ha. and 10,800 ha. respectively. Coffee, tea and pyrethrum are the main cash crops.

According to the D.A.O. Kiambu (1988) the total area of horticultural crops under irrigation is about 352 ha. Their distribution in the district is shown in Table 3.2.

Table 3.2 Area of horticultural crops under irrigation, Kiambu District; Per division

Division	Hectarage	Percent of total
Kiambaa	6.2	1.8
Limuru	114.5	32.5
Gatundu	29.7	8.4
Thika	29.7	8.4
Kikuyu	111.6	31.7
Lari	60.5	17.2
Githunguri	..	..

Source : D.A.O., Kiambu, 1988 Annual Report.

According to the list of irrigation farmers compiled by the Ministry of Agriculture in 1988, the district has 298 private farmers irrigating using pumps. Out of these, 75 farmers had the required characteristics for this study. They had engine or electrical pumpsets; used surface water sources; had sprinkler irrigation systems; and grew vegetables, with a total farm area not exceeding 8 ha. The total farm area included the area not irrigated. The distribution of these irrigation farmers in the district is shown in Table 3.3.

Table 3.3 Distribution of private irrigation farmers using pumps in Kiambu District

Division	Farmers using pumps	Farmers with study characteristics
Kikuyu	132	47
Limuru	67	10
Thika	33	6
Gatundu	13	5
Kiambaa	9	2
Lari	32	0
Githunguri	12	5
Total	298	75

Source : List of individual Irrigating smallholders, M.O.A.

The sample of irrigation farmers included in this study was drawn from the three divisions having the highest number of farmers using pumps and with the required characteristics; Kikuyu, Limuru and Thika. The climatic and agro- ecological characteristics of the specific study area are presented in Table 3.4.

Table 3.4 Climatic and Agro-Ecological Characteristics of the specific study areas

Division	Location	AEZ	Annual Average rainfall (mm)	90% Exceedance Probability Effective rainfall (mm)	Annual mean Temperature (^{0}C)	Altitude (m)	Soil type	ET_{0} (mm/day)
1. Kikuyu	Nyathuna Kabete Muguga	LH2	1100	600	17.6-15.2	1980-2280	Humic Nitosols	4.5
2. Limuru	Ngecha	LH2	1100	600	17.6-15.2	1980-2280	Humic Nitosols	4.5
3. Thika	Gatuanyaga Juja Munyu	UM5	665	330	20.9-19.9	1360-1520	Pelic Vertisols	5.0

Sources : Jaetzold & Schmidt (1983), M.O.A. (1987)

4. LITERATURE REVIEW

4.1 Smallholders

The Ministry of Economic Planning, Kenya, adopts three categories of farmers for planning purposes, based on the sizes of their farm holdings (F.A.O., 1983). Small farmers have upto 2 ha., medium farmers, 2-8 ha., and large farmers have farm holdings above 8 ha.

The Ministry of Agriculture, and the Ministry of Co-operative Development, Kenya, on the other hand, have two classes of farmers, also based on the size of their agricultural holdings. Smallholders have upto 8. ha and large farmers over 8 ha. (M.O.A.,1975).

4.2 Financial Analysis of Irrigation Development

The purpose of financial analysis is to identify the actual year by year costs and benefits which can be expected after starting the irrigation development (Thompson et al., 1983). The analysis assesses the financial conditions that would be encountered in developing and operating the irrigated farm; and evaluates the capability of the irrigation development to repay the funding costs associated with capital costs of the irrigation enterprise. It enables the farmer to assess the profitability of the irrigation development in its entire useful life (Thompson, 1983).

According to Bergmann and Boussard (1976), F.A.O. (1970), farmers decide on whether or not to use availed resources on the basis of financial profitability, neither the prospect of an improved diet nor a better housing is sufficient to encourage them to expose themselves to risks.Where incomes are low,the question of risks and uncertainity may be even more crucial than profitability.

4.3 With and Without Irrigation Comparison

The with and without irrigation comparison shows whether the results expected are sufficient to induce the farmers to use the water and to undertake the investment. This comparison uses two different but hypothetical situations i.e. the way the farm would develop with and without irrigation (Bergmann and Boussard, 1976, Satpathy, 1984).

The economic situation of farmers in the irrigation area may be compared with that of farmers in an area which has been irrigated for over ten years. The two areas should be comparable in climate, soil, water supply and agricultural structure (Bergmann and Boussard, 1976). They add that the development of the area without the project can also be estimated based on observation of irrigable, though not yet irrigated areas, that are roughly comparable with the one being studied. The results obtained by the most progressive farmers should be examined in order to estimate the potential output of the area to be developed.

4.4 Costs and Benefits of Irrigation Projects

4.4.1 Types of Costs and benefits

Yang (1965), Gittinger (1982), Brown (1982), Nir (1983) give detailed descriptions of benefits and costs associated with agricultural projects.

There are two general categories of benefits and costs. Intangible and tangible benefits and costs.

a) Intangible benefits and costs

These are benefits and costs to which no value in monetary terms can be assigned. Though they represent a true value, they are not incorporated in the analysis because they are difficult to value.

b) Tangible benefits and costs.

These are benefits and costs which can be expressed in monetary terms. They are further classified as Primary (direct) and Secondary (indirect) benefits and costs.According to Roemer & Stern (1975),the costs relevant to project analysis are expenditures on goods and services actually used by the project during both the investment and operating stages.Relevant benefits are the goods and the services actually produced by the project.

Primary benefits represent the value of the immediate goods and services which emanate from the project. Primary costs include the value of the materials and services used for undertaking the project.

The secondary benefits represent the added value over and above the immediate products and services which the project induces. They are the benefits created outside the project itself. Secondary costs are incurred in securing the secondary benefits.

According to Nir (1983),the economic evaluation of an irrigation system should be based on a comparison of total benefit to total costs.

Gittinger (1982) differentiates between economic and financial analysis.He notes that in financial analysis secondary costs and benefits are not included.The benefits and costs should be expressed in the same terms either as present worth values or as annual values. Time element of costs and benefits should be considered. Two methods are used for converting all the costs and benefits to a common time basis. "The annual amortization method" and "The present worth summation method".

4.4.2 Primary Costs of a Sprinkler Irrigation Project

The irrigation costs can be classified as investment costs, operating costs, taxes, insurance, and other irrigated crop and agricultural enterprise production costs (Nir, 1983; Thompson et al., 1983).

a) Investment costs include the following:-

Diesel Engine System	Electric Motor System
Planning and design costs	Planning and design costs
Land purchase	Land purchase
Water permit fee	Water permit fee
Water Conveyance	**Water Conveyance:**
Pipes	Pipes
Laying of pipes	Laying of pipes
Fittings and equipments	Fittings and equipments
Valves	Valves
Water Supply	**Water Supply**
Pump house	Pump house
Diesel engine	Electric motor
Pump	Pump
-	Power connection

Irrigation Equipment:	**Irrigation Equipment:**
Pipes	Pipes
Hydrants	Hydrants
Sprinklers	Sprinklers
Other fittings	Other fittings

(b) Operating costs include:-

<u>Diesel Engine System</u>	<u>Electric Motor System</u>
Energy costs	Energy costs
Repairs & maintenance	Repairs & maintenance
Labour	Labour
Engine oil & filters	-

4.4.3 Investment and operating costs of an Irrigation System

a) Investment costs of prime movers

i) Diesel engines

Mubayi and Le (1977) have given an approximate relationship between capital costs and brake horsepower of slow speed diesel engines (1.5 to 25 hp) based on data collected worldwide, at 1975 costs as:-

$$C = 700 + 90 P$$

Where C = U.S. dollars

P = Horsepower

Bish International (1987) on the other hand, basing their data on Lister diesel engines in Kenya, estimate the investment cost of a diesel engine as:-

$$C = 4{,}000 \; P$$

Where C = Kenya shillings (Ksh.)

P = Kilowatts.

In 1987 1 US$ was equivalent to Ksh.16.5 (Finance, December 1988).

ii) Electric motors.

The cost of motors according to Mubayi et al. (1977), varies depending on the rated horsepower, quality of construction and manufacturer. They give the average costs based on world wide data, as a function of hp:-

$$C = 400 + 20 \; P$$

Where C = U.S. dollars

P = horsepower (hp)

According to Bish International (1987) investment costs of motors in Kenya, is given by:-

$$C = 1450 \; P$$

Where C = Kenya Shillings

P = Kilowatts

b) Operating costs of an irrigation system

i) Energy costs for operating the irrigation system.

Energy costs are estimated by calculating the quantity of energy to be used annually for irrigation and applying the appropriate prices to determine the cost (Thompson et al. 1983; James, 1988).

According to Bish International (1987) electricity is the cheapest and most reliable source of power. Energy costs when using electric motors are approximately half of that when using diesel.

The energy used for pumping varies with static lift; the pressure supplied to operate sprinklers, friction losses in the pipe lines, and the efficiency of the pump and motor (Thompson et al., 1983). The amount of energy consumed also varies with the size of the prime mover (Yang, 1965; Lonnemark, 1967).

When using diesel engines, fuel consumption, according to Bish International (1987) can vary from 0.21 kg per kWhr to 0.28 kg per kWhr. The amount of fuel consumed per kilowatt-hour by an engine in good condition and proper adjustments depends on the kind of fuel, the altitude, the temperature, the speed and on whether or not the engine is fully loaded (Israelsen, 1950).

Mubayi and Le (1977) noted that the generation costs of energy from small diesel engines, 1.5-26 hp (1.1-18.7 kW) and operated at slow speed <1500 rpm, is a function of price of fuel and number of hours of use. At full load, the fuel consumption (f) as derived from manufacturers' charts is given by:-

$$f = 0.21 \text{ kg/hp - hr; } (0.28 \text{ kg/kWhr})$$

or

$$f = 0.24 \text{ litres/hp-hr; } (0.32 \text{ l/kWhr}).$$

They report that the average fuel consumption in U.S. is 0.34 l/hp - hr. (0.46 l/kWhr), whereas in India the average fuel consumption is 0.28 litres/hp - hr. (0.38 l/kWhr) for diesel engines 12 to 20 hp used for irrigation.

In general, Mubayi and Le (1977) have given the components of costs of energy generated by an engine of horse power P, on annual basis as:-

Fuel costs; $F = f\ P\ h\ C_f$

Lubrication costs, $L = j\ p\ h\ C_j$

Where F = fuel costs

L = lubrication costs

h = number of hours of operation per year

P = horsepower

C_f = the delivered price of fuel per litre

j = Lubricant consumption l/hp-hr.

C_j = the lubricant price per litre

f = fuel consumption l/hp - hr.

ii) Repairs and maintenance costs of an irrigation system

Repairs and maintenance cover undertakings such as minor adjustments to complete overhauling of the machine. The cost of repairs varies with machines, operators, the age , the condition and amount of use of the machine.

Maintenance costs include wear and tear on the pump, prime mover, pipes and sprinklers; and the replacement of corroded or calcified pipelines (Finkel et al., 1983). Internal combustion engines require more frequent maintenance than electric motors (Mubayi and Le, 1977).

According to Yang (1965) the repair costs of a machine cannot be determined by the actual costs within a short period because the amount of repairs increases with age and most repairs are the results of the cumulative use in the past. In a given year, there may not be any need for repairs, while in another year a large cost may be incurred. He advocates the use of the average annual costs of repairs for each kind of machine, based on the experience of a number of persons over a number of years.

Kay (1983) reports that, for a diesel engine, a top overhaul is normally required after 2000 hr. operation and major engine overhaul after 5000 hr. During its life the engine may require three top overhauls and one major overhaul.

Thompson et al. (1983) have given the annual maintenance and repair costs, expressed as percentage of the initial cost (Table 4.1)

Mubayi and Le (1977) reported that lubricant consumption as stated by manufacturers is a little less than 1% of fuel consumption and that in India the lubricant consumption is given as 4% that of fuel. In Kenya the consumption is 5% that of fuel (Bish International, 1987).

Table 4.1 Annual maintenance and repairs for sprinkler irrigation system compoents.

Component	Useful life (h)	Period yr.	Annual maintenance and repairs %*
Pump centrifugal	32,000-50,000	16-25	3-5
Power transmission			
Gearhead	30,000-36,000		5-7
V-belt	6,000	3	5-7
Prime mover			
Electric motor	50,000-70,000	25-35	1.5-2.5
Diesel Engines	28,000	14	5-8
Pipe PVC buried		40	0.25-0.75
Pipe steel, galvanized, surface		15	1.0-2.0
Pipe Aluminium, sprinkler use surface		15	1.5-2.5
Sprinkler heads		8	5-8
Reservoirs		none	1.0-2.0

*Annual maintenance and repair costs are expressed as a percentage of the initial cost.

Source: Thompson et al., (1983).

4.4.4 Cost of Farm Labour

The labour component includes both skilled and unskilled labour. Labour may be either hired or family labour.

According to Brown (1979), to estimate all possible costs in calculating the profit for each enterprise, labour is treated as though it were all hired. He adds that the total cost of labour can be estimated in two different ways, either by adding the imputed cost of family labour to the actual cost of hired labour or by estimating the time required for all operations and then multiplying the results by the wage rate in the area.

The amount of labour required to perform similar operations on different farms may vary because of differences in quality of labour, the level of skill and experience, and the incentives offered. In calculating the cost of production and the enterprise profit, it is sufficient to use the average requirements on farms of similar type and size operating under roughly similar conditions (Brown, 1979).

Labour for operating a sprinkler irrigation system, depends on the type of system used, the frequency of irrigation, number of irrigations to be applied, the duration of water applications and the type of crop grown (Thompson et al. 1983).

4.4.5 Cost of Production Inputs

Production inputs include farm tools and implements, seeds, pesticides and fertilizers. The cost of inputs is derived by multiplying the quantities used by the unit price (Brown, 1979).

4.4.6 Cost of Land

Land value in financial analysis is based on the form of tenure and on whether or not transfer of ownership is involved (Brown, 1979).

According to Gittinger (1982), if farmers shift from rainfed enterprise to irrigated enterprise without changing the land ownership, the cost of land is its contribution to the value of the rainfed enterprise production that the farmers must forego to use the land for the irrigated enterprise. This cost of land is automatically provided for when the farm budget is laid to show the difference with and without the project; and therefore a separate entry for the cost of land is not needed, either in the financial or in the economic accounts.

4.4.7 Taxes and Insurance

Payment of insurance, and taxes, including duties and tariffs, is a cost in financial analysis.

4.4.8 Debt Service

Payment of interest and repayment of capital is treated as an outflow in financial analysis.

4.4.9 Benefits in Irrigation Projects

4.4.9.1 Primary Benefits

The primary benefits on an irrigation system consists of the value of the crop produced. The market value of the crop depends on the quantity harvested, the quality of the produce which is determined by size, shape, flavour, uniformity etc.; and on change in "time of sale", which is made possible by out of season production (Nir, 1983). The out of season production which corresponds with the time of low produce supply, takes the advantage of high produce demand.

Increased yields result from the addition of water to soils during dry spells (Woodward,1959). Israelsen (1950) reported that with irrigation, yields of onions were increased 233%, beets 86%, carrots 66%, and early cabbage approximately 100 per cent.

For many crops,according to Woodward (1959),the quality of the product may be equally or more important than the yield obtained. He reports that this was true of such crops as tobacco, french beans ,lettuce and berries. Tobacco grown under irrigation resulted in both higher yields and improved quality.

4.4.9.2 Residual Value

Nir (1983) observes that though residual value is not a benefit of the project, it is included in the analysis as a benefit.

According to Gittinger (1982) residual value is the value of an asset remaining unused at the end of a project. It is taken to be the "resale value" of an asset that is used and then put up for sale. Salvage value is a form of residual value, it is the value of an asset at the end of its useful life.

Bowers (1975), Donnel (1973); Thompson et al., (1983); Tarquin and Blank (1976) have given the methods for estimating the residual value of an asset. Based on the "Declining Balance Depreciation" method, the residual value is estimated by the following formula:-

$$RV = P(1 - x / L)^n$$

Where RV = the residual value of the asset

P = purchase price of the asset

n = the age of the asset in years at which depreciation is determined.

x = the ratio of the depreciation rate used to that of the straight line depreciation method. The value of x may be any number between 1 and 2.

If x = 2, the method is called - Double - declining - balance method

L = the estimated useful life of the asset in years.

Tarquin and Blank (1976) giving an example, indicate that if an asset has a useful life of L years, the straight line rate of depreciation would be: 100/L % .He cautions that the residual value should be equal or more than the salvage value.

4.5 Pricing Project Costs and Benefits

Gittinger (1982) explains how to value the project costs and benefits. The salient points can be summarised as follows:-

- In a competitive market, the market price of an item is the best estimate of its marginal value product and its opportunity cost.
- To determine a market price for agricultural commodities produced in a project, a good rule is to seek the price at the point of first sale. The price at the point of first sale can be accepted as the farm gate price, even if this point is in a nearby village market. The farm gate price is the best price to value home consumed production.

- In financial analysis the market price is used in valuing the project costs and benefits. The price for land and labour is the price actually paid. Brown (1979) explains in detail how to value land and labour.

According to Yang (1965), if opportunity cost is used as a basis for cost determination, each farm enterprise is considered as an independent entity and its cost of production is determined according to the market value of all services and supplies used in production, whether or not they are provided on the same farm.

The cost of land, labour, power, equipment, seed, manure and other things should be estimated according to the prices or rates which the farmer would have to pay if the same kind of land were rented, if labour and equipment were hired and if seed, fertilizers and manure were bought (Yang, 1965).

Thompson et al. (1983) indicate that when assessing the cost of an irrigation enterprise, the actual price quotations are obtained at a given date for all elements of the irrigation enterprise. Costs of developments carried out at an earlier date can be obtained and adjusted to a common time basis using cost trend indexes.

Livingstone and Ord (1980), Blyth (1966) and Culyer (1985) have illustrated how to use the price indexes.

4.6 Farm Models

A farm model is a simplified representation of a farm. It is used to typify the different kinds of farming situations that may be found in a project. One of its functions is to facilitate the analysis of the project's effect on the various groups of participating farmers (Brown, 1979; Msechu, 1979; Fortzo and Winch, 1978).

When farms are similar, one of them may be selected a representative; but when they are different, they should be seperated into relatively homogenous groups, within which only minor variations exist (Brown, 1979).

According to Gittinger (1982), in most agricultural projects, half a dozen or so model farm investment analysis would be sufficient. A model farm investment analysis should be conducted for each major group of soil and water conditions, for each major difference in size of holdings, and for each major cropping pattern. For a project that uses a better known technology, only half a dozen to a dozen interviews for each model farm budget may be required.

The model farm budget compare the situation with the project to that anticipated without the project for the duration of the project.

4.7 Farm Resource Budget

Resources are divided into three broad categories, land, labour and capital. Budgets are prepared for each resource to co-ordinate demand and supply.

4.7.1 Land Budget

The inventory for land resources shows the total area of the farm land, the arable acreage, the types of land use patterns and farming methods, the physical yields for each crop, levels of management and land tenure arrangements (Brown, 1979).

The budget for land resources shows the kind of crops grown, their acreage and cropping sequence (Brown, 1979).

4.7.2 Labour Budget

Labour budgets are based on labour requirements of each crop. They are usually prepared on a monthly or seasonal basis.

Labour profiles are prepared for each enterprise on the farm on per unit of land basis e.g. per hectare. The profiles are used to give the labour requirements for the farm enterprises (Brown, 1979). TARDA (1976) reported crop labour requirements per hectare as shown in Table 4.2.

Table 4.2 Crop labour requirements per hectare.

Crop	Mandays per crop
Maize	90
Pulses	90
Horticultural crops	580
Bananas	135
Coffee	650
Tobbaco	420

Source: TARDA (1976).

4.7.3 Budget for Capital Physical Resources

Resource budgets, when expressed in physical quantities, cover such items as transport, machinery, tools, equipment, fertilizers, chemicals and other inputs procured off farm sources. The budgets show the scheduling of the physical inputs required for each enterprise on the farm, and for the farm as a whole. They indicate what items are needed, when they are needed and how they would be supplied (Brown, 1979).

4.7.4 Unit Activity Farm Budget

A unit activity budget is a budget that applies only to some particular investment activity. It is an alternative approach in farm investment analysis, to that of whole farm budgets. Unit activity budgets have the advantage of being easier to prepare, since it is not necessary to collect and analyze information on any farm production activity other than the one to be encouraged in the project (Gittinger, 1982). Wandurua (1987) has used the unit activity budget approach in the Financial and Economic analysis of Kimana-Tikondo Smallholder irrigation project, Kenya.

A farm budget, in project analysis, is prepared to estimate the incremental net benefit arising on the farm as a result of the project (Gittinger, 1982).

According to Gittinger (1982), net benefit after financing is most important for judging incentive effects of the project. He states that, it is probably an estimate of this amount that most farmers make when they decide whether or not to participate in a project.

The incremental net benefit is the additional amount of benefit the farmer would receive by participating in the project over and above what he would receive without the project. It is the direct incentive to the farmer to participate in the project.

Net benefit increase, which Gittinger (1982) defines as the present worth of the incremntal net benefit after financing with the project divided by the present worth of the net benefit after financing without the project, expressed as a percentage, is a measure of this direct incentive to the farmer.

When discounted, the incremental net benefit before financing forms the basis for measurements of project worth. The measurement thus derived, based on all resources engaged in the project, irrespective of whether the resources come from the farmer's contribution or from a lending institution, judge the financial viability of the investment on the farm.

4.8 Measures of Project Worth

4.8.1 Time-Adjustment Accounting Convention

According to Gittinger (1982), the discounting process assumes that every transaction falls at the end of the accounting period.

The initial investment can be considered to take place at the end of year 1 of the project, regardless of whether it will actually take a full year or only a few weeks. Year 2 then is the first accounting period in which increases in operating cost and incremental benefits occur (Gittinger, 1982; Bergmann and Boussard, 1976).

Working capital according to Coy (1982) is the difference between current assets and current liabilities, and refers to the funds required to finance operations. In agriculture, working capital is required to pay for the labour, materials and other operating costs to plant, cultivate and harvest crops.

The incremental working capital needed at the beginning of the year is entered separately at the end of the year preceding the one in which it is required for production. At the end of the project, the incremental working capital for each year is added algebraically and taken out of the project as part of the residual value (Gittinger, 1982).

Land use according to the accounting procedure adopted would remain unchanged in year 1. It is shown as is without irrigation.

4.8.2 Discounted Measures of Project Worth

4.8.2.1 Internal Rate of Return

The incremental net benefit stream is used to measure the worth of a project by finding the discount rate that makes the net present worth of the incremental net benefit stream equal to zero. This discount rate is the internal rate of return. It is the maximum interest rate a project could pay for the resources used if the project was to recover its investment and operating costs and still break even. It is the earning rate of a project (Gittinger, 1982; Hague, 1971).

The selection criteria for internal rate of return is to accept all independent projects having an internal rate of return equal to or greater than the opportunity cost of capital.

4.8.2.2 Net Present Worth (NPV)

Net present worth is the difference between the present worths of the benefits and costs of a project. The rate used for discounting is the opportunity cost of capital (Brown 1979; Lipsey, 1971). The selection criteria is to accept projects for which the net present worth is positive.

4.8.2.3 Net Benefit-Investment Ratio

The net benefit-investment ratio according to Gittinger (1982) is the present worth of the positive incremental net benefit divided by the present worth of negative incremental net benefit. It is calculated by taking the net benefits as the net present worth of the incremental benefit stream in those years after the stream had turned positive and the investment as the present worth of the incremental net benefit stream in the early years of a project when it is negative.

The selection criteria for the net benefit-investment ratio is to accept all projects with a net benefit-investment ratio of one or greater when discounted at the opportunity cost of capital.

4.9 Opportunity Cost of Capital

According to Lipsey (1971) the opportunity cost of using any resource is the benefit foregone or the cost of not using the resource in its best alternative use. He adds that it is what is currently foregone by using the factor of production. With resources obtained from outside the farm this cost is measured by the price paid for their services. With resources already owned by the farm this is usually measured by the amount for which the resources could be leased or sold.

The opportunity cost of capital, is the opportunity cost of using investment resources in a project rather than in their next best alternative use. It is usually expressed in the form of an interest rate (Gittinger, 1982).

The rate of interest is the price paid for borrowing money. The market rate of interest is the rate actually paid on loans (Lipsey, 1971). It measures the cost of capital resources in the economy since, as the "going" rate in the market it presents a rate which other viable projects and borrowers can afford to pay (Livingstone and Ord, 1980). According to Upton (1979), where farmers can borrow or lend money at interest,the market rate of interest represents the opportunity cost for the farmer's own capital.

In financial analysis the opportunity cost of capital is usually a weighted average cost to the farm of equity capital and of borrowed capital from likely sources (Gittinger, 1982).

In financial and economic analysis of Kimana- Tikondo smallholder irrigation project Wandurua (1987) adopts a 14% discount rate.

Table 4.3 Principal Interest Rates, 1986-1988.

Lending Institution	Interest rates %, as at 31st December 1986	1987	1988
Kenya Commercial Banks			
Savings deposits	11	11	10
Loans and advances*	14	14	15
Agricultural Finance Corp.			
Land Purchase loans	12	12	12
Seasonal crop loan	14	14	14
Other loans	13	13	13

Source: Central Bureau of Statistics, Economic survey, 1989.
* Loans and advances for less than 3 years.

4.10 Length of the Project Period

According to Gittinger (1982) the length of the project period may be chosen such that it becomes comparable to the economic life of the project. He adds that the technical life of the major investment item may be used to establish the period of project analysis.

The life of a machine varies greatly with the material and design of the machine itself, the amount of care and repair given to it and the amount and the condition of use made of it (Yang, 1965).

Michael et al., (1972), Pillsbury (1968), Thompson et al. (1983), Mubayi and Le (1977), Kay (1983), and Dewees (1984) have given the useful lives of various investment items used in irrigation development.

According to Culpin (1975), reservoirs, electric motors and buried mains can be given an estimated life of 20 years. The life of a diesel pump set should not be expected to exceed 15 years. Thompson et al (1983) estimates the useful life of a diesel engine to be 14 years when used at 2000 hr per year.

4.1.1 Horticultural Crops

Horticultural crops are the garden crops. They include the flowers, the fruits and the vegetables (M.O.A., 1966). The names and varieties of vegetables grown in Kenya, and their ecological and husbandry requirements can be found in M.O.A. (1966) and in A.I.C. (1981).

The seed rates, growth periods, and yields of some major vegetables are shown in Table 4.4.

Table 4.4 Seed rates, growth periods and yields of some vegetables.

Vegetable	Seed rate (kg/ha)	Growth period (days) Transplanting to harvesting)	Yields (t/ha)
Kale	1	50-85	8-35
Cauliflower	0.5	60-120	12-25
Cabbage	0.5-0.7	80-110	12-40
Spinach	3*	50-60	10
Lettuce	0.75	60-85	5-15
Tomatoes	0.5	70-100	5-15

Sources: Tindall (1983).
* Simlaw seeds handouts.

4.12 Crop water requirements

Crop water requirements, ET (crop) is defined by Doorenbos and Pruitt (1975) as the depth of water, regardless of its source, required by a crop or a diversified pattern of crops for evapotranspiration; in mm/day. The main sources for crop water requirements are rainfall and irrigation.

In irrigated agriculture, effective rainfall is that portion of the total annual or seasonal rainfall which is useful directly and/or indirectly for crop production at the site where it falls. The effective part of rainfall may vary between zero and near 100% (Doorenbos, 1976).

The quantity of water needed in addition to the effective rainfall to satisfy the crop water requirements is the amount that must be supplied by irrigation. This quantity of water is the consumptive use of applied water (Michael et al, 1972).

Methods of estimating the effective rainfall and its probability of occurrence are given by Dastane (1974). However, according to Campbell (1986), the estimation of the effective contribution of rainfall to crop water requirements, and more significantly to reduction in irrigation requirements, is a contentious subject.

Campbell (1986) assumed "50% effectiveness of 75% probable rainfall" in estimating rainfall contribution under irrigation.

Effective rainfall should be estimated on a probability basis. The probabilities chosen depend on the yield predictions, cost of the system and financial returns. For high value crops the probability suggested is 9 out of 10 years, whereas for low value crops, rainfall surpassed 5 years out of 10 is considered adequate (Dastane, 1974).

Jaetzold and Schmidt (1983) have drawn isohyets for average annual rainfall, and 60% probability of exceedance seasonal rainfall for respective districts in Kenya.

Doorenbos and Pruitt (1975) give approximate range of seasonal ET(crop) for vegetables and tomatoes as 250-500 mm and 300-600 mm respectively.

According to M.O.A. (1987) crop factors for small vegetables and tomatoes at various development stages are as shown in Table 4.5. In irrigation scheme design, the Ministry of Agriculture, Kenya, takes the crop factor as an average for different crops and their growth stages, allowing also for some non-cropped plots. As a rule of thumb a crop factor of 0.9 is used (M.O.A., 1987).

Table 4.5 Crop factors for vegetables

Crop	Development stage		
	Early in season	Peak	Maturing
Tomato	0.5	1.1	0.6
Small vegetables	0.5	1.0	0.8-0.9

Source: M.O.A. (1987)

5. METHODOLOGY

5.1 Characteristics of the Studied Farms

The irrigation farms considered in the study had he following characteristics:-

a) Individually organised private smallholder farms, which had pumped sprinkler irrigation systems. A smallholder was defined as a farmer with a total farm area not exceeding 8 ha.

b) The irrigation water was abstracted from surface water sources.

c) The prime mover used was either a combustion engine or an electric motor.

d) Grew horticultural crops specifically vegetables.

The rainfed farms, for the "with" and "without" irrigation comparison had the following requirements.

a) private smallholder farms, i.e. $\leq$ 8 ha.

b) Farms within the same area as the irrigation farms included in the study.

5.2 Study Area

The study was conducted in Kiambu district, specifically in Kikuyu, Limuru and Thika divisions. About 80% of the district's irrigation farmers with the required characteristics were found in these three divisions.

5.3 Selection of Farmers

5.3.1 Irrigation Farmers

A purposive sample (Casley and Lury, 1982) of 43 irrigation farmers was made from a list of farmers with the required characteristics compiled by the Ministry of Agriculture, Irrigation and Drainage Branch; Nairobi. From Kikuyu division 27 farmers; Limuru division 10 farmers, and from Thika division 6 farmers.

The size of samples from Limuru and Thika divisions was restricted by the number of farmers, with the desired qualities, available.

Out of the 43 farmers selected, 34 were successfully interviewed. Twenty from Kikuyu, nine from Limuru and five from Thika.

5.3.2 Rainfed Farmers

A purposive sample of 18 farmers was made, with the assistance of Agricultural extension staff of the areas. The number of farmers in each division was in proportion to the number of irrigation farmers successfully interviewed. From Kikuyu division 10, Limuru division 5 and Thika division 3. Out of the 18 farmers 14 were successfully interviewed. Eight from Kikuyu, three from Limuru and three from Thika.

The purposive method of sampling was adopted, because it was felt from the outset that the study involved the collection "of sensitive data on farmers incomes" (Yang, 1965). Another factor considered was the time the farmer had to personally spare to be interviewed (Upton, 1979). It was made clear right from the beginning that the farmers were extremely busy and "time is money".

A subjective criterion was therefore used to select approachable and patient farmers based on the knowledge of the extension staff of the areas. The author was taken round the farms by the extension staff of the respective areas to be introduced, to explain what was entailed in the interview and to seek appointments with the farmers for the interviews.

5.4 Data Collection

5.4.1 Method of Data Collection

A single visit, rapid assessment survey method was used (Casley and Lury, 1982). Farmers were interviewed by the author himself using a prepared questionnaire (Appendix A) as a guide. The data was given by the farmer from his memory based on specific strips of land that are cropped as distinct planning units. The data was collected between October 1988 and June 1989.

5.4.2 Production Data

Each farmer was asked to name the crops that he normally grew. Out of this list of crops, the farmer was interviewed on three to four major crops. The number of crops interviewed on depended on the amount of time the farmer was willing to offer. At least three hours were required to conduct a satisfactory interview.

The type of data collected for each crop enterprise is detailed in the Appendix C.

5.4.3 Investment Data

The farmer was interviewed on the components of the irrigation system as detailed in the questionnaire (Appendix A). The historic prices of these components were collected from the farmers, whereas their current market prices were collected from the dealers.

5.5 Procedures of Data Analysis

5.5.1 Data From the Sampled Farms

The data from the sampled irrigation farms were used to develop representative "unit activity" farm models. Statistical measures of central tendency were used to arrive at the plot sizes; prime mover and pump capacities; placement, type, size and length of the laterals and mainline pipes.

The mean production data for respective crop enterprises within the same agro-ecological zone were used in the farm models.

5.5.2 Farm Models

Six farm models (Table 5.1), based on the following characteristics, were developed:-

a) Cropping pattern

b) Agro-ecological zone

c) Type of prime mover

d) Net irrigated area.

Table 5.1 Unit activity Farm Models

Characteristics	Farm models					
	A	B	C	D	E	F
A.E. zone	LH2	LH2	LH2	LH2	UM5	UM5
Net irrigation area (ha)	0.6	0.6	1.2	1.2	0.6	1.2
Prime mover	Motor	Engine	Motor	Engine	Engine	Engine
Cropping pattern*	X	X	X	X	Y	Y

* Cropping pattern: X denotes growing of lettuce, spinach, cauliflower, kale, cabbage, and tomatoes all grown simultaneously in the irrigated plot.

* Cropping pattern Y denotes growing of tomatoes, podbeans, kales and cauliflower.

The studied farms naturally fell into two agro-ecological zones. The Kikuyu - Limuru farms fell into lower highland 2 (LH2) zone; whereas those in Thika fell into upper midland 5 (UM5) zone.

To determine the model irrigated farm sizes, the farms were put into two classes based on the size of their net irrigated areas. One class consisted of those farms with net irrigated areas of upto 1 ha; and the other farms with net irrigated areas greater than 1 ha. The model plot size within each of these classes was used as the model farm size, Table 6.1(b).

To determine the cropping patterns in the model farms, the crops grown by the majority of interviewed farmers within the same agro-ecological zone were considered, Table 5.1. The Lettuce, cauliflower, cabbage and pod beans were grown three times in a year; whereas the tomatoes, spinach and kales were grown twice a year. Maize, potatoes and beans in the rainfed areas were grown twice a year.

To determine the type and capacity of prime mover to use in the model farms, it was considered that there were two types of prime movers in use: the electric motor and the diesel engine. The capacity of the motor with the highest frequency distribution within the surveyed farms was used in the model farms, Table B34. For the Diesel engine the engine capacity with the highest frequency within each of the two distinct agro-ecological zones was used in the respective models, Table B35.

The length of the mainline for the models was based on the median mainline length within the irrigated areas, for the plots with net irrigated area of 1 ha and below and for those above 1 ha; Table 6.8.

The size of the mainline in the models was based on the model mainline size within the above two classes of net irrigated areas. The mode was similarly used to determine the length, the size and the number of sets of laterals and sprinklers to be used in the models.

5.5.3 Financial Analysis

a) For each of the six "unit activity" farm models, a land budget, a physical capital budget, seasonal labour budget and a financial farm budget was prepared.

b) The goods and services used in the farm models were valued at the current market prices prevailing during the study period. Constant prices were used for the financial analysis. For items such as reservoir, electricity service line and pump house whose current market prices could not be obtained, building and construction price indices were used to estimate their 1988 value (Bergmann and Bousard 1976; Thompson et al., 1983).

c) The 12% market interest rate, the rate actually paid on A.F.C. loans by the irrigation farmers, was used as the discount rate or opportunity cost of capital.

d) The length of the project period used in the analysis was 15 years based on the economic life of the diesel combustion engine.

e) Time value was discounted.

f) Net present worth, financial internal rate of return and net-benefit-investment ratio were used as the financial performance indicators. Net benefit increase, was used to measure the potential increase in the farmer"s incremental net benefit after financing.

h) The "without irrigation" benefits and costs were assumed to be the costs and benefits for a progressive farmer in the same agro-ecological zone, and using rainfed agriculture. The most prevalent cropping pattern in the agro-ecological zone was adopted (Bergmann and Boussard, 1976).

5.6 Assumptions in the Analysis

a) The irrigated portion of the total holding was assumed to be an independent business on the farm and was treated as a unit activity (Gittinger, 1982).

b) The irrigation farmers would belong to the category of the rainfed progressive farmers, and they would have grown the same major crop enterprises on the land portion that they now irrigated.

c) At the time of the data collection the irrigation farmers had attained the maximum level of production; and the maximum level of production was achieved in the fourth year of the project. The production levels being 50% and 75% for the second and third years respectively. This is an arbitrary basic assumption to fix the upper limit of the farmer's production capacities for analysis purposes.

d) Production was assumed to begin in the second year of the project. Cash flow during the first year of project was made up of investment alone (Bergmann and Boussard, 1976; Gittinger, 1982).

e) The 90% probability of exceedance mean annual effective rainfall, as determined by USDA, SCS (1967) probability method and the Indian effective rainfall method (Dastane 1974; Doorenbos, 1976), was all assumed to have been used up by the crops. The consumptive use of applied water was supplied by irrigation.

f) Land, farmhouse, fencing and small farm tools were considered common for both irrigation and rainfed farmers and were therefore not included in the farm budgets since they netted out (Gittinger, 1982; Bergmann and Boussard, 1976).

g) An average crop factor of 0.8 was used for both the small vegetables and tomatoes.

h) The useful life of the investment items used in the irrigation system was compiled as shown in Table 5.2 (Thompson et al, 1983, Pillsbury, 1968).

Table 5.2 Assumed useful life of the investment items

Investment item	Useful life (Years)
1. Water supply	
- Housing	15
- Reservoir	8
2. Pump centrifugal	15
3. Power transmission	
- gear head	10
- V-belts	3
4. Electric motors	20
5. Diesel engines	15
6. Pipe	
Aluminium (main and laterals)	15
Steel galvanised surface	15
P.V.C. (main buried)	40
7. Sprinkler heads	8
8. Misc. fittings Al. (valves, couplers, elbows)	15
9. Misc. fittings PVC	40

Source : Thompson et al (1983)

Pillsbury (1968)

6. RESULTS

The sample irrigation farms fell within two agro-ecological zones. The Limuru and Kikuyu farms were in the Subhumid, lower highland zone (LH2), also described as the wheat/maize Pyrethrum zone. The Thika farms were in the semi-arid, upper midland zone (UM5) or the livestock-sorghum zone.

6.1 Water Resources

The sample farmers abstracted the irrigation water from perennial springs and streams. In Limuru division, the farmers used the Mutugutu stream and the Gitangu Springs; in Kikuyu, they used Mutugutu , Mwateta, Turarii, Kamoriathi, Mathare, Karunguthiu and Gitathuru streams. In Thika, the sample farmers used Thiririka, Ndarugu and the Thika rivers.

According to the sample irrigation farmers , high rate of water abstraction sometimes caused the water levels in the rivers to fall too low for their pumps. The farmers constructed dug reservoirs to store water and from which they pumped.

In Limuru, the average capacity of the reservoirs was 64 m^3; in Kikuyu 400 m^3. In Thika division reservoirs were not constructed, farmers abstracted water directly from the river.

6.2 Land Use and Cropping Pattern

6.2.1 Farm Size and Land Use

The average farm size of the sample irrigated farms was 2.2 ha. Their range was 0.5 ha to 6.4 ha. The average net irrigated area was 1.1 ha with a range of 0.3 to 2.4 ha. Fifty percent of the irrigated sample farms had a net irrigated area of 1.0 ha or less (Table 6.1).

Ninety one percent of the sample irrigated plots were managed by the farm owners, 6% were under share-cropping system and 3% were on tenancy basis.

The net irrigated area was divided into sub-plots. The width of the sub-plot was based on the lateral spacing along the main line and the length of the sub-plot was determined by the width of the farm, and the mainline placement. Each sub-plot was cropped as a unit all of it under a given crop.

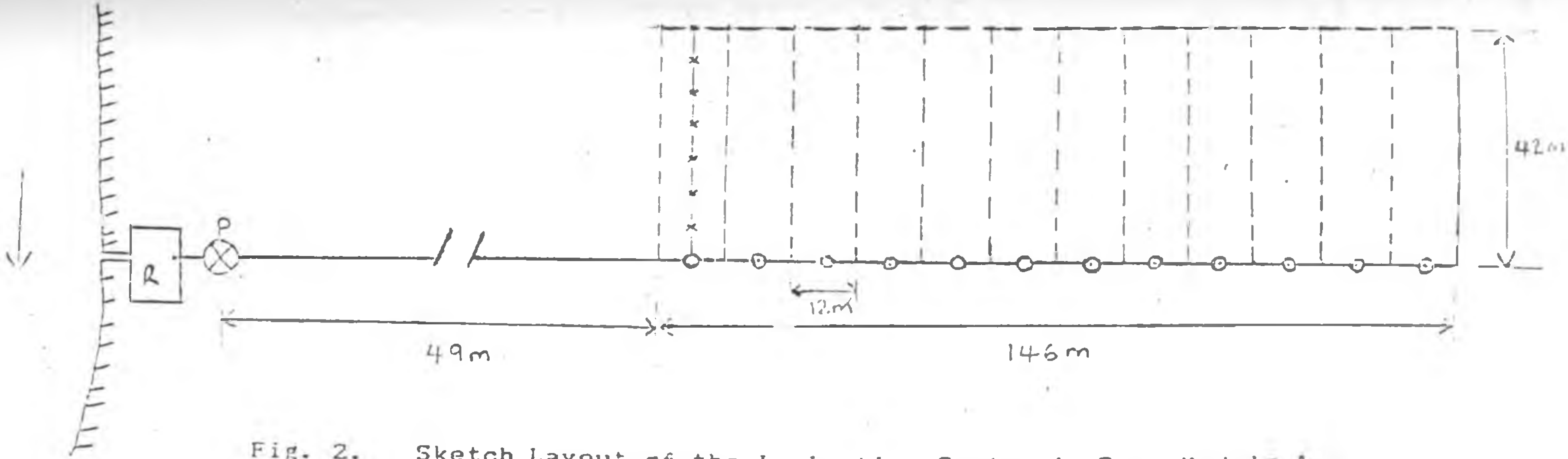

Fig. 2. Sketch Layout of the Irrigation System in Farm Models A, B and E.

R Reservoir

River bank

Mainline

Lateral line & sprinklers

Hydrant

Subplot

P Pump house

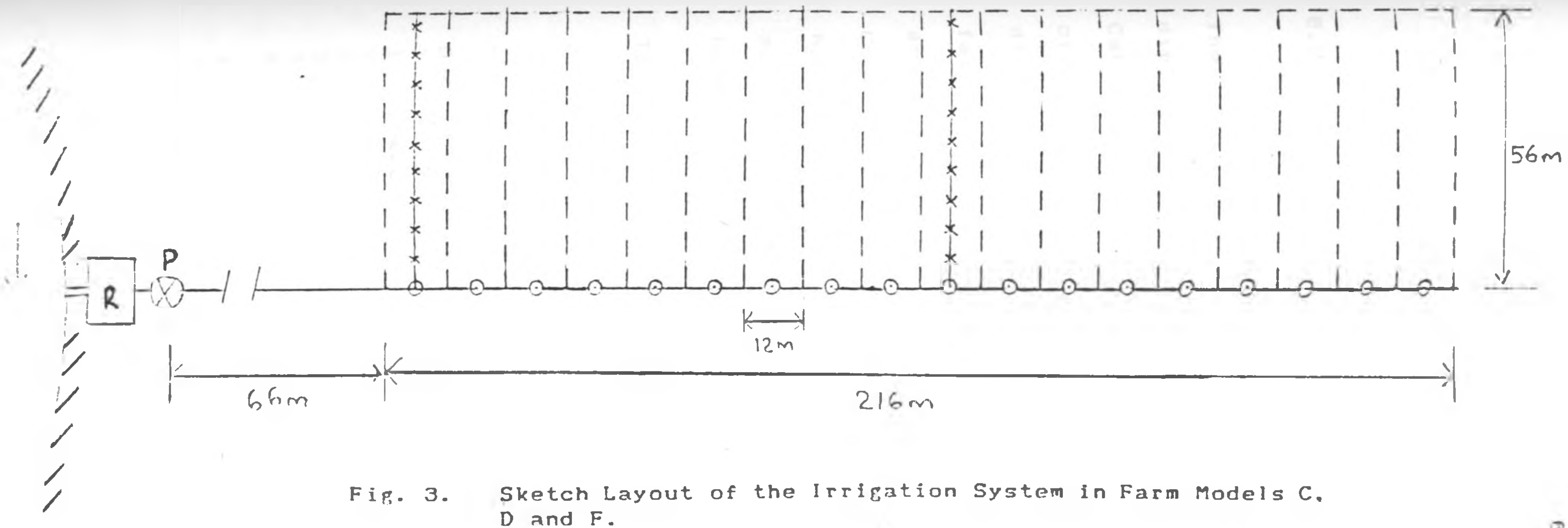

Fig. 3. Sketch Layout of the Irrigation System in Farm Models C, D and F.

6.2.2 Cropping Pattern

The main irrigated crops grown in Limuru and Kikuyu divisions were Cauliflower, Spinach, Lettuce, Kales, Cabbages and Tomatoes. Under rainfed conditions the main crops grown were maize, potatoes and beans. In Thika division, the cropping pattern among the irrigation farmers was not as consistent as in the Limuru-Kikuyu area; the main crops grown were the Kales, tomatoes, Cauliflowers and pod beans i.e. ordinary field beans harvested and sold in pods just before they dried. The main rainfed crops grown in Thika division were maize and beans intercropped.

Table 6.1(a) Distribution of farm sizes and net irrigated areas.

Plot size range (ha)	whole farm size frequency	net irrigated area frequency
≤ 0.5	1	4
0.6 - 1.0	4	13
1.1 - 1.5	8	11
1.6 - 2.0	5	4
2.1 - 2.5	8	2
2.6 - 3.0	2	—
3.1 - 3.5	2	—
3.6 - 4.0	2	—
4.1 - 8.0	2	—
Total frequency	34	34

Table 6.1(b) Average plot sizes for net irrigated areas

Plot Size	Mean	Mode	Median	frequency
$\leq$ 1.0 ha	0.65	0.6	0.6	17
> 1.0 ha	1.5	1.2	1.4	17

The lettuce, cabbage, cauliflower and pod beans were three month crops, and a sub-plot could be planted with these crops three times in a year. The tomatoes took 5-6 months in the plot while the spinach and kales were allowed in the field for 6-8 months.

6.3 Farm Inputs and Farm Produce

The average seasonal input requirements and gross outputs per hectare for the major crops grown, by the sample farmers, under irrigation are given in table 6.2 as summarised in Appendix C. The average seasonal input requirements for crops under rainfed conditions are shown in Table 6.3. Prices for farm inputs as collected from the farmers and dealers are shown in Table 6.4. Table 6.5 and Table 6.6 give the average seasonal operating expenditure for labour, materials and transport per crop per hectare for irrigated and rainfed crops respectively. Lettuce and tomatoes were directly sown and therefore they required thinning. Farm yard manure was used at every planting.

Except for tomatoes all the other crops under irrigation were sold as they stood in the field; the buyer was responsible for harvesting and handling of the crop. Due to this method of farm produce marketing, the farmers were not able to give the crop yields; instead they gave the gross income received per sub-plot per crop.

In Kikuyu/Limuru area the tomatoes were sold at the Wangige Market ; in Thika division, the sample farmers sold their produce at both Thika and Nairobi Markets.

Table 6.2 Average seasonal input requirements and gross output per enterprise per hectare; irrigated crops

Resources	Units	Agro-ecological zone LH2						Agro-ecological zone UM5			
(a) LABOUR:	Workday	Lettuce	Cabbages	Cauliflowers	Tomatoes	Spinach	Kale	Cauliflowers	Tomatoes	Kale	Beans
1. Land preparation & Harrowing		73	71	71	71	71	71	77	77	77	77
2. Furrows /holes		25	21	17	21	17	22	22	18	23	0
3. Fertilizer		2	5	8	9	6	4	14	3	5	2
4. Manure		31	31	41	35	57	40	0	9	10	0
5. Transplant/sowing		12	33	27	21	18	40	52	13	81	16
6. Thinning		53	0	0	20	0	0	0	17	0	0
7. Weeding		217	97	90	162	312	231	99	205	365	82
8. Spraying		2	3	8	181	2	4	5	90	44	1
9. Staking		0	0	0	68	0	0	0	20	0	0
10. Tying + desuckering		0	0	0	344	0	0	0	110	0	0
11. Irrigation		22	22	22	45	45	68	22	34	34	22
12. Harvesting + Packing		0	0	0	316	0	0	70	224	0	84
Total labour		437	283	284	1293	528	480	361	820	639	284
(b) MATERIALS:											
1. Seed	Kg	0.9	1.3	1.0	1.1	4.1	1.0	0.9	1.1	0.7	75
2. Fertilizer:	Kg										
D.A.P		37	143	202	285	346	121	277	446	194	0
20:20:0		53	81	87	147	64	44	0	0	0	0
Urea		9	134	207	27	88	162	140	0	0	0
C.A.N		0	33	91	122	255	148	0	0	510	522
Manure	ton.	17	13	19	19	32	20	0	4.4	10	0
chemical:											
Dithane M-45	Kg	1.2	0	3.7	81	1.1	0	0	25	19	0
Ambush	L.	1.3	2.3	2.4	5.8	0.7	2.0	1.3	4.6	9	0.8
Strings	Ksh.	0	0	0	697	0	0	0	170	0	0
Stakes	Ksh.	0	0	0	5024	0	0	0	1722	0	0
Transportation	Ksh.x1000	0	0	0	12	0	0	12.6	14.3	0	3.3
YIELDS	ton	..	..	24	48	..	..	16	23	..	5.3
GROSS OUTPUT	Ksh.x1000	142.0	67.4	120.8	622.5	178.0	118.0	65.3	106.0	36.2	39.2

Source: Appendix C.

Table 8.3 Average seasonal input requirements and gross output per enterprise per hectare rainfed crops

Resources	Units	Agro-ecological zone LH2			Agro-ecological zone UM5	
(a) LABOUR:	Workday	Maize	Beans	Potatoes	Intercropped Maize and	Beans
1. Land preparation & Harrowing		40	40	40	54	—
2. Furrows /holes		17	20	27	18	0
3. Fertilizer		1	2	1	0	0
4. Manure		16	8	18	10	0
5. Transplant/sowing		8	20	37	11	22
6. Thinning		0	0	0	0	0
7. Weeding		79	98	104	—	150
8. Spraying		0	0	12	4	0
9. Staking		0	0	0	0	0
10 Tying + desuckering		0	0	0	0	0
11. Irrigation		0	0	0	0	0
12. Harvesting + Packing		39	38	76	27	43
Total labour		200	224	315	124	215
(b) MATERIALS:						
1. Seed	Kg	29	119	2100	30	120
2. Fertilizer:	Kg					
D.A.P		45	59	155	10	0
20:20:0		0	0	0	0	0
Urea		0	0	0	0	0
C.A.N		0	0	0	0	0
3. Manure	ton.	3	2	7	1.4	0
4. Chemicals:						
Fungicide	Kg	0	0	4.8	0	0
Insecticide	L.	0	0	0	8.5	0.4
5. Strings	Ksh.	0	0	0	0	0
6. Stakes	Ksh.	0	0	0	0	0
7. Transportation	Ksh.x1000	0	0	0	0	0
(c) Yields	ton	3.0	2.0	12.8	1.9	2.0
(d) Gross output	Ksh.x1000	10.9	22.9	30.1	4.1	13.7

Table 6.4 Prices for Farm inputs and produce

Item		Unit cost (Ksh.)
Farm labour (per workday)		25.00
Seeds for crops (per kg):		
Maize		10.40
Beans	(6.85 for UM5)	11.00
Potatoes		3.10
Cabbage		292.80
Lettuce		920.00
Cauliflowers		1952.00
Spinach		237.00
Kale		194.30
Tomatoes		988.20
Fertilizer (per 50kg):		
D.A.P		354.00
20:20:0		314.00
C.A.N		208.65
Urea		244.05
Manure (per ton)		386.00
Farm chemicals:		
Dithane M-45 (per kg)		139.85
Ambush (Per litre)		254.10
Diesel (per litre)		5.73
Lubricant (Per litre)		22.00
Transport hire (1 ton Pick Up):		
Thika division to Nairobi		500.00
Limuru /Kikuyu to Wangige		250.00
Farm produce prices	Kikuyu/Limuru	
Thika		
Maize (Ksh/kg)	3.65	2.15
Beans (Ksh/kg)	11.00	6.85
Potatoes (Ksh/80kg bag)	188.00	—

Table 6.5 Seasonal operating expenditure (Labour, Materials & Transport) per crop per hectare; irrigated crops; (Ksh.)

(a)

Operating Expend.	Crop enterprises in AEZ LH2 lettuce	cabbage	cauliflower	tomatoes	spinach	kales
Labour	10900	7100	7100	32300	13200	12000
Materials	8500	8300	13800	30500	18000	11000
Transport	0	0	0	12000	0	0
Total	19400	15400	20900	74800	31200	23000
Gross output	142000	67400	120800	622500	178000	118000

(b)

Operating Expend.	Crop enterprises in AEZ UM5 Cauliflower	Tomatoes	Kale	Beans
Labour	9000	20500	16000	7100
Materials	3800	12500	12400	2900
Transport	12600	14300	0	3300
Total	25400	47300	28400	13300
Gross output	65300	106000	36200	39200

Table 6.6 Seasonal operating expenditure and gross output per crop per hectare; rainfed crops: (Ksh).

Operating Expend.	LH2 zone Maize	Beans	Potatoes	UM5 zone Maize/Beans intercropped
Labour	5000	5600	7900	8500
Materials	1800	2500	11000	2000
Total	6800	8100	18900	10500
Gross output	10900	22000	30100	17800

6.4 The Irrigation System

6.4.1 Design and Installation

Fifteen percent of the irrigation farmers had their irrigation systems installed by irrigation contractors. The others relied on their fellow farmers and local plumbers advice on the choice and installation of the irrigation system.

According to the dealers of Irrigation System pumpsets, interviewed by the author, the cost of technical advice for the selection of the suitable irrigation systems was incorporated in the price of the pumpset irrespective of whether the farmer used the dealers advice or not.

6.4.2 The Pumpset

a) Primemover

Fifty three percent of the irrigation farms used electric motors, the motor capacities ranged from 2 hp to 30 hp (Table B34). The motors were operated from the electricity mains. The average cost of installing the electricity service line at 1988 prices was Ksh. 30,358.

6.4.3 The irrigation Pipe System

Ninety seven percent of the farms had a semi permanent irrigation system, with hand move laterals; 3% had portable pumpsets and laterals, with permanent mainline.

a) The mainline

Fifty six percent of the farms used PVC buried pipes and 44% used galvanised steel pipes on the surface. Sixty eight percent of the farms had a uniform size of the mainline whereas 32% had at least two sizes of the mainline pipes. The frequency distribution of the mainline diameter size, based on the major length of the mainline is shown in Table 6.7.

Forty seven percent of the irrigation farms used diesel engine pumpsets (Table B35), the engine capacities ranged from 4.25 hp to 17 hp. Fifty six percent of the engines were of 10 hp and above and the rest under diesel engine driven; and 80% of them were under 10 hp capacity. Seventy five percent of the diesel engines used by the sample irrigation farmers were of Lister make.

b) Pumps

All the farmers used centrifugal pumps; 91% of them were single stage pumps; the other 9% were multi-stage.

The dominant pump makes within the sample were Southern Cross and Kirloskar; being 59% and 15% of the total, respectively. The available information on the pumps and from the manufacturers' pump selection charts, for these dominant pump makes, indicate their capacities to range from 6l/s against a 55 m head at 2900 rpm to 26 l/s against 100 m head at 2900 rpm. From the collected data (Table B36) these pumps were used to supply irrigation water to net irrigated areas ranging from 0.3-2.4 ha.

Table 6.7 Frequency distribution of the mainline sizes.

Diameter size (mm)	37.5	50	62.5	75	Total
Frequency (farms)	2	18	5	9	34
Percentage of total	6%	53%	15%	26%	100

The average length of the mainline for all sample farms and for the farms with net irrigated areas greater than 1.0 ha and for those with net irrigated areas equal to less than 1.0 ha is shown in Table 6.8 .

Table 6.8 The average length of the Mainline (metres)

	Within the sample	N.I.A $\leq$ 1.0 ha	N.I.A > 1.0 ha
Mean	246.8	206.6	286.9
Median	216.4	195.1	280.5

Fifty three percent of the farms had their mainlines side placed; the other 47% had the mainline placed at the centre of the farm.

b) The lateral line and the Sprinklers

Eighty eight percent of the farms used quick coupling aluminium irrigation pipes and 12% used plastic hose pipes.

The size frequency distribution of the aluminium lateral pipes in the farms is shown in Table 6.9 .

Table 6.9 Lateral size frequency distribution in the farms.

Lateral size (mm)	38	50	Total
Frequency (farms)	8	22	30
Percentage of total	27	73	100

Sixty two percent of all sample farms used two sets oflaterals; whereas 38% used one set of laterals for irrigation. Eighty two percent of those farms with net irrigated area greater than 1.0 ha used two sets of laterals whereas 59% of those with net irrigated area of equal or less than 1.0 ha irrigated with one set of laterals.

The mean lateral length per set for all sample farms was 48.6 m. For those farms with net irrigated area greater than 1.0 ha and having the side placement of the mainline, the lateral length was 54.9 m, whereas for those with net irrigated area equal to or less than 1.0 ha was 45.7 m.

Ninety one percent of the sample farms had the laterals spaced at 12 m intervals along the mainline; 6% had a spacing of 18 m and 3% had a 6 m spacing.

All the sample farms used small rotary double nozzle sprinklers; 91% of the farms had the sprinklers mounted on steel risers, 0.6 m tall on average. The risers were mainly made from 19 mm diameter steel pipes. All the farms had their sprinklers spaced at a distance of 6 m along the lateral line.

The farmers received the market information concerning their produce from National radio, the local press and the feedback from the buyers.

6.4.4 Operation of the irrigation system

Irrigation set time and frequency

On average the irrigation farmers operated their pumpsets 6 hours per day; and spent an average of 17 minutes in shifting each lateral set. The average irrigation set-time and frequency for the crops grown in the two considered agro-ecological zones are shown in Table 6.10. The average shifting labour requirement per irrigation per hectare was 0.75 workdays.

Table 6.10 Average irrigation set-time and frequency for the crops grown in LH2 and UM5 agro-ecological zones.

Crops	LH2 zone set-time (hrs)	LH2 zone Frequency (days)	UM5 zone set-time (hrs)	UM5 zone frequency (days)
Lettuce	1	3	—	—
Spinach	1	3	—	—
Kales	1	2	2	4
Cabbage	1.5	3	—	—
Cauliflower	1	3	1.5	3
Tomatoes	1.25	3	1.75	4
Pod beans	—	—	1.5	3

b) Energy use for irrigation

The irrigation farmers used either diesel fuel or electricity from the national grid line as their source of irrigation energy. The average monthly expenditure on electricity bill, for the peak months, for all the sample farmers using motors was Ksh. 867. The average monthly electricity bill for the peak months, for those farms with net irrigated area less or equal to 1.0 ha was Ksh. 543, whereas for those with net irrigated area greater than 1.0 ha was Ksh.1,126 (Appendix B38).

The average rate of diesel fuel consumption for all the farms that used the diesel engines was 0.26 l/hp-hr (Appendix B39).

6.5 Financing of the Irrigation Development

Sixty five percent of the sample farmers used their own resources to finance their irrigation development; 35% borrowed funds. Of those who used loans, 67% borrowed from Agricultural Finance Corporation (A.F.C); 25% from commercial banks and 8% from co-operative societies. The borrowed capital was for purchasing the pumpset and the pipes.

6.6 Pump House

Ninety four percent of the farmers had constructed a Pump house; 6% had no Pump house. Fifty nine percent of the Pump houses were temporary structures, whereas 41% were permanent structures.

The average cost of construction of the temporary and permanent structures, at 1988 prices was Ksh. 3136 and Ksh. 9021 respectively.

6.7 Financial Analysis of the Irrigation Farms

The financial analysis of the irrigation farms was based on six farm models (Table 5.1) which were developed on the basis of the information and data collected during the study. Summarised data compiled from the study and used in the financial analysis is presented in Tables 6.11 to Table 6.26. The supporting detailed data is presented in appendix B.

Table 6.11 Cropping intensity in study areas

Farm model	Without Irrigation	With Irrigation
A	2.0	2.6
B	2.0	2.6
C	2.0	2.5
D	2.0	2.5
E	2.0	2.4
F	2.0	2.5
Average	2.0	2.5

Source : Appendix B, Table B1 - B4

Table 6.12 Gross value of production for the farm models (Thousands Ksh.).

Farm model	Without Project	With Project				
Year	1 - 15	1	2	3	4	5 - 15
A	22.9	22.9	142.9	214.5	286.0	286.0
B	22.9	22.9	142.9	214.5	286.0	286.0
C	42.6	42.6	282.7	424.2	565.5	565.5
D	42.6	42.6	282.7	424.2	565.5	565.5
E	21.4	21.4	46.0	69.1	92.1	92.1
F	42.7	42.7	88.3	132.3	176.5	176.5

Source : Appendix B; Table B5-B8

Table 6.13 Annual labour requirement for the farm models (Work days)

Farm model	Without Project	With Project	
Year	1 - 15	1	2 - 15
A	291	291	744
B	291	291	744
C	570	570	1456
D	570	570	1456
E	407	407	740
F	814	814	1441

Table 6.14 Annual energy costs for the farm models

Farm models	A	B	C	D	E	F
Pump Operation hours per year*	592	592	459	459	1190	897
Energy costs/yr. (Ksh.)	2900	14100	5700	10900	11500	8700
Lubrication costs** (Ksh.)	—	2700	—	2100	2200	1700
Total energy & Lubrication	2900	16800	5700	13000	13700	10400

* Estimated on the basis of the available effective rainfall and the lateral sets used at once

** Lubrication estimated at 5% of the fuel consumption

Table 6.15 Annual labour, materials, transport and repairs and maintenance costs for the farm models (Thousand Ksh.)

Farm model	Farming system	Labour	Farm input materials	Transport	Repairs & maintenance
A	Irrigation:	19.3	21.4	2.4	2.5
	Rainfed:	7.3	6.0	—	—
	I/R ratio*	2.6	3.6	—	—
B	Irrigation:	19.3	21.4	2.4	7.9
	Rainfed:	7.3	6.0	—	—
	I/R ratio	2.6	3.6	—	—
C	Irrigation:	38.1	42.2	4.8	3.4
	Rainfed:	14.3	11.3	—	—
	I/R ratio	2.7	3.7	—	—
D	Irrigation:	38.1	42.2	4.8	8.8
	Rainfed:	14.3	11.3	—	—
	I/R ratio	2.7	3.7	—	—
E	Irrigation:	18.7	10.8	11.7	5.3
	Rainfed:	10.2	2.4	—	—
	I/R ratio	1.8	4.5	—	—
F	Irrigation	36.8	21.7	22.0	6.2
	Rainfed	20.4	4.8	—	—
	I/R ratio	1.8	4.5	—	—

* ratio obtained by dividing Irrigation component of expenditure by its corresponding Rainfed expenditure.

Table 6.16 Total annual operating expenditure for the farm models (Thousand Ksh.)

	Without Project (I)	With Project (II)	(III)	Ratio (III)/(I)
Farm model year	1 - 15	1	2 - 15	
A	13.3	13.3	47.9	3.6
B	13.3	13.3	67.2	5.0
C	25.5	25.5	92.4	3.6
D	25.5	25.5	105.1	4.1
E	12.6	12.6	59.9	4.8
F	25.2	25.2	96.3	3.8
Average	—	—	—	4.2

Table 6.17 Components of annual operating expenditure expressed as a percentage of total annual operating expenditure.

Component	Farm model A	B	C	D	E	F
Labour	40	28	41	36	31	38
Energy & Lubrication	6	25	6	12	23	11
Farm input Materials	44	32	45	40	18	22
Transport	5	3	5	4	19	23
Repairs & Maintenance	5	12	3	8	9	6
Total	100	100	100	100	100	100

Table 6.18 Components of the initial capital investment cost for the farm models (Thousands Ksh.)

Component	A	B	C	D	E	F
			Farm model			
a) Water supply:						
Pumping unit	55.5	122.6	55.5	122.6	84.4	84.4
Electricity connection	30.4	—	30.4	—	—	—
Pumphouse	12.3	9.0	12.3	9.0	9.0	9.0
Reservoir	6.0	6.0	6.0	6.0	—	—
Sub-total	104.2	137.6	104.2	137.6	93.4	93.4
100a/d (%)	74%	79%	54%	60%	72%	51%
b) Water conveyance:						
pipes & fittings	14.4	14.4	37.2	37.2	14.4	37.2
Laying pipe	2.1	2.1	2.4	2.4	2.1	3.8
Sub-total	16.5	16.5	39.6	39.6	16.5	41.0
100b/d (%)	12%	9%	20%	18%	13%	22%
c) Irrigation:						
Equipment:	20.1	20.1	50.7	50.7	20.2	50.7
100c/d (%)	14%	12%	26%	22%	15%	27%
Initial capital						
d) Total Initial Capital Invest.	140.9	174.3	194.5	227.9	130.1	185.1
100d/d (%)	100%	100%	100%	100%	100%	100%
e) Initial Invest. cost/ha	234.8	290.6	162.1	189.9	216.9	154.2

Table 6.19 With project farm budget 0.6 ha farm model A
(Thousand Ksh.)

Item	Project year 1	2	3	4	5	6	7	8	9 - 14	15
Inflow										
Gross value of production	22.9	142.9	214.5	286.0	286.0	286.0	286.0	286.0	286.0	286.0
Incremental residue value	—	—	—	—	—	—	—	—	—	30.9
Total inflow	22.9	142.9	214.5	286.0	286.0	286.0	286.0	286.0	286.0	316.9
Outflow										
Investment	140.9	0	0	0	0	0	0	8.4	0	0
Incremental working capital	10.4	0	0	0	0	0	0	0	0	0
Operating expenditure*	13.3	47.9	47.9	47.9	47.9	47.9	47.9	47.9	47.9	47.9
Total outflow	164.6	47.9	47.9	47.9	47.9	47.9	47.9	56.3	47.9	47.9
Net benefit before financing										
With project	(141.7)**	95.0	166.6	238.1	238.1	238.1	238.1	229.7	238.1	269.0
Without project	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Incremental	(151.3)	85.4	157.0	228.5	228.5	228.5	228.5	220.1	228.5	259.4
Financing										
Loan receipts	90.0	0	0	0	0	0	0	0	0	0
Debt services	—	28.8	26.6	24.5	22.3	20.2	0	0	0	0
Net financing	90.0	(28.8)	(26.6)	(24.5)	(22.3)	(20.2)	0	0	0	0
Net benefit after financing										
With project	(51.7)	66.2	140.2	213.6	215.8	217.9	238.1	229.7	238.1	269.0
Without project	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Incremental	(61.3)	56.6	130.4	204.0	206.2	208.3	228.5	220.1	228.5	259.4

Net present worth at 12% for all resources engaged = 1054.5
Financial rate of return to all resources engaged = 93%
Financial rate of return to farmers own resources = 158%

** The figures in bracket are negative values

* The maintenance and repair costs of the irrigation equipment and pump set are based on annual costs calculated as percentage of the initial cost Table 4.1.

Table 6.20 With project farm budget 0.6 ha farm model B
(Thousand Ksh.)

Item	Project year 1	2	3	4	5	6	7	8	9 - 14	15
Inflow										
Gross value of production	22.9	142.9	214.5	286.0	286.0	286.0	286.0	286.0	286.0	286.0
Incremental resudue value	—	—	—	—	—	—	—	—	—	40.1
Total inflow	22.9	142.9	214.5	286.0	286.0	286.0	286.0	286.0	286.0	326.1
Outflow										
Investment	174.3	0	0	0	0	0	0	8.4	0	0
Incremental working capital	16.2	0	0	0	0	0	0	0	0	0
Operating expenditure	13.3	67.2	67.2	67.2	67.2	67.2	67.2	67.2	67.2	67.2
Total outflow	203.8	67.2	67.2	67.2	67.2	67.2	67.2	75.6	67.2	67.2
Net benefit before financing										
With project	(180.9)	75.7	147.3	218.8	218.8	218.8	218.8	210.4	218.8	258.9
Without project	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Incremental	(190.5)	66.1	137.7	209.2	209.2	209.2	209.2	200.8	209.2	249.3
Financing										
Loan receipts	157.2	0	0	0	0	0	0	0	0	0
Debt services	—	50.3	46.5	42.7	39.0	35.4	0	0	0	0
Net financing	157.2	(50.3)	(46.5)	(42.7)	(39.0)	(35.4)	0	0	0	0
Net benefit after financing										
With project	(23.7)	25.4	100.8	176.1	179.8	183.4	218.8	210.4	218.8	258.9
Without project	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6	9.6
Incremental	(33.3)	15.8	91.2	166.5	170.2	173.8	209.2	200.8	209.2	249.3

Net present worth at 12% for all resources engaged = 906.9

Financial rate of return to all resources engaged = 70%

Financial rate of return to farmers own resources = 166%

Table 6.21 With project farm budget 1.2 ha farm model C
(Thousand Ksh.)

Item	1	2	3	4	5	6	7	8	9 - 14	15
	Project year									
Inflow										
Gross value of production	42.6	282.7	424.2	565.5	565.5	565.5	565.5	565.5	565.5	565.5
Incremental residue value	—	—	—	—	—	—	—	—	—	50.2
Total inflow	42.6	282.7	424.2	565.5	565.5	565.5	565.5	565.5	565.5	615.7
Outflow										
Investment	194.5	0	0	0	0	0	0	12.3	0	0
Incremental working capital	20.1	0	0	0	0	0	0	0	0	0
Operating expenditure	25.5	92.4	92.4	92.4	92.4	92.4	92.4	92.4	92.4	92.4
Total outflow	240.1	92.4	92.4	92.4	92.4	92.4	92.4	104.7	92.4	92.4
Net benefit before financing										
With project	(197.5)	190.3	331.8	473.1	473.1	473.1	473.1	460.8	473.1	523.3
Without project	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
Incremental	(214.6)	173.2	314.7	456.0	456.0	456.0	456.0	443.7	456.0	506.2
Financing										
Loan receipts	143.4	0	0	0	0	0	0	0	0	0
Debt services	—	45.9	42.5	39.0	35.6	32.0	0	0	0	0
Net financing	143.4	(45.9)	(42.5)	(39.0)	(35.6)	(32.0)	0	0	0	0
Net benefit after financing										
With project	(54.1)	144.4	289.3	434.1	437.5	441.1	473.1	460.8	473.1	523.3
Without project	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
Incremental	(71.2)	127.3	272.2	417.0	420.4	424.0	456.0	443.7	456.0	506.2

Net present worth at 12% for all resources engaged = 2165.2
Financial rate of return to all resources engaged = 123%
Financial rate of return to farmers own resources = 253%

Table 6.22 With project farm budget 1.2 ha farm model D
(Thousand Ksh.)

Item	Project Year 1	2	3	4	5	6	7	8	9 - 14	15
					Inflow					
Gross value of production	42.6	282.7	424.2	565.5	565.5	565.5	565.5	565.5	565.5	565.5
Incremental residue value	—	—	—	—	—	—	—	—	—	57.4
Total inflow	42.6	282.7	424.2	565.5	565.5	565.5	565.5	565.5	565.5	622.9
					Outflow					
Investment	227.9	0	0	0	0	0	0	12.3	0	0
Incremental working capital	23.9	0	0	0	0	0	0	0	0	0
Operating expenditure	25.5	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.1	105.1
Total outflow	277.3	105.1	105.1	105.1	105.1	105.1	105.1	117.4	105.1	105.1
					Net benefit before financing					
With project	(234.7)	177.6	319.1	460.4	460.4	460.4	460.4	448.1	460.4	517.8
Without project	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
Incremental	(251.8)	160.5	302.0	443.3	443.3	443.3	443.3	431.0	443.3	500.7
					Financing					
Loan receipts	210.5	0	0	0	0	0	0	0	0	0
Debt services	—	67.4	62.3	57.3	52.2	47.1	0	0	0	0
Net financing	210.5	(67.4)	(62.3)	(57.3)	(52.2)	(47.1)	0	0	0	0
					Net benefit after financing					
With project	(24.2)	110.2	256.8	403.1	408.2	413.3	460.4	448.1	460.4	517.8
Without project	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1
Incremental	(41.3)	93.1	239.7	386.0	391.1	396.2	443.3	431.0	443.3	500.7

Net present worth at 12% for all resources engaged = 2078.2

Financial rate of return to all resources engaged = 105%

Financial rate of return to farmers own resources = 328%

Table 6.23 With project farm budget 0.6 ha farm model E
(Thousand Ksh.)

Item	Project Year 1	2	3	4	5	6	7	8	9 - 14	15
					Inflow					
Gross value of production	21.4	46.0	69.1	92.1	92.1	92.1	92.1	92.1	92.1	92.1
Incremental residue value	—	—	—	—	—	—	—	—	—	33.6
Total inflow	21.4	46.0	69.1	92.1	92.1	92.1	92.1	92.1	92.1	125.7
					Outflow					
Investment	130.1	0	0	0	0	0	0	2.4	0	0
Incremental working capital	14.2	0	0	0	0	0	0	0	0	0
Operating expenditure	12.6	59.9	59.9	59.9	59.9	59.9	59.9	59.9	59.9	59.9
Total outflow	156.9	59.9	59.9	59.9	59.9	59.9	59.9	62.3	59.9	59.9
					Net benefit before financing					
With project	(135.5)	(13.9)	9.2	32.2	32.2	32.2	32.2	29.8	32.2	65.8
Without project	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Incremental	(144.3)	(22.7)	0.4	23.4	23.4	23.4	23.4	21.0	23.4	57.0
					Financing					
Loan receipts	119.0	0	0	0	0	0	0	0	0	0
Debt services	—	38.1	35.2	32.4	29.5	26.0	0	0	0	0
Net financing	119.0	(38.1)	(35.2)	(32.4)	(29.5)	(26.6)	0	0	0	0
					Net benefit after financing					
With project	(16.5)	(52.0)	(26.0)	(0.2)	2.7	5.6	32.2	29.8	32.2	65.8
Without project	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8	8.8
Incremental	(25.3)	(60.8)	(34.8)	(9.0)	(6.1)	(3.2)	23.4	21.0	23.4	57.0

Net present worth at 12% for all resources engaged = (38.3)

Financial rate of return to all resources engaged = 8%

Financial rate of return to farmers own resources = 6%

Table 6.24 With project farm budget 1.2 ha farm model F
(Thousand Ksh.)

Item	Project Year 1	2	3	4	5	6	7	8	9 - 14	15
					Inflow					
Gross value of production	42.7	88.3	132.3	176.5	176.5	176.5	176.5	176.5	176.5	176.5
Incremental residue value	—	—	—	—	—	—	—	—	—	50.3
Total inflow	42.7	88.3	132.3	176.5	176.5	176.5	176.5	176.5	176.5	226.8
					Outflow					
Investment	185.1	0	0	0	0	0	0	6.3	0	0
Incremental working capital	21.3	0	0	0	0	0	0	0	0	0
Operating expenditure	25.2	96.3	96.3	96.3	96.3	96.3	96.3	96.3	96.3	96.3
Total outflow	231.6	96.3	96.3	96.3	96.3	96.3	96.3	102.6	96.3	96.3
					Net benefit before financing					
With project	(188.9)	(8.0)	36.0	80.2	80.2	80.2	80.2	73.9	80.2	130.5
Without project	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Incremental	(206.4)	(25.5)	18.5	62.7	62.7	62.7	62.7	56.4	62.7	113.0
					Financing					
Loan receipts	172.3	0	0	0	0	0	0	0	0	0
Debt services	—	55.2	51.0	46.9	42.7	38.4	0	0	0	0
Net financing	172.3	(55.2)	(51.0)	(46.9)	(42.7)	(38.4)	0	0	0	0
					Net benefit after financing					
With project	(16.6)	(63.2)	(15.0)	33.3	37.5	41.8	80.2	73.9	80.2	130.5
Without project	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Incremental	(34.1)	(80.7)	(32.5)	15.8	20.0	24.3	62.7	56.4	62.7	113.0

Net present worth at 12% for all resources engaged = 91.6

Financial rate of return to all resources engaged = 18%

Financial rate of return to farmers own resources = 21%

Table 8.25 Present worth of benefits and costs before financing
for the model farms, discounted at 12%
(Thousand Ksh.)

Item	Farm model A	B	C	D	E	F
Gross benefits:						
With project	1553.7	1555.3	3067.8	3069.1	517.2	990.0
Without project	156.0	156.0	290.1	290.1	145.8	290.8
Incremental	1397.7	1399.3	2777.7	2779.0	371.4	699.2
Costs:						
With project	433.8	583.0	766.2	874.5	495.5	779.2
Without project	90.6	90.6	173.7	173.7	85.8	171.6
Incremental	343.2	492.4	592.5	700.8	409.7	607.6
Net benefits:						
With project	1119.9	972.3	2301.6	2194.6	21.7	210.8
Without project	65.4	65.4	116.4	116.4	60.0	119.2
Incremental	1054.5	906.9	2185.2	2078.2	(38.3)*	91.6
Net benefits						
Increase (ratio)	16.12	13.87	18.77	17.85	(0.64)	0.77
Benefits/cost ratio	4.07	2.84	4.69	3.96	0.91	1.15

* Figures in brackets indicate negative values

Table 8.26 The financial measures of project worth for the model farms

Financial measure	Farm model A	B	C	D	E	F
Net present worth before financing at 12% discount rate (Thousand K.sh.)	1054.5	906.9	2185.2	2078.2	(38.3)	91.6
Financial rate of return before financing	93%	70%	123%	105%	8%	18%
Financial rate of return after financing	158%	166%	253%	328%	6%	21%
Net benefit:						
Investment ratio	8.8	6.3	12.4	10.2	0.8	1.4
Benefit-cost ratio before financing	4.07	2.84	4.69	3.96	0.91	1.15

* Figures in brackets indicate negative values

7. DISCUSSION

7.1. Costs of the Irrigation Development

7.1.1 Capital Investment Costs

The initial capital investment costs for the smallholder pumped sprinkler irrigation systems represented by the farm models A, B, C, D, E, and F (table 6.18) ranged from KShs.130,100 for model E to KShs.227,900 for model D. Farm model E represented the famers in Thika Division with a net irrigated area of 0.6 ha and using 6.5 hp diesel engine; while model D represented farms in Kikuyu/Limuru Divisions with 1.2 ha net irrigated area and using a 16 hp diesel engine.

In Thika Division, the total initial capital investment cost that was required to develop a sprinkler irrigation system was KShs.130,100 for a net irrigated area of 0.6 ha and KShs.185,100 for a net irrigated area of 1.2 ha; Farm models E and F respectively.

In Kikuyu/Limuru Divisions the total initial capital investment cost required on a farm with 0.6 ha net irrigated area was KShs.140,900 if the farmer used an electric motor or KShs.174,300 if he used a diesel engine as the prime mover; farm models A and B respectively. For the farmers with 1.2 ha net irrigated area, within this same area, the initial capital investment cost required was KShs.194,500 for electric motor operated systems and KShs.227,900 for the diesel engine operated systems; farm models C and D respectively.

A comparison between the initial capital investment costs of farm models A and B; C and D, indicated that irrigation developments using diesel engines as prime movers incurred 20 per cent more capital investment costs than those using electric motors; other factors being the same.

For the farms of equal net irrigated area and using diesel engines, the Thika farms required less capital investment costs than the Kikuyu/Limuru farms. The basic differences were due to the fact that, Thika farms did not require reservoirs, they used large perennial rivers, and the diesel engine prime movers were of smaller capacity than those used in Kikuyu/Limuru Divisions. The

Thika farms were in a plain where the static heads were lower compared to Kikuyu-Limuru farms whose water sources occurred in steep valleys. Water horsepower (WHP), the useful energy required for pumping water is directly proportional to discharge and total head (Michael, 1978).

$$\text{WHP} = \frac{\text{Discharge in litres per second x total head (m)}}{75}$$

The cost of prime mover is a function of its capacity (Mubayi et al, 1977); Bish International, 1987).

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The initial investment cost, *cateris paribus*, increased with net irrigated area; however, the initial capital investment cost per hectare was higher for those farms with small net irrigated area, Farm models A, B and E, than for those with larger net irrigated area, farm models C, D and F (Table 6.18). Israelsen (1950) reported that as the hectarage under irrigation per farm increased the initial capital cost per hectare decreased.

Among the three components of the initial capital investment cost of the pumped sprinkler irrigation system, shown in Table 6.18, the water supply component accounted for 51 to 79 per cent of initial capital investment cost. The water conveyance component accounted for 9 to 22 per cent, while the irrigation equipment component accounted for 12 to 27 per cent of the total initial capital investment cost. On the average, the water supply component cost constituted 65%, the water conveyance 16% and the irrigation equipment component 19%, of the initial capital investment cost.

During the life of the project, capital replacement costs would be required for sprinkler and dredging of the reservoirs (Table 6.19 to 6.24).

7.1.2 Operating Costs

The annual operating expenditures and their components for the farm models are shown in Tables 6.14, 6.15, 6.16 and 6.17. The total annual operating expenditures ranged from KShs.47,900 to KShs.67,200 for the 0.6 ha farms; and from KShs.92,400 to KShs.105,100 for the 1.2 ha farms. Energy lubrication and repairs and maintenance were the main components that caused the variation within the farms of the same size (Table 6.17).

By changing from rainfed agriculture to irrigated agriculture, the farmer's annual operating expenditure on the farm increased about four times on average (Table 6.16).

(i) Energy Cost:

Annual energy costs for the model farms as shown in Table 6.14 indicated that the irrigation farms which used diesel engines, farm models B, D, E and F spent more on energy than those which used electric motors, Farm models A and C. For the farms of the same size, Farm model B spent about 5 times more on energy than Farm model A, whereas Farm model D spent about 2 times more on energy than Farm model C.

Although farmers in Thika Division operated their pumps double the time their counterparts in Kikuyu and Limuru Division did, due to the fact that they used lower capacity diesel engine, 6.5 hp, compared to 16 hp used by the later, they incurred 20% less on energy cost.

The electric motor operated irrigation farms used 6% of their total annual operating expenditure on energy cost; whereas diesel engine operated irrigation farms used 11-25% of their total annual operating costs to defray energy and lubrication costs (Table 6.17).

(ii) Farm Labour:

Table 6.23 indicates that the irrigation farmers within both the Subhumid and semi-arid climatic zones used, approximately the same amount of annual labour in their farms, 740 workdays and 1460 workdays for the 0.6 has and 1.2 ha respectively. However, the labour requirements within and among the enterprises differed (Table 6.5).

The electric motor operated irrigation systems spent 40% of their total annual operating expenditure on farm labour, whereas for the diesel engine operated irrigation systems, the farm labour accounted for 33 per cent of the total annual operating expenditure; on average.

With irrigation, the annual farm labour requirement increased 2.6 times in Kikuyu/Limuru Divisions and 1.8 times in Thika Division; compared with the without irrigation annual labour requirements of the respective divisions (Table 6.13).

(iii) Farm Input Materials:

The major farm input materials used by the irrigation farmers were seeds, fertilizers, manures and pesticides (Table 6.2). The irrigation farmers in the subhumid climatic zone, farm models A to D, spent twice as much on farm inputs as their corresponding counterparts, farm models E and F, in the semi-arid zone (Table 6.15).

The cost of the farm input material accounted for 44 to 45 per cent of the total annual operating expenditure for electric motor operated irrigation systems, farm models A and C. For the diesel operated systems, the cost accounted for 32 to 40 per cent in Kikuyu/Limuru Divisions and 18 to 22 per cent for the farms in Thika Division (Table 6.17).

With irrigation the farmers in Kikuyu/Limuru Divisions spent 3.7 times, and those in Thika Division spent 4.5 times as much on farm inputs compared to the without irrigation farmers in the respective areas.

(iv) Transport Costs:

Transport costs on farm produce from the farms to the markets accounted for 4% and 21% of the total annual operating expenditure on average, for the irrigation farms in Limuru/Kikuyu divisions and Thika Division respectively.

Except for tomatoes, all crops in Limuru-Kikuyu divisions were sold while standing in the field, on the other hand, Thika irrigation farmers had to hire transport for all their farm produce, except for the Kales, to the Nairobi and Thika town markets. The rainfed farmers in the considered areas sold their surplus produce on the farm or in small quantities in the nearby local markets.

(v) Repairs and Maintenance Cost:

The irrigation farmers spent between 3 to 12% of their total annual operating expenditure on repairs and maintenance of the irrigation systems (Table 6.17). Farmers using electric motors, spent an average of 4% of their total annual operating expenditure on the repairs and maintenance, whereas those who used diesel engines spent an average of 9%. Carruthers and Clark (1981) reported that pumping costs were lowest if electric power was used because diesel pumps incurred higher costs for both fuel and maintenance.

7.1.3 Present Worth of Project Costs

The present worth of costs with and without the irrigation projects are shown in Table 6.25.

The present worth of costs without the irrigation project were equal for the same size farms within the same agro-ecological and geographical zones. Rainfed agriculture farmers with 0.6 ha and 1.2 ha plots in Kikuyu/Limuru Divisions spent 6% and 1% more on their plots, respectively, than their counterparts in Thika Division, over the life of the projects.

The present worth of costs with the irrigation, projects, among the farm models, were highest for farm model D and least for farm model A. By using diesel engines instead of electric motors as primemovers, farmers with 0.6 ha and 1.2 ha net irrigated area increased their present worth of costs by 34% and 14% respectively.

The incremental costs that the farmers incurred by changing from rainfed agriculture to irrigated agriculture over the life of the project are shown in Table 6.25. On average, the incremental costs were 4.7 and 3.6 times that of the without irrigation costs, for the 0.6 ha and 1.2 ha plots respectively.

7.2 Benefits of the Irrigation Development

The primary benefit of an irrigation system, according to Nir (1983) consists of the value of the crop produced. The year to year gross values of production for the farm models are shown in Table 6.12. The annual benefits received by the farmers with irrigation from year four onwards, that is, after the production had stabilized, were about 13 times and 4 times that received by the farmers without irrigation facilities on the subhumid and semi-arid agro-ecological zones respectively.

In Table 6.25, the present worth of benefits accruing to farmers with and without irrigation over the life of the irrigation project discounted at 12%, are shown. For the farms of the same size, the Kikuyu-Limuru irrigation farmers received 3 times the benefits received by the

Thika irrigation farmer,however, without irrigation, the farmers with 1.2 ha plots in both Kikuyu-Limuru and Thika areas received approximately equal benefits from their farms, while those with 0.6 ha plots in Kikuyu-Limuru area received 7% more benefit compared to those with plots of the same size in Thika area.

The incremental benefits accruing to the farmers for developing irrigation facilities were positive for all the farm models considered (Table 6.25). The incremental benefits were about KShs.1.4 million for farm models A and B; KShs.2.8 million for farm models C and D; KShs.0.4 million for model E and KShs.0.7 million for model F. The positive incremental benefits received by the irrigation farmers, were attributed to:

- Crop substitution
- Intensification of land use
- Independence from the dictates of the weather

(i) Crop Substitution

Without irrigation, the main crops grown were maize, potatoes and beans in the subhumid zone of Kikuyu-Limuru divisions, and maize intercropped with beans in the semi-arid zone of Thika Division. With irrigation development, the farmers changed their cropping pattern and were able to introduce new types of crops, substituting vegetables for the afore mentioned rainfed crops. Vegetables are high value crops compared to the latter (Table 6.2 and 6.3). Vegetables are seldom grown in subhumid climates without irrigation; farmers consider irrigation as insurance, and some cannot justify the high investment in high value production without supplemental irrigation to minimize the uncertainties of rainfall (Israelsen, 1950; Jensen, 1983). One hot dry period of ten days or even less when lettuce is heading, for example, may seriously damage or even completely ruin the crop (Woodward, 1959).

(ii) Intensification of Land Use:

Without irrigation the farmers achieved a cropping intensity of 2.0 with irrigation facilities, farmers were able to intensify their land use by triple cropping. The cropping intensity went up to about 2.5 (Table 6.11). The increase in cropping intensity effectively increased the cropped area and hence the increase in the quantity produced by the farmer.

(iii) Independence from the dictates of the weather without irrigation farmers found themselves at the mercy of weather; schedules of their farm activities were controlled and frustrated by the unpredictable weather.

The irrigation development accorded farmers flexibility in the management and planning of their farm activities. Irrigation gave them freedom, as it were, from the dictates of the weather.

With irrigation the farmers were able to manipulate their planting schedules so as to maintain sales of a given crop throughout the year, to satisfy a standing supply order or to have the crop ready at a predetermined time, usually coinciding with periods of peak produce demand.

7.2.1 Incremental Net Benefits

The incremental net benefit is the difference between the net benefit generated by using irrigation facilities and the net benefit received without the use of the facilities. It is additional amount of benefit the farmer gets by investing in irrigation over and above what he would receive without the irrigation facilities. It is the direct incentive to the farmer to invest in irrigation (Gittinger, 1982; Withers and Vipond, 1980).

With exception of Farm model E, the considered farm models had positive incremental net benefits. The net benefit increase ratios for the Farm models in Kikuyu-Limuru area ranged from 13.9 to 18.8 while that for the Thika Farm models ranged from -0.6 to 0.8 (Table 6.25). A negative net benefit increase ratio indicated a disincentive to the farmer to change from rainfed agriculture to irrigated agriculture. According to Withers and Vipond (1980) whether to irrigate or not is decided purely on the estimated profitability of doing so.

7.3 Financial Viability of the Irrigation Projects

The Net Present Worth, the financial rate of returns, the net benefit-investment ratio and the benefit/cost ratio, discounted measures of project worth, were used to assess the financial viability of the irrigation projects.

The measures and their values for each farm model are shown in Table 6.26.

7.3.1 Net Present Worth

The net present worths for farm models A, B, C, D, and F were all positive, whereas the net present worth of farm model E was negative. The present selection criteria based on the net present worth is to accept all independent projects with zero or greater net present worth, when discounted at the opportunity cost of capital (Gittinger, 1982).

On the basis of net present worth, projects A, B, C, D and F were financially viable, while project E was not. When the net present worth is negative the benefit stream is not sufficient to recover investment.

Project A and B; C and D were mutually exclusive, since they compared diesel engine primemover against electric motor, all other factors being the same. The net present worth of Project A was bigger than that of project B, while that of project C was bigger than that of project D. Projects A and C, the ones that used electricity, were therefore financially more attractive than projects B and D that used diesel.

7.3.2 Financial Rate of Return

The financial rates of returns before financing for the farm models were 93%, 70%, 123%, 105%, 8% and 18% for farm models A to F respectively.

The project selection criteria used based on the financial rate of return is to accept all independent projects with financial rate of return equal to or greater than opportunity cost of capital. In this study the opportunity cost of capital was assumed to be 12%.

Farm models A, B, C, D and F were therefore financially viable projects, while project E was not.

The financial rates of return after financing indicated the financial rates of return to the farmers' own capital. The rates of return after financing, for farm models A, B, C, D and F were larger than their corresponding financial rates of return before financing. According to Gittinger (1972), the higher the proportion of borrowed capital a farmer can use, the higher the rate of return which he can realize on his own capital investment, but the higher the risk to which he exposes his own capital.

7.3.3 Net benefit-Investment Ratio (N/K ratio)

The net benefit-investment ratios for the farm models were 8.8, 6.3, 12.4, 10.2 for models A, B, C and D; 0.8 and 1.4 for models E and F respectively.

The net benefit-investment ratio project selection criterion, requires that all independent projects with net benefit-investment ratio of 1 or greater when discounted at opportunity cost of capital be accepted in order of ratio value until available investment funds are exhausted (Gittinger, 1982).

Projects A, B, C, D and F had their net benefit-investment ratios greater than 1, while project E had its net benefit-investment ratio less than 1. On the basis of net benefit-investment ratio, projects A, B, C, D and F were acceptable, they were financially viable. Project E was not acceptable, it was financially not worthwhile.

The net benefit-investment ratios of the farm models indicated that the order of their implemention should be C, D, A, B, and F assuming they were all independent projects. Project E would not be worthwhile implementing.

Inspection of the net benefit-investment ratio indicates that, the investment costs for farm models A, B, C, D and F could rise by as much as 780%, 530% 1140%, 920% and 40% respectively before the N/K ratio dropped to 1. On the other hand, the net benefits could fall by as much as 89%. 84%, 92%, 90% and 28% respectively, before the N/K ratio dropped to 1.

The investment costs for farm model E, would have to fall by 20% or the net benefits rise by 25% before N/K ratio rose to 1.

7.3.4 Benefit-Cost Ratio (B/C Ratio)

The benefit-cost ratios were calculated on the basis of incremental costs (Table 6.25). The benefit-cost ratio project selection criterion, accepts all independent projects with a benefit-cost ratio of 1 or greater when the benefits and cost streams are discounted at the opportunity cost of capital.

The farm models A, B, C, D and F had their benefit-cost ratios greater than 1. They were, therefore, on the basis of benefit-cost ratio financially viable projects. Farm model E had a benefit-cost ratio of 0.91 which is less than 1; hence by the benefit-cost project selection criterion, it was not acceptable, it was not a profitable project.

Incremental costs would have to rise by 307% for project A, 184% for project B, 369% for project C, 296% for project D and 15% for project F before the incremental net benefit was driven to zero. For project E, the incremental costs would have to fall by 9% for the incremental net benefit to rise to zero.

Incremental benefits would have to fall by 75% for project A, 65% for project B, 79% for project C, 75% for project D and 13% for project F before the incremental net benefit fell to zero. The incremental benefits for project E would have to rise by 10% before the incremental net benefit became zero.

The four discounted measures of project worth, used in this study, accepted the projects A, B, C, D and F as financially viable projects, the projects were able to recover the invested capital that is return of capital; and earned the farmer a return on his capital. The farmers were better off with irrigation than with rainfed agriculture. The four discounted measures of project worth rejected farm model E as a financially attractive project; the farmer would not be able to earn a return on his capital nor be able to recover his capital.

Based on the benefit-investment ratio, the irrigation farm models in Kikuyu-Limuru divisions were more financially attractive than those of Thika Division. In the former, all the farm models ranked higher than those in the latter.

Examining the benefits with and without the project; and the costs with and without the project; Table 6.25, the gross benefits with the projects emerged as the major cause of the difference between the financial performance of Kikuyu-Limuru farms and Thika farms. Comparing farm models of equal size, Kikuyu-Limuru farms made 3 times as much gross benefits as Thika farms.

As stated by Upton (1979); the system of farming found in any particular area and the management decisions of farmers are influenced by the following main features of the environment:-

(i) density of agricultural population

(ii) natural resources

(iii) location in relation to markets, roads and railways

(iv) institutions relating to the land e.g. land tenure

(v) technical knowledge and capital resources available

Observations and discussions between the irrigation farmers and this author indicated that the location of the farms in relation to the markets and the development of transport facilities were the major environmental features that contributed to the big difference in the gross benefit between the Kikuyu-Limuru irrigation farms and Thika irrigation farms.

The smallholder irrigation farmer played the role of the farm manager, the farm labourer, the purchasing and marketing personnel. These roles competed for the farmer's limited time. Spending too much time on one caused adverse effects on the others.

Thika farmers, who sold their produce in Nairobi, had to transport the produce well over 40 km, they had to hire transport to and from the farm since the public transport facilities in the vicinity of the farms were absent. Marketing of small quantities of produce presented a big problem to the farmer and it often led to deterioration of produce quality and/or loss of produce as the farmer waited to get enough produce to justify hiring transport.

The transport, purchasing and marketing activities distracted the Thika farmer from his role as the farm manager on account of the greater amount of time he spent travelling to and fro. He was, therefore, unable to give proper supervision to labour and regular attention to the crops when required. According to Upon (1979) profit is the product of management; and without inputs of management a farm would not exist. This author observed that the quality of the farm produce from the Thika farms was lower than that of the Kikuyu-Limuru irrigation farms. Average crop yields in the latter were also higher than those of the Thika farms. The cauliflower and tomato yields for the Kikuyu-Limuru farms were respectively, 50% and 109% more than those of the Thika farms (Table 6.2). The gross value of production ceteris paribus depends on the quantity and quality of the produce harvested (Nir 1983).

The public transport facilities in the Kikuyu-Limuru area were very good. Except during the wet weather when the Ngecha-Wangige road became impassable, matatus and buses moved to and from Nairobi via Wangige market regularly. This made it possible for farmers to acquire farm inputs of whatever quantity and apply them promptly.

The Kikuyu-Limuru farmers normally sold their produce standing in the field, and they did not need to go out looking for the buyers. The Kikuyu-Limuru farmers, therefore, unlike Thika farmers had more time to plan and manage their farms.

7.4 The Incentive to Change from Rainfed to Irrigated Agriculture

According to Upton (1979) economic decisions of what to produce, and how to produce are made based on the assumption that farmers grow crops and keep livestock for the satisfaction of their personal wants.

> " They are then assumed to maximise their satisfactions by maximising profits; the profits enable them to buy things which improve diets, health and education as well as increase the range of choice open to them in material possessions. "

Farmers make rational decisions by comparing costs and benefits in relation to their existing knowledge and social circumstances,

> " they attempt to maximise their profits and to minimise their risks and they are unlikely to adopt an innovation if they think that on average over a period of years it will add more to costs than to the expected benefit. " (Upton, 1979).

Incremental net benefit is the additional profit the farmer would receive by changing from rainfed agriculture to irrigated agriculture. The objective of the farmer in changing from rainfed agriculture to irrigated agriculture would then be to maximise the incremental net benefit. According to Gittinger (1982) the incremental net benefit is the farmer's incentive to change from rainfed to irrigated agriculture.

The incremental net benefits for the Kikuyu-Limuru irrigation farms were large and positive, Table 6.25, indicating a large incentive to the farmers to invest in irrigation development. The effect of this large incentive was demonstrated by the fact that 60% of the irrigation farmers this author interviewed in Thika Division had left their homes and families in Kikuyu Division to buy or hire land that they could develop by irrigation in Thika Division.

7.5 Agricultural Services Available to Irrigated Farmers

7.5.1 Agricultural Credit:

The results in section 6.5, indicated that 35% of the irrigation farmers used borrowed funds to finance their irrigation development. Three sources for the borrowed funds were identified as Agricultural Finance Co-operation; Commercial Banks and Saving Co-operative Societies, in order of their importance.

The financial rates of return for all the resources engaged in irrigation development for farm models A, B, C, D and F were found to be greater than the 12% interest rate charged for the borrowed funds (Table 6.26). The financial rates of return for the farmers' own resources were found to be even higher for the same farm models. The implication was that the farmers who borrowed funds to finance their irrigation developments gained more financially than those who wholly financed the irrigation development from their own resources. This was so because the farmer paid a fixed interest for the borrowed money and any return to capital in excess of that fixed interest was available for remuneration to his own capital.

7.5.2 Farm Produce Marketing and Farm Input Supply

The irrigation farmers in the studied areas privately and individually organised for the procurement of their farm inputs and marketing of their farm produce.

In Kikuyu-Limuru areas, the farmers obtained farm input such as seeds, fertilizers and pesticides from the local shops and from Nairobi. Farm yard manure was bought on contract. Farm produce was sold standing in the farm.

In Thika Division, the farmers had to travel to Thika town or to Nairobi to buy the farm inputs and to sell their farm produce. Transport problems in the area made timely procurement of farm inputs and disposal of farm produce difficult and expensive.

7.5.3 Technical Services

The study revealed that 85% of the irrigation farmers had relied on the technical advice of other farmers and local artisans to select the pumpset, instal and operate the irrigation system. Enquiries made by the author on four firms dealing with irrigation equipment, revealed that the farmer paid the cost of technical advice which was incorporated in the cost of the pumpset, irrespective of whether the farmer sought the advice or not. The farmer would, however, be required to meet the transport charges of the technician, to and from the farm. All the same, proper irrigation system design was vital since poor design or operation could double operation and maintenance costs for water application (Woodward, 1959).

8. CONCLUSION

Irrigation farm models that used diesel engine prime movers incurred more investment costs than those that used electric motors (Table 6.18), other factors being equal.

The water supply component of the pumped sprinkler irrigation system accounted for more than 50% of the total initial capital investment cost of the irrigation system. On the average the water supply component cost constituted 65%, irrigation equipment component 19% and the water conveyance component 16% of the total initial capital investment of the irrigation system (Table 6.18).

By changing from rainfed agriculture to irrigated agriculture the farmer's annual operating expenditure on the farm increased about four times on average.

Diesel operated irrigation systems spent more on energy costs than electricity operated irrigation systems. Diesel operated irrigation systems spent 11-25% of their total annual operating costs on energy and lubrication costs, compared to 6% for the electric motor operated systems.

With irrigation, annual farm labour requirement increased approximately two times compared to the without irrigation annual labour requirement.

With irrigation the annual farm input expenditure increased four times compared to the without irrigation situation.

Farmers with diesel operated irrigation systems used a higher proportion of their total annual operating expenditure on the repairs and maintenance compared to electricity operated systems, being 9% and 4% respectively.

By using diesel engines instead of electric motors as prime-movers, farmers incurred higher project costs; the present worth of costs for 0.6 ha and 1.2 ha plots increased by 34% and 14% respectively. Irrigation farms that used electric power were more financially attractive than those that used diesel engines, *ceteris paribus.*

For the farms of the same size, the Kikuyu-Limuru irrigation farmers received three times the benefits received by the Thika irrigation farmers, whereas without irrigation the difference in benefits was at most 7%.

The incremental benefits accruing to the farmers for developing irrigation facilities were positive for all the farm models, this was attributed to crop substitution, intensification of land use and farmer's independence from the dictates of the weather, made possible by the provision of irrigation facilities.

With exception of farm model E, all the irrigation farm models considered in the study had a positive incremental net benefit. The three measures of project worth, used to measure the financial viability of the projects: the net present worth, the financial rate of return, the net benefit-investment ratio, all indicated that with exception of farm model E, irrigation projects represented by farm models A, B, C, D and F were financially viable projects.

Geographical locations of the farms in relation to the markets and the development of transport facilities were the major environmental features that influenced the level of net benefits received by the farmer.

Thirty-five percent of the irrigation farmers used borrowed funds to finance their irrigation development.

Eighty-five percent of the irrigation farmers had relied on technical advice of other farmers and local artisans to select, instal and operate their irrigation systems. It is therefore recommended that a technical evaluation of the irrigation systems be conducted to ascertain whether higher technical efficiencies could be attained through better design and operation of the irrigation systems.

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APPENDIX A: QUESTIONNAIRE FOR DATA COLLECTION :

ECONOMICS OF THE INDIVIDUALLY ORGANISED PRIVATE SMALLHOLDER IRRIGATION PROJECTS.

Date:

1. Name of the farmer:
2. Sublocation:
3. Division:
4. Agro-ecological zone:
5. Land tenure:
6. Total farm size (acres):
7. The area actually irrigated (acres):
8. Source of the water:

   Perennial or seasonal:
9. **Water pumping system and its components:**

   a) Prime mover:

   Type Make.

   Capacity (specify units) kW /Hp

   Year bought: year installed

   cost (Kshs.) new/ old

   supplier (name)

b) Water pump:

Type: make:

Capacity: Discharge: Head: (units)

Cost (Kshs): Year bought:

Supplier(name):

c) Water distribution system:

Type of pipes:

i) Main line size length cost/unit total cost

-

-

-

-

total cost for (i):

ii) Laterals size length cost/unit total cost

total cost for (ii):

iii) Risers

Number of: cost/unit: Total cost:

iv) Sprinklers

Number of: Cost/unit Total cost:

Type: Nozzle size:

v) Accessories

Number unit cost Total cost

- couplers
- bends

- foot valve
- Tees
- Gate valves
- Non return valve
- prime mover frame

vi) Total for (i + ii +....+v)

10. Water application:

a) Pump operation (hrs./day):

b) Irrigation interval for crops (days):

A

B

C

D

E

c) Number of irrigations/life of crop:

A B C D E

d) Labour used /application: Mandays

e) Number of sets per day:

11. Fuel:

a) Type:

c) Price / litre:

d) Amount used for irrigation /season: lts

12. Electricity:

a) Power consumed /season: kWh.

b) Cost /unit: c) Installation cost

13. Crop	md	cost/md	cost/area
i) land prep.			
harrowing			
ii) Planting			
furrows			
fertiliser			
manure			
transplan/sowing			
iii) Weeding			
-			
-			
-			
-			
iv) Spraying			
(a)			
(b)			
v) Staking			
vi). Tying			
vii) Harvesting			
viii) Packaging			
ix) Watering			
x) Transport			

INPUTS:	RATE	UNIT COST	COST/HA.
a) Seeds			
b) Fertilizer			
-			
-			
-			
-			
-			
c) Manure			
d) Chemicals			
-			
-			
-			
-			
-			
e) Yield			
f) Sales			
g) Labour			

APPENDIX B: DETAILED DATA USED FINANCIAL ANALYSIS

Table B1: Land use; 0.6 ha, Farm models A and B. LH2 AEZ.

Type of use and crop	Without project	With project Year 1	Year 2-15
Cultivated area (ha)			
Maize	0.60	0.60	0.00
Potatoes	0.40	0.40	0.00
Beans	0.20	0.20	0.00
Lettuce	0.00	0.00	0.31
Cabbage	0.00	0.00	0.31
Spinach	0.00	0.00	0.20
Kale	0.00	0.00	0.20
Cauliflower	0.00	0.00	0.31
Tomatoes	0.00	0.00	0.20
Total cultivated area	1.20	1.20	1.53
Total cropland	0.60	0.60	0.60
Cropping intensity	2.00	2.00	2.55

Table B2: Land use; 1.2 ha, Farm models C and D, LH2 AEZ.

Type of use and crop	Without project	With project Year 1	Year 2-15
Cultivated area			
Maize	1.46	1.46	0
Potatoes	0.74	0.74	0
Beans	0.2	0.2	0
Lettuce	0	0	0.6
Cabbage	0	0	0.6
Spinach	0	0	0.4
Kale	0	0	0.4
Cauliflower	0	0	0.6
Tomatoes	0	0	0.4
Total cultivated area	2.4	2.4	3
Total cropland	1.2	1.2	1.2
Cropping intensity	2	2	2.5

Table B3: Land use; 0.6 ha, Farm model E UM5 AEZ.

Type of use and crop	Without project	With project Year 1	With project Year 2 - 15
Cultivated area (ha)			
Maize and Beans	1.2	1.2	0
Cauliflower	0	0	0.46
Tomatoes	0	0	0.31
Pod Beans	0	0	0.46
Kales	0	0	0.31
Total cultivated area	1.2	1.2	1.54
Total cropland	0.6	0.6	0.6
Cropping intensity	2	2	2.57

Table B4: Land use ;1.2 ha, Farm model F, UM5 AEZ.

Type of use and crop	Without project	With project Year 1	With project Year 2 - 15
Cultivated area			
Maize and Beans	2.4	2.4	0
Cauliflower	0	0	0.79
Tomatoes	0	0	0.66
Pod Beans	0	0	0.79
Kales	0	0	0.66
Total cultivated area	2.4	2.4	2.9
Total cropland	1.2	1.2	1.2
Cropping intensity	2	2	2.42

Table B5: Gross value of production Farm Models A and B (0.6 ha, AEZ LH2) (KSh.)

	Without project	With project				
Crop	Year 1 - 15	Year 1	Year 2	Year 3	Year 4	Year 5-15
Maize	6,500	6,500	-	-	-	-
Potatoes	12,000	12,000	-	-	-	-
Beans	4,400	4,400	-	-	-	-
Lettuce	-	-	22,000	33,000	44,000	44,000
Cabbage	-	-	10,400	15,700	20,900	20,900
Cauliflower	-	-	18,700	28,000	37400	37400
Tomatoes	-	-	62,200	93,400	124,500	124,500
Spinach	-	-	17,800	26,700	35,600	35,600
Kale	-	-	11,800	17,700	23,600	23,600
Total	22,900	22,900	142,900	214,500	286,000	286,000

Table B6: Gross value of production Farm Model E (0.6 ha, AEZ UM5) (KSh.)

	Without project	With project				
Crop	Year 1 - 15	Year 1	Year 2	Year 3	Year 4	Year 5-15
Maize and Beans	21,400	21,400	-	-	-	-
Cauliflower	-	-	15,000	22,500	30,000	30,000
Tomatoes	-	-	16,400	24,700	32,900	32,900
Kale	-	-	5,600	8,400	11,200	11,200
Pod beans	-	-	9,000	13,500	18,000	18,000
Total	21,400	21,400	46,000	69,100	92,100	92,100

Table B7: Gross value of production farm models C and D (1.2 ha,AEZ LH2) (KSh.)

	Without project	With project				
Crop	Year 1 - 15	Year 1	Year 2	Year 3	Year 4	Year 5-15
Maize	15,900	15,900	-	-	-	-
Potatoes	22,300	22,300	-	-	-	-
Beans	4,400	4,400	-	-	-	-
Lettuce	-	-	42,600	63,900	85,200	85,200
Cabbage	-	-	20,200	30,300	40,400	40,400
Cauliflower	-	-	36200	54400	72500	72500
Tomatoes	-	-	124,500	186,800	249,000	249,000
Spinach	-	-	35,600	53,400	71,200	71,200
Kale	-	-	23,600	35,400	47,200	47,200
Total	42,600	42,600	282,700	424,200	565,500	565,500

Table B8: Gross value of production Farm Model F(1.2 ha,AEZ UM5) (KSh.)

	Without project	With project				
Crop	Year 1 - 15	Year 1	Year 2	Year 3	Year 4	Year 5-15
Maize and Beans	42,700	42,700	-	-	-	-
Cauliflower	-	-	25,800	38,700	51,600	51,600
Tomatoes	-	-	35,000	52,500	70,000	70,000
Kale	-	-	12,000	17,900	23,900	23,900
Pod beans	-	-	15,500	23,200	31,000	31,000
Total	42,700	42,700	88,300	132,300	176,500	176,500

Table B9: Annual Operating expenditure for Farm model A (0.6 ha, motor, AEZ LH2) (KSh.)

Operating expenditure	Without project Year 1 -15	With project Year 1	With project Year 2 -15
Crops			
Maize	4100	4100	-
Potatoes	7600	7600	-
Beans	1600	1600	-
Lettuce	-	-	5900
Cabbage	-	-	4700
Spinach	-	-	6200
Kales	-	-	4400
Cauliflower	-	-	6400
Tomatoes	-	-	14900
Total crops expenditure	13300	13300	42500
Operation & Maintenance			
Pumpset & accessories	-	-	1600
Mainline & accessories	-	-	200
Laterals & accessories	-	-	500
Pumphouse & resevoir	-	-	200
Power	-	-	2900
Total operation & Maint.	-	-	5400
	-	-	
Total Annual Operating Expend.	13300	13300	47900

le B10: Annual operating expenditure for Farm model B (0.6 ha, Engine, AEZ LH2) (KSh.)

rating expenditure	Without project Year 1 -15	With project Year 1	Year 2-15
ps			
aize	4100	4100	-
otatoes	7600	7600	-
eans	1600	1600	-
ettuce	-	-	5900
abbage	-	-	4700
pinach	-	-	6200
ales	-	-	4400
auliflower	-	-	6400
omatoes	-	-	14900
tal crops expenditure	13300	13300	42500
eration & Maintenance			
Pumpset & accessories	-	-	7000
ainline & accessories	-	-	200
Laterals & accessories	-	-	500
Pumphouse & resevoir	-	-	200
Power	-	-	16800
tal operation & Maint.	-	-	24700
tal Annual Operating Expend.	13300	13300	67200

Table B11: Annual operating expenditure for Farm Model C (1.2 ha, motor, AE2 LH2) (KSh.)

Operating expenditure	Without project Year 1 -15	With project Year 1	With project Year 2-15
Crops			
Maize	9900	9900	-
Potatoes	14000	14000	-
Beans	1600	1600	-
Lettuce	-	-	11400
Cabbage	-	-	9000
Spinach	-	-	12200
Kales	-	-	8700
Cauliflower	-	-	12300
Tomatoes	-	-	29700
Total crops expenditure	25500	25500	83300
Operation & Maintenance			
Pumpset & accessories	-	-	1600
Mainline & accessories	-	-	300
Laterals & accessories	-	-	1300
Pumphouse & resevoir	-	-	200
Power	-	-	5700
Total operation & Maint.	-	-	9100
Total Annual Operating Expend.	25500	25500	92400

Table B12: Annual Operating expenditure for Farm model D (1.2 ha, Engine, AEZ LH2) (KSh.)

Operating expenditure	Without project Year 1 -15	With project Year 1	With project Year 2 -15
Crops			
Maize	9900	9900	-
Potatoes	14000	14000	-
Beans	1600	1600	-
Lettuce	-	-	11400
Cabbage	-	-	9000
Spinach	-	-	12200
Kales	-	-	8700
Cauliflower	-	-	12300
Tomatoes	-	-	29700
Total crops expenditure	25500	25500	83300
Operation & Maintenance			
Pumpset & accessories	-	-	7000
Mainline & accessories	-	-	300
Laterals & accessories	-	-	1300
Pumphouse & resevoir	-	-	200
Power	-	-	1300
Total operation & Maint.	-	-	21800
Total Annual Operating Expend.	25500	25500	105100

e B13: Annual operating expenditure for Farm model E (0.6 ha, Engine, AEZ UM5) (KSh.)

ating expenditure	Without project Year 1 -15	With project Year 1	With project Year 2-15
s			
ize and Beans	12600	12600	-
liflower	-	-	11600
atoes	-	-	14600
Beans	-	-	6000
es	-	-	8700
crops expenditure	12600	12600	40900
tion & Maintenance			
set & accessories	-	-	4500
line & accessories	-	-	200
erals & accessories	-	-	500
house & resevoir	-	-	100
er	-	-	13700
operation & Maint.	-	-	19000
Annual Operating Expend.	12600	12600	59900

e B14: Annual operating expenditure for Farm model F (1.2 ha, Engine, AEZ UM5) (KSh.)

ating expenditure	Without project Year 1 -15	With project Year 1	With project Year 2-15
s			
ize and Beans	25200	25200	-
liflower	-	-	19900
atoes	-	-	31000
Beans	-	-	10300
es	-	-	18500
crops expenditure	25200	25200	79700
tion & Maintenance			
set & accessories	-	-	4500
line & accessories	-	-	300
erals & accessories	-	-	1300
house & resevoir	-	-	100
er	-	-	10400
operation & Maint.	-	-	16600
Annual Operating Expend.	25200	-	96300

Table B15: Incremental working capital,Farm model A. (KSh.)

	Project Year			
Item	1	2	3-15	Total
Total operating expend.	13300	47900	47900	-
Incremental operating expend.	-	34600	0	34600
Incremental working capital	10400	0	0	10400

Table B16: Incremental working capital, Farm model B. (KSh.)

	Project Year			
Item	1	2	3 -15	Total
Total operating expend.	13300	67200	67200	-
Incremental operating expend.	-	53900	0	53900
Incremental working capital	16200	0	0	16200

Table B17: Incremental Working Capital Farm model C. (KSh.)

	Project Year			
Item	1	2	3 -15	Total
Total operating expend.	25500	92400	92400	-
Incremental operating expend.	-	66900	0	66900
Incremental working capital	20100	0	0	20100

Table B18: Incremental working capital, Farm model D. (KSh.)

Item	Project Year 1	2	3 -15	Total
Total operating expend.	25500	105100	105100	-
Incremental operating expend.	-	79600	0	79600
Incremental working capital	23900	0	0	23900

Table B19: Incremental working capital, Farm model E. (Ksh.)

Item	Project Year 1	2	3 -15	Total
Total operating expend.	12600	59900	59900	-
Incremental operating expend.	-	47300	0	47300
Incremental working capital	14200	0	0	14200

Table B20: Incremental working capital, Farm Model F. (Ksh.)

Item	Project Year 1	2	3 -15	Total
Total operating expend.	25200	96300	96300	-
Incremental operating expend.	-	71100	0	71100
Incremental working capital	21300	0	0	21300

Table B21: Unit cost; annual repairs & maintenance cost and Residual values of the investment components.

Investment components	unit cost Kshs.	Annual repairs & maintenance	Residual value at end of 15 Yrs.
Pumpset & accessories			
motor 25 hp.	27000	540	5559
starter motor	9840	197	2026
frame & coupling	8000	480	1647
diesel engine 16 hp.	94100	6116	10999
diesel engine 6.5 hp.	55900	3633.5	6534
centrifugal pump	10630	425	1242
Mainline & accessories			
pvc pipe 2"	141.45	0.7	66
pvc pipe 3"	331	1.65	153
pvc tee 2"	165	0.8	76
pvc tee 3"	480	2.4	222
pvc hydrant stand	11	0.05	5
Al. starter nipple 2"	241	4.8	28
gate valve 2"	180	2.7	21
non return valve 2"	850	12.75	99
non return valve 3"	1860	27.9	217
foot valve 2"	1600	24	187
foot valve 3"	`000	30	234
pvc elbow bend 2"	128	0.6	59
pvc elbow bend 3"	370	1.85	171
Laterals & accessories			
Al.pipe 2"	1413.4	28.3	165
Al. double end couplers	772.2	15.4	90
Al. elbow starter 2"	1497.6	30	176
Al. end cup 2"	579.15	11.6	68
sprinkler	350	22.8	35
GI riser 3/4",2ft tall	52.7	0.8	6
Pumphouse -permanent	9021	90.2	1054
Reservoir	6000	120	

Table B22: Physical capital investment Farm model A (0.6 ha, AEZ LH2)

Investment Item	Unit cost Kshs	Project Year 1	2 - 7	8	9 - 15
Primemover					
motor 25 hp	27000	27000	0	0	0
accessories	17840	17840	0	0	0
Centrifugal pump	10630	10630	0	0	0
Mainline & accessories					
2" pvc pipe,33 pieces	141.45	4667.85	0	0	0
2" hydrant unit,12 units	597	7164	0	0	0
2"non return valve	850	850	0	0	0
2"foot valve & elbow bend	1728	1728	0	0	0
Laterals & accessories					
2" Al pipe,7 pieces	1413.4	9893.8	0	0	0
2" couplers & risers 7 pcs	824.9	5774.3	0	0	0
sprinklers,7 pieces	350	2450	0	2450	0
elbow starter & end cup	2076.85	2076.85	0	0	0
Reservoir	6000	6000	0	6000	0
Irrig. system installation		2140	0	0	0
Electricity service line		30358	0	0	0
wiring pump house		3300	0	0	0
Pump house	9021	9021	0	0	0
Total capital investment		140893.8	0	8450	0

Table B23: Physical capital investment Farm model B (0.6 ha, AEZ LH2)

Investment Item	Unit cost Kshs	Project Year 1	2 - 7	8	9 - 15
Primemover					
diesel engine 16 hp	94100	94100	0	0	0
accessories	17840	17840	0	0	0
Centrifugal pump	10630	10630	0	0	0
Mainline & accessories					
2" pvc pipe,33 pieces	141.45	4667.85	0	0	0
2" hydrant unit,12 units	597	7164	0	0	0
2"non return valve	850	850	0	0	0
2"foot valve & elbow bend	1728	1728	0	0	0
Laterals & accessories					
2" Al pipe,7 pieces	1413.4	9893.8	0	0	0
2" couplers & risers 7 pcs	824.9	5774.3	0	0	0
sprinklers,7 pieces	350	2450	0	2450	0
elbow starter & end cup	2076.85	2076.85	0	0	0
Reservoir	6000	6000	0	6000	0
Irrig. system installation	-	2140	0	0	0
Pump house	9021	9021	0	0	0
Total capital investment	-	174335.8	0	8450	0

Table B24: Physical capital investment Farm model C (1.2 ha, AEZ LH2)

Investment Item	Unit cost Kshs	Project Year 1	2 - 7	8	9 - 15
Primemover					
motor 25 hp	27000	27000	0	0	0
accessories	17840	17840	0	0	0
Centrifugal pump	10630	10630	0	0	0
Mainline & accessories					
3" pvc pipe,47 pieces	351.5	16520.5	0	0	0
3" hydrant unit,18 units	912	16416	0	0	0
3"non return valve	1860	1860	0	0	0
3"foot valve & elbow bend	2370	2370	0	0	0
Laterals & accessories					
2" Al pipe,18 pieces	1413.4	25441.2	0	0	0
2" couplers & risers 18 pcs	824.9	14848.2	0	0	0
sprinklers,18 pieces	350	6300	0	6300	0
elbow starter & end cup	2076.15	4153.5	0	0	0
Reservoir	6000	6000	0	6000	0
Irrig. system installation	-	2420	0	0	0
Electricity service line	-	30358	0	0	0
Wiring pump house	-	3300	0	0	0
Pump house	9021	9021	0	0	0
Total capital investment	-	194478.4	0	12300	0

Table B25: Physical capital investment Farm model D (1.2 ha, AEZ LH2)

Investment Item	Unit cost Kshs	Project Year 1	2 - 7	8	9 - 15
Primemover					
diesel engine 16 hp	94100	94100	0	0	0
accessories	17840	17840	0	0	0
Centrifugal pump	10630	10630	0	0	0
Mainline & accessories					
3" pvc pipe,47 pieces	351.5	16520.5	0	0	0
hydrant unit,18 units	912	16416	0	0	0
3"non return valve	1860	1860	0	0	0
3"foot valve & elbow bend	2370	2370	0	0	0
Laterals & accessories					
2" Al pipe,18 pieces	1413.4	25441.2	0	0	0
2"couplers & risers 18 pcs	824.9	14848.2	0	0	0
sprinklers,18 pieces	350	6300	0	6300	0
elbow starter & end cup	2076.15	4153.5	0	0	0
Reservoir	6000	6000	0	6000	0
Irrig. system installation	-	2420	0	0	0
Pump house	9021	9021	0	0	0
Total capital investment	-	227920.4	0	12300	0

Table B26: Physical capital investment Farm model E (0.6 ha, AE2 UM5).

Investment Item	Unit cost Kshs	Project Year 1	2 - 7	8	9 - 15
Primemover					
diesel engine 6.5 hp	55900	55900	0	0	0
accessories	17840	17840	0	0	0
Centrifugal pump	10630	10630	0	0	0
Mainline & accessories					
2" pvc pipe,33 pieces	141.45	4667.85	0	0	0
2" hydrant unit,12 units	597	7164	0	0	0
2"non return valve	850	850	0	0	0
2"foot valve & elbow bend	1728	1728	0	0	0
Laterals & accessories					
2" Al pipe,7 pieces	1413	9893.8	0	0	0
2" couplers & risers 7 pcs	824.9	5774.3	0	0	0
sprinklers,7 pieces	350	2450	0	2450	0
elbow starter & end cup	2076.85	2076.85	0	0	0
Reservoir					
Irrig. system installation	-	2140	0	0	0
Pump house	9021	9021	0	0	0
Total capital investment	-	130135.8	0	2450	0

Table B27: Physical capital investment Farm model F (1.2 ha, AEZ UM5). (KSh.)

Investment Item	Unit cost Kshs	Project Year 1	2 - 7	8	9 - 15
Primemover					
diesel engine 6.5 hp	55900	55900	0	0	0
accessories	17840	17840	0	0	0
Centrifugal pump	10630	10630	0	0	0
Mainline & accessories					
3" pvc pipe,47 pieces	351.5	16520.5	0	0	0
hydrant unit,18 units	912	16416	0	0	0
3"non return valve	1860	1860	0	0	0
3"foot valve & elbow bend	2370	2370	0	0	0
Laterals & accessories					
2" Al pipe,18 pieces	1413.4	25441.2	0	0	0
2"couplers & risers 18 pcs	824.9	14848.2	0	0	0
sprinklers,18 pieces	350	6300	0	6300	0
elbow starter & end cup	2076.15	4153.5	0	0	0
Irrig. system installation	-	3800	0	0	0
Pump house	9021	9021	0	0	0
Total capital investment	-	185100.4	0	6300	0

Table B28: Without Project Farm budget, Farm models A & B. (KSh.)

Item	Project year 1	2 - 15
Inflow		
Gross value of production	22900	22900
Total outflow	22900	22900
Outflow		
Operating expenditure	13300	13300
Total outflow	13300	13300
Net benefit before financing	9600	9600

Table B29: Without Project Farm budget, Farm models C & D. (KSh.)

Item	Project year 1	2 - 15
Inflow		
Gross value of production	42600	42600
Total outflow	42600	42600
Outflow		
Operating expenditure	25500	25500
Total outflow	25500	25500
Net benefit before financing	17100	17100

Table B30: Without Project Farm budget, Farm model E .(KSh.)

Item	Project year 1	2 - 15
Inflow		
Gross value of production	21400	21400
Total outflow	21400	21400
Outflow		
Operating expenditure	12600	12600
Total outflow	12600	12600
Net benefit before financing	8800	8800

Table B31: Without Project Farm budget, Farm model F. (KSh.)

Item	Project year 1	2 - 15
Inflow		
Gross value of production	42700	42700
Total outflow	42700	42700
Outflow		
Operating expenditure	25200	25200
Total outflow	25200	25200
Net benefit before financing	17500	17500

Table B32: Capital investment for the Farm models. (KSh.)

Farm model	Project year 1	2 - 7	8	9 - 15	Initial capital investment per ha.
A	140900	0	8400	0	234800
B	174300	0	8400	0	290500
C	194500	0	12300	0	162100
D	227900	0	12300	0	189900
E	130100	0	2400	0	216800
F	185100	0	6300	0	154200

Table B33: Residual values for the farm models. (KSh.)

Farm models	Total residual value	Incremental working capital	Incremental residual value
A	20500	10400	30900
B	23900	16200	40100
C	30100	20100	50200
D	33500	23900	57400
E	19400	14200	33600
F	29000	21300	50300

Table B34 Capacity - frequency distribution for Motors

Capacity	2 hp	15 hp	20 hp	25 hp	30 hp	Total
Frequency	1	4	5	7	1	18

Table B35 Capacity - frequency distribution for diesel engines

Capacity(hp)	4.25	6.5	7.5	8.5	10	13	16	17	other	Total
Frequency	1	3	1	1	1	3	4	1	1	16

Table B36: Net Irrigated areas, capacities of prime movers and pumps

Farm (Code)	Whole Farm Size (ha)	Net Irr. Area (ha)	Prime Mover (type)	(capacity, Hp)	Pump (type)	(make)
K1	2.4	1.2	M	20	C	Kirloskar
K2	4.0	1.6	M	25	C	"
K3	2.2	0.8	M	20	C	"
K4	8.4	2.4	D	16	C	Vogel
K5	1.7	1.4	M	15	C	S. Cross
K6	1.8	1.4	M	20	C	Kirloskar
K7	6.4	1.5	D	16	C	S. Cross
K8	1.4	1.2	D	8.5	C	S. Cross
K9	1.6	1.0	M	20	C	S. Cross
K10	0.6	0.6	D	10	C	Ajax
K11	0.6	0.4	D	13	C	Kirloskar
K12	2.0	1.6	D	13	C	S. Cross
K13	1.4	1.2	M	20	3 Stage C	KSB
K14	1.4	0.6	D	17	C	S. Cross
K15	1.5	0.4	D	4.25	C	S. Cross
K16	2.4	0.4	D	16.2	C	S. Cross
K17	0.5	0.3	D	6.5	C	S. Cross
K18	1.0	0.6	M	2	4 Stage C	..
K19	3.2	0.6	M	25	C	S. Cross
K20	3.2	2.4	M	25	C	Kirloskar
L1	0.8	0.8	M	15	C	S. Cross
L2	1.2	0.8	M	25	C	S. Cross
L3	1.5	1.5	M	15	C	S. Cross
L4	2.8	1.0	M	25	C	S. Cross
L5	2.0	1.2	M	25	C	S. Cross
L6	2.4	2.0	M	30	C	S. Cross
L7	2.2	1.2	D	16	C	S. Cross
L8	2.4	0.6	M	15	C	S. Cross
L9	2.4	1.2	M	25	C	S. Cross
T1	1.2	1.2	D	13	5 Stage C	..
T2	4.0	0.8	D	..	C	..
T3	2.6	1.6	D	6.5	C	..
T4	1.3	0.8	D	6.5	C	S. Cross
T5	2.1	0.8	D	7.5	C	..
Mean	2.2	1.1	-	-	-	-
Range	0.5 - 6.4	0.3 - 2.4	-	2 - 30	-	-

M = Motor, D= Diesel engine, C = Centrifugal, S. Cross = Southern cross

Table B37 Electricity service line installation cost

Farm	Historic cost (Ksh)	Year	At 1988 cost (Ksh)
K1	35,365	1986	43,653
K2	21,000	1985	27,684
K3	12,000	1987	13,239
K5	33,288	1985	43,883
K6	50,000	1987	55,161
K9	40,000	1984	58,466
K13	25,000	1984	36,541
K18	2,700	1985	3,559
K19	8,000	1984	11,693
K20	8,000	1984	11,693
L1	9,800	1982	16,987
L2	2,000	1984	2,923
L3	2,000	1983	3,295
L4	7,000	1984	10,231
L5	5,000	1982	8,667
L6	18,800	1980	41,191
L8	2,100	1981	4,210
L9	70,000	1980	153,370

Mean at 1988 Cost $\bar{X}$ = 30,358 Ksh.

Table B38: Mains Power Consumption (Ksh./Month)

Farms with net irrigated area:-

≤ 1.0 Ha.		≥ 1.0 Ha.	
Farm	Ksh./Month	Farm	Ksh./Month
K3	350	K1	850
K9	600	K2	750
K18	250	K5	360
K19	240	K6	800
L1	500	K13	600
L2	1000	K20	300
L4	800	L3	1000
L8	600	L5	3000
		L6	2200
Mean Ksh.	543	Mean Ksh.	1126

Table B39 Fuel Consumption (Diesel)

Farm	L/Hr	Engine (hp)	L/hp - Hr
K4	2.1	16	0.13
K7	1.5	16	0.09
K8	2.2	8.5	0.26
K10	1.3	10	0.13
K11	5	13	0.38
K12	4.0	13	0.31
K14	3	17	0.18
K15	1.7	4.25	0.40
K16	5	16.2	0.31
K17	2	6.5	0.31
L7	5.8	16	0.36
T1	2.4	13	0.18
T3	2	6.5	0.31
T4	2	6.5	0.31
T5	1.7	7.5	0.2
	Mean	0.26	L/hp - hr

APPENDIX C: CROP PRODUCTION DATA ON INDIVIDUAL SAMPLE FARMS

Table C1 Beans

A) LABOUR OPERATIONS	MD	FARMS RK1	RK4	RK5	RK6	RK7	RK8	RL1	ROWTIL (RK1...RL1)	$\bar{X}$
1. Land Prep + Harrowing		31	32	39	40	28	35	30	235	34
2. Furrow/Holes		12	0	52	10	28	26	10	138	20
3. Fertilizer		0	7	4	2	0	2	0	15	2
4. Manure		29	9	0	0	10	0	10	58	8
5. Transplan/sowing		23	24	39	10	28	9	10	143	20
6. Thinning		0	0	0	0	0	0	0	0	0
7. Weeding		101	32	310	80	71	35	60	689	98
8. Spraying		0	0	0	0	0	0	0	0	0
9. Staking		0	0	0	0	0	0	0	0	0
10. Tying + Desuckering		0	0	0	0	0	0	0	0	0
11. Irrigation		0	0	0	0	0	0	0	0	0
12. Harvesting + Packing		58	41	52	20	35	24	20	250	36
13. Transportation		0	0	0	0	0	0	0	0	0
b) MATERIALS										
1. Seed	Ton	115	102	232	140	35	110	100	834	119
2. Fertilizer		0	48	194	125	0	49	0	416	59
DAP	kg									
20:20:0	kg	0	0	0	0	0	0	0	0	0
Urea	kg	0	0	0	0	0	0	0	0	0
CAN/ASN	kg	0	0	0	0	0	0	0	0	0
3. Manure	Kg	5	4	0	0	3	0	2	14	2
4. Chemical										
Dithane M-45	Kg	0	0	0	0	0	0	0	0	0
Ambush	L	0	0	0	0	0	0	0	0	0
Other										
5. Strings	Ksh	0	0	0	0	0	0	0	0	0
6. Stakes	Ksh	0	0	0	0	0	0	0	0	0
c) YIELD	Ton	2.6	2.1	2.9	1.3	1	2.2	1.8	13.9	2
d) GROSS OUTPUT	1000/=	28.5	25.2	34.8	15.1	12	26.3	12	153.9	22.0

Table C2 Potatoes

		FARMS										
a) LABOUR OPERATIONS	MD	RK1	RK2	RK3	RK5	RK6	RK7	RL8	RL2	RL3	ROWTTL (RK1...RL3)	%
1. Land Prep + Harrowing		43	36	83	39	40	28	35	44	55	403	45
2. Furrow/Holes		12	13	49	52	20	18	17	24	41	246	27
3. Fertilizer		--	1	0	4	0	0	0	0	3	8	1
4. Manure		0	18	10	29	20	10	17	20	38	162	18
5. Transplan/sowing		17	32	74	52	30	28	30	29	41	333	37
6. Thinning		0	0	0	0	0	0	0	0	0	0	0
7. Weeding		101	135	221	155	60	47	52	87	83	941	104
8. Spraying		9	7	15	17	5	20	16	3	16	108	12
9. Staking		0	0	0	0	0	0	0	0	0	0	0
10. Tying + Desuckering		0	0	0	0	0	0	0	0	0	0	0
11. Irrigation		0	0	0	0	0	0	0	0	0	0	0
12. Harvesting + Packing		60	90	29	155	60	106	31	87	69	687	76
13. Transportation		0	0	0	0	0	0	0	0	0	0	0
b) MATERIALS												
1. Seed	Ton	2.3	1.62	1.24	2.32	2.25	2.12	2.2	2.61	2.2	18.94	2.1
2. Fertilizer												
DAP	Kg	1064	135	0	129	0	0	0	0	69	1397	155
20:20:0	Kg	0	0	0	0	0	0	0	0	0	0	0
Urea	Kg	0	0	0	0	0	0	0	0	0	0	0
CAN/ASN		0	0	0	0	0	0	0	0	0	0	0
3. Manure	Ton	4	5	8	10	18	3	5	3	3	59	7
4. Chemical												
Dithane M-45	Kg	4.5	3	3.7	9	2.7	4.8	2.2	3.8	10	43.7	4.8
Ambush	L	0	0	0	0	0	0	0	0	0	0	0
Other												
5. Strings	Ksh	0	0	0	0	0	0	0	0	0	0	0
6. Stakes	Ksh	0	0	0	0	0	0	0	0	0	0	0
c) YIELD	Ton	15.4	12	7.4	12	27	11	11	7.7	12	115.5	12.8
d) GROSS OUTPUT	1000/=	21.9	27	24.8	25.8	90	23.6	19.5	17.4	20.7	270.7	30.1

Table C3 Lettuce

a) LABOUR OPERATIONS	MD	K1	K2	K3	K4	K5	K6	K7	K9	K10	K11	K12	K13	K14	K15	K16	K17	K18	K19	K20	L4	L6	L8	L9	ROWTTL (K1...L9)	%
		FARMS																								
1. Land Prep + Harrowing		51	102	119	41	97	89	81	40	50	44	55	82	125	60	80	41	54	58	58	50	116	112	80	1685	73
2. Furrow/Holes		29	20	0	0	0	0	0	0	0	0	0	21	25	0	40	0	18	0	39	0	10	0	0	202	25
3. Fertilizer		0	1	0	0	0	0	0	0	2	0	3	0	10	0	2	0	7	0	2	3	10	16	0	56	2
4. Manure		57	68	119	30	39	67	27	0	20	18	48	62	28	0	11	5	28	0	21	11	20	16	19	714	31
5. Transplan/sowing		30	14	53	4	10	2	14	3	6	11	2	--	3	30	11	1	4	45	3	2	10	3	16	277	12
6. Thinning		--	--	52	38	58	67	68	17	--	25	--	52	150	--	--	36	--	--	--	22	--	--	--	585	53
7. Weeding		215	408	277	154	310	355	202	100	320	89	116	103	300	333	40	286	150	227	116	122	210	149	400	4982	217
8. Spraying		0	0	0	11	8	0	7	3	3	1	5	0	0	0	2	5	2	5	0	0	3	2	0	57	2
9. Staking		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10. Tying + Desuckering		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Irrigation		14	22	22	21	32	45	22	36	48	18	18	6	36	27	8	78	18	24	12	30	12	36	18	603	26
12. Harvesting + Packing		129	0	0	0	0	0	0	0	0	0	0	0	0	0	21	0	0	0	36	0	0	0	0	186	0
13. Transportation		6500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6500	0
b) MATERIALS																										
1. Seed	Kg	0.	--	1.6	2.0	1.9	1.0	1.0	0.5	0.5	0.5	1.1	0.5	1.2	0.03	0.12	0.7	0.5	0.7	1.0	1.1	1.0	1.1	1.6	20.55	0.9
2. Fertilizer																										
DAP	Kg	0	408	0	0	0	0	0	0	0	0	0	0	0	0	0	0	250	0	194	0	0	0	0	852	37
20:20:0	Kg	0	0	0	0	0	0	0	0	0	0	280	0	338	0	0	0	0	0	0	222	200	186	0	1226	53
Urea	Kg	0	0	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	9
CAN/ASN		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Manure	Ton	30	16	35	19	45	31	9	0	7	9	7	21	10	0	8	11	50	25	7	7	9	18	10	384	17
4. Chemical																										
Dithane M-45	Kg	0	0	0	5.1	0	0	--	3.0	0.9	1.0	3.0	0	1.1	0	0	6.4	0	2.8	0	0	2.4	0.6	0	26.3	1.2
Ambush	L	0	0	0	0	5.8	3.5	--	0	0.9	0	2.0	0	0.8	0	0.4	0	1.5	10.0	0	0	2.4	0.6	0	27.9	1.3
c) YIELD	Ton	26	--	--	--	--	--	20	--	--	--	--	--	--	--	30	--	--	45	39	--	--	--	--	160	--
d) GROSS OUTPUT	1000/=	130	272	86	172.8	252.2	222	81	53	100	306	70	82.4	337.5	294	48	39.3	200	136.2	93.1	55.5	100	74.6	80	3265.6	142.0

Table C4: Sukuma

a)	LABOUR OPERATIONS	MD	K2	K3	K6	K7	K8	K9	K10	K12
1.	Land Prep + Harrowing		102	79	89	81	75	40	50	45
2.	Furrow/Holes		20	26	--	27	19	0	10	34
3.	Fertilizer		7	0	--	3	3	1	2	4
4.	Manure		68	79	67	27	19	29	20	60
5.	Transplan/sowing		41	53	--	--	32	34	32	40
6.	Thinning		0	0	0	0	0	0	0	0
7.	Weeding		218	79	400	270	450	132	180	160
8.	Spraying		2	1	10	2	10	9	3	2
9.	Staking		0	0	0	0	0	0	0	0
10.	Tying + Desuckering		0	0	0	0	0	0	0	0
11.	Irrigation		45	45	90	45	72	72	96	24
12.	Harvesting + Packing		20.5	0	0	0	0	0	0	0
13.	Transportation	1000/=	0	0	0	0	0	0	0	0
b)	MATERIALS									
1.	Seed	Kg	1.4	1.3	2	1	1.5	1	1	1.1
2.	Fertilizer									
	DAP	Kg	0	0	1110	0	0	0	0	0
	20:20:0	Kg	0	0	0	0	0	0	200	280
	Urea	Kg	680	0	0	0	0	100	0	0
	CAN/ASN	Kg	340	0	0	525	300	100	0	0
3.	Manure	Ton	41	35	31	9	13	23	7	11
4.	Chemical									
	Dithane M-45	Kg	0	0	0	0	--	0	0	0
	Ambush	L	0.5	0.5	4	--	--	5	1.2	1
c)	YIELD	Ton	82	--	--	--	90	--	--	--
d)	GROSS OUTPUT	1000/=	147.6	53.7	44.4	54	80	87	128	404.6

FARMS											
K16	K18	K19	K20	L1	L7	ROWTTL (K2..L7)	%	T1	T2	ROWTTL (T1..T2)	%
80	54	58	58	87	136	1034	74	61	81	142	71
23	4	13	39	26	39	280	22	16	30	46	23
2	18	6	2	3	4	55	4	6	4	10	5
11	28	45	41	69	0	563	40	0	20	20	10
11	14	39	39	35	116	486	40	93	68	161	81
0	0	0	0	0	0	0	0	0	0	0	0
60	367	454	97	208	155	3230	231	246	484	730	365
6	6	2	1	0	4	58	4	6	81	87	44
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
16	72	48	24	18	16	683	49	81	36	117	58
91	193	0	50	0	0	354.5	0	0	0	0	0
7.2	6.8	0	11.3	0	0	25.3	0	0	0	0	0
0.2	1	0.8	0.5	0.7	0.4	13.9	1.0	0.8	0.6	1.4	0.7
0	0	0	194	0	388	1692	121	388	0	388	194
0	0	136	0	0	0	616	44	0	0	0	0
0	1400	0	0	87	0	2267	162	0	0	0	0
120	500	182	0	0	0	2067	148	0	1020	1020	510
8	50	25	13	8	0	274	20	0	20	20	10
0	0	0	0	0	0	0	0	0	38	38	19
1	4.5	5	0.9	0	0.8	24.4	2.0	1.7	15.3	17	9
72	68	102	87	41	--	542	--	--	--	0	--
57.6	155.2	163.4	139.7	55	77.6	1647.8	118	29	43.5	72.5	36.2

Table C5 Cauliflowers

											FARMS														
a) LABOUR OPERATIONS	MD	K1	K2	K4	K5	K7	K9	K11	K12	K14	K15	K17	K20	L2	L3	L4	L6	L8	ROWTTL (K1..L8)	$\bar{X}$	T1	T3	T4	ROWTTL (T1..T4)	$\bar{X}$
1. Land Prep + Harrowing		51	102	41	97	81	40	44	45	100	60	41	58	66	109	50	116	112	1213	71	61	66	101	228	76
2. Furrow/Holes		17	20	16	20	27	0	11	11	0	30	10	11	26	42	17	20	16	294	17	16	16	34	66	22
3. Fertilizer		1	1	3	--	1	5	1	4	10	25	3	4	8	2	5	30	22	125	8	0	7	34	41	14
4. Manure		108	68	19	39	27	17	22	33	23	16	20	49	69	118	33	16	21	698	41	70	0	0	70	0
5. Transplan/sowing		34	41	19	--	27	14	11	40	19	17	10	39	21	36	33	30	37	428	27	66	40	50	156	52
6. Thinning		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7. Weeding		121	109	77	--	108	65	36	40	94	121	41	39	91	126	83	170	112	1433	90	197	33	67	297	99
8. Spraying		3	16	11	12	2	5	4	4	25	3	5	2	3	3	3	9	5	115	8	10	2	3	15	5
9. Staking		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10. Tying + Desuckering		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Irrigation		14	22	21	32	15	36	18	12	36	29	234	12	12	33	30	12	36	604	36	41	33	50	124	41
12. Harvesting + Packing		65	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	115	0	0	62	78	140	70
13. Transportation	1000/=	4250	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4250	0	0	14.8	10.5	25.3	12.6
b) MATERIALS																									
1. Seed	Kg	0.9	1.4	1.6	--	0.3	1	0.6	0.6	2.5	0.3	1.8	0.4	--	1	0.6	1	1.1	15.1	1.0	0.8	1	0.8	2.6	0.87
2. Fertilizer																									
DAP	Kg	0	340	0	--	0	0	253	0	205	272	0	194	433	525	333	300	373	3228	202	0	410	420	830	277
20:20:0	Kg	0	0	0	0	0	0	0	281	205	0	714	0	0	0	278	0	0	1478	87	0	0	0	0	0
Urea	Kg	0	680	1000	0	0	334	0	562	98	218	0	194	216	0	222	0	0	3524	207	0	0	420	420	140
CAN/ASN	Kg	645	0	0	0	262	334	0	0	0	0	0	0	0	0	0	300	0	1541	91	0	0	0	0	0
3. Manure	Ton	30	41	19	45	9	12	9	7	23	17	32	20	16	10	13	5	18	326	19	5	0	0	5	0
4. Chemical																									
Dithane M-45	Kg	17.2	1.4	5.1	19	0	0	5.7	0	12	0	0	0.6	0.8	1.3	0	0	0	63.1	3.7	0	0	0	0	0
Ambush	L	4.3	1.6	5.8	0	1	4	0.25	2	10	0.5	3.2	0.6	2.3	0.6	0.6	2.4	2.2	41.35	2.4	1.8	0.7	1.5	4	1.3
Other	Ksh	0	0	--	0	0	0	0	0	0	0	0	0	0	0	660	1800	0	2460	0					0
c) YIELD	Ton	17	19	--	19	24	43	22	--	--	27	11	29	13	--	40	15	34	313	24	--	12	21	33	16
d) GROSS OUTPUT	1000/=	119	190.4	194	194	120	173.7	108	84.9	198	136.4	23.5	145.5	78	84	55.5	60	89.5	2054.4	120.8	69.7	59	67.2	195.9	65.3

Table C6: Spinach

a) LABOUR OPERATIONS	MD	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K14	K16	K17	K18	K19	K20	L1	L3	L5	L9	T4	ROWTTL (K1..L9)	%
1. Land Prep + Harrow		51	102	79	41	97	89	81	75	40	50	44	45	100	80	41	54	60	58	87	109	36	80	101	1499	68
2. Furrow/Holes		29	20	26	11	19	--	27	19	0	10	11	34	4	6	18	4	15	14	26	13	12	32	34	350	17
3. Fertilizer		0	7	0	3	0	--	16	3	1	3	6	5	0	2	18	20	--	2	2	4	5	27	2	124	6
4. Manure		57	68	79	19	38	67	27	19	17	40	18	60	86	12	5	132	45	41	69	269	24	64	0	1256	57
5. Transplan/sowing		17	--	53	29	6	3	--	3	19	5	13	3	18	2	24	14	39	3	12	21	48	24	50	356	18
6. Thinning		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7. Weeding		362	218	79	230	698	400	432	450	149	220	163	269	600	60	163	500	454	233	291	210	432	240	403	6853	312
8. Spraying		0	0	0	0	0	13	2	0	2	3	6	8	11	4	0	2	2	0	0	0	0	0	0	53	2
9. Staking		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00	0	0	0	0
10. Tying + Desuckering		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Irrigation		27	45	45	42	63	90	45	72	72	96	36	24	72	16	68	72	48	24	18	47	73	-	99	1095	52
12. Harvesting + Packing		586	245	0	0	310	0	0	0	0	0	0	0	0	91	0	225	0	100	0	0	0	0	18	1557	0
13. Transportation	1000/=	51.7	17.9	0	0	29.7	0	0	0	0	0	0	0	0	1.8	0	6.8	0	17.1	0	0	0	0	17	125	0
b) MATERIALS																										
1. Seed	Kg	2	--	2	1.6	14.5	3	5.2	2	8	2.5	2.5	--	6.2	0.16	--	2.6	1.14	4.9	4.3	2.1	5	8	4.2	77.6	4.1
2. Fertilizer																										
DAP	Kg	0	340	0	0	0	1110	0	0	0	0	1900	0	0	0	2142	700	0	194	0	630	600	0	910	7616	346
20:20:0	Kg	0	0	0	960	0	0	0	0	0	200	0	0	0	0	0	0	136	0	103	0	0	0	0	1399	64
Urea	Kg	0	680	0	0	0	0	0	0	134	0	0	0	0	0	0	500	0	0	0	630	0	0	0	1944	88
CAN/ASN	Kg	0	0	0	0	0	0	2100	338	67	0	0	375	0	120	0	500	182	0	0	0	0	1920	0	5602	255
3. Manure	Ton	70	41	35	19	45	27	9	13	14	7	9	11	42	5	21	200	25	13	10	38	6	48	0	708	32
4. Chemical																										
Dithane M-45	Kg	0	0	0	0	0	6	0	0	0	0	6.8	6	4.5	0	0	0	1.4	0	0	0	0	0	0	24.7	1.1
Ambush	L	0	0	0	0	0	4	1	0	1	1.6	0	0	0	1	0	1.5	5	0	0	0	0	0	0	15.1	0.7
5. Strings		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6. Stakes		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
c) YIELD	Ton	207	163	--	--	124	--	--	130	--	--	--	--	--	18	38	68	--	157	43	--	--		34	948	--
d) GROSS OUTPUT	1000/=	310.5	326	120	215	124.2	710.4	158	172.8	94	128	222	202.3	135	18	38	155.2	204.3	261.9	57.8	151.2	48	64	192	3916.6	178.0

Table C7: Tomatoes

a) LABOUR OPERATIONS	MD	K4	K8	K9	K10	K15	K16	K18	L2	L4	L5	L6	L7	L8	ROWTTL (K4..L8)	X̄	T1	T2	T3	T4	ROWTTL (T1..T4)	X̄
									FARMS													
1. Land Prep + Harrow		41	75	40	50	60	80	54	66	50	36	116	136	112	916	70	61	81	66	101	309	77
2. Furrow/Holes		14	19	14	20	30	23	4	26	33	12	20	39	16	270	21	16	7	18	34	73	18
3. Fertilizer		2	5	3	3	38	3	7	0	5	2	5	6	37	116	8.9	0	--	7	3	10	3
4. Manure		38	113	17	20	30	7	28	69	33	56	25	0	21	457	35	70	10	0	34	114	9
5. Transplan/sowing		19	19	7	20	30	7	4	--	10	6	30	78	19	249	21	16	3	16	17	52	13
6. Thinning		0	19	0	20	0	0	0	--	--	--	--	--	--	39	20	--	--	--	17	17	17
7. Weeding		192	263	133	258	121	120	121	221	133	240	100	116	93	2109	162	197	322	99	202	820	205
8. Spraying		330	271	178	107	360	160	126	104	200	51	80	233	159	2357	181	62	45	197	58	362	90
9. Staking		19	75	19	40	61	80	36	156	67	144	50	97	37	881	68	0	25	20	34	79	20
10. Tying + Desuckering		230	900	200	200	545	240	164	312	300	528	400	233	225	4477	344	16	260	62	101	439	110
11. Irrigation		42	72	48	96	57	16	72	5	26	48	24	16	72	594	46	81	36	66	99	282	70
12. Harvesting + Packing		233	900	254	80	252	120	800	0	178	242	240	617	199	4115	316	67	200	328	302	897	224
13. Transportation	1000/=	10.5	18	20	3.2	18	11.6	19.2	0	10.6	14.5	--	12.3	0	138.1	12	3.2	9	32.6	12	57	14.3
b) MATERIALS																						
1. Seed	Kg	3.8	0.5	1	0.5	0.4	0.2	1	--	1.1	0.6	1	1.1	1.9	13.1	1.1	1	0.6	1	1.7	4.3	1.1
2. Fertilizer																						
DAP	Kg	0	0	0	500	272	0	500	0	780	300	500	485	373	3710	285	0	125	820	840	1785	446
20:20:0	Kg	1000	625	0	0	0	0	0	0	0	0	0	290	0	1915	147	0	0	0	0	0	0
Urea	Kg	0	0	334	0	0	0	0	0	0	0	0	0	0	334	27	0	0	0	0	0	0
CAN/ASN	Kg	0	0	0	0	690	120	500	0	56	0	0	0	224	1590	122	0	0	0	0	0	0
3. Manure	Ton	38	22	12	6	32	5	50	16	25	14	15	0	18	253	19	3.7	10	0	4	17.7	4.4
4. Chemical																						
Dithane M-45	Kg	19	57	167	60	106	29	285	31	67	48	52	58	75	1054	81	31	8	20	42	101	25
Ambush	L	8	0	0	0	8	0	9	0	0	0	42	6	2.2	75.2	5.8	3.3	3.3	0	12	18.6	4.6
5. Strings		950	--	--	--	380	--	1000	--	800	900	200	1160	185	5575	697	0	--	--	170	170	170
6. Stakes		4350	4500	5445	9000	4317	3033	3900	4533	4533	4533	4533	9615	3025	65317	5024	0	1813	1440	3633	6886	1722
c) YIELD	Ton	42	72	80	16	45	29	48	28	43	58	50	74	36	621	48	11	18	39	24	92	23
d) GROSS OUTPUT	1000/=	276.5	480	5344	108	227.3	115.2	192	93.6	213.1	384	240	347.6	71.6	8092.9	622.5	25.6	82.5	196.8	121	425.9	106

Table C8: Cabbage

			FARMS													
a) LABOUR OPERATIONS	MD	K1	K12	K13	K14	K15	K16	K17	K19	L1	L2	L3	L4	L9	ROWTTL (K1..L9)	X̄
1. Land Prep + Harrow		51	45	82	100	60	80	41	58	87	66	109	50	80	909	70
2. Furrow/Holes		17	8	20	0	30	23	15	13	26	26	42	17	32	269	21
3. Fertilizer		0	3	0	6	25	3	3	6	4	8	2	5	0	65	5
4. Manure		60	24	40	12	16	11	5	45	0	69	59	33	32	406	31
5. Transplan/sowing		34	40	40	19	17	11	10	39	53	39	36	33	60	431	33
6. Thinning		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7. Weeding		121	67	124	94	121	40	41	91	172	91	126	83	96	1267	97
8. Spraying		3	4	2	3	3	3	5	3	2	3	3	4	4	42	3
9. Staking		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10. Tying + Desuckering		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11. Irrigation		14	12	6	36	29	8	60	24	9	8	33	30	18	287	22
12. Harvesting + Packing		65	0	0	0	0	0	0	0	0	0	0	0	0	65	0
13. Transportation	1000/=	6.5	0	0	0	0	4.8	0	0	0	0	0	0	0	11.3	0
b) MATERIALS																
1. Seed	Kg	0.9	0.5	2.6	1.6	0.25	2	1.8	0.8	1.7	--	0.5	1.1	1.6	15.35	1.3
2. Fertilizer																
DAP	Kg	0	0	0	164	272	0	0	0	660	433	0	333	0	1862	143
20:20:0	Kg	0	281	0	0	0	0	357	136	0	0	0	278	0	1052	81
Urea	Kg	0	562	0	0	218	0	0	0	0	216	525	222	0	1743	134
CAN/ASN	Kg	0	0	0	131	0	120	0	182	0	0	0	0	0	433	33
3. Manure	Ton	15	7	21	11	17	8	21	25	0	16	6	13	8	168	13
4. Chemical																
Dithane M-45	Kg	0	0	0	0	0	0	0	0	0	0	1.3	0	0	1.3	0
Ambush	L	4	2	1.2	8.8	0.5	0.4	3.2	5	1.2	2.3	0.6	1.2	0	30.4	2.3
c) YIELD	Ton	26	--	--	--	--	48	14	--	--	--	--	--	--	88	--
d) GROSS OUTPUT	1000/=	52	85.7	77.2	164	45.4	33.6	35.7	68.1	26.1	78	84	66.6	60	876.4	67.4

Table C9: Maize

a) LABOUR OPERATIONS	MD	FARMS RK1	RK2	RK3	RK4	RK5	RK6	RK7	RL1	RL2	RL3	ROWTTL (RK1..RL3)	$\bar{X}$
1. Land Prep + Harrow		43	36	83	32	39	40	28	30	44	47	422	42
2. Furrow/Holes		9	27	7	8	13	10	28	10	29	25	166	17
3. Fertilizer		0	0	0	3	2	3	0	0	2	3	13	1
4. Manure		6	90	14	0	6	0	10	10	7	22	165	16
5. Transplan/sowing		1	16	7	3	4	7	10	10	7	12	79	8
6. Thinning		0	0	0	0	0	0	0	0	0	0	0	0
7. Weeding		34	135	138	63	77	60	94	60	58	71	790	79
8. Spraying		0	0	0	0	0	0	0	0	0	0	0	0
9. Staking		0	0	0	0	0	0	0	0	0	0	0	0
10. Tying + Desuckering		0	0	0	0	0	0	0	0	0	0	0	0
11. Irrigation		0	0	0	0	0	0	0	0	0	0	0	0
12. Harvesting + Packing		43	90	21	38	46	40	24	40	29	20	391	39
13. Transportation	1000/=	0	0	0	0	0	0	0	0	0	0	0	0
MATERIALS													
1. Seed	Kg	29	27	28	25	39	25	24	20	44	25	286	29
2. Fertilizer													
DAP	kg	0	117	0	40	65	125	0	0	44	55	446	45
20:20:0	Kg	0	0	0	0	0	0	0	0	0	0	0	0
Urea	Kg	0	0	0	0	0	0	0	0	0	0	0	0
CAN/ASN	Kg	0	0	0	0	0	0	0	0	0	0	0	0
3. Manure	Ton	3	2	8	0	5	0	0	5	2	2.5	27.5	3
4. Chemical													
Dithane M-45	Kg	0	0	0	0	0	0	0	0	0	0	0	0
Ambush	L	0	0	0	0	0	0	0	0	0	0	0	0
5. Strings		0	0	0	0	0	0	0	0	0	0	0	0
6. Stakes		0	0	0	0	0	0	0	0	0	0	0	0
c) YIELD	Ton	2.6	6	--	2.8	4.6	2.2	2.1	2.7	2.6	1.8	27.4	3.0
d) GROSS OUTPUT	1000/=	8.7	20.3	17.3	9.3	15.3	7.5	7.1	9	8.7	6	109.2	10.9

Table C10: Irrigated podbeans

a) LABOUR OPERATIONS	MD	FARMS T3	T4	ROWTTL (T3..T4)	$\bar{X}$
1. Land Prep + Harrow		66	101	167	84
2. Furrow/Holes		0	0	0	0
3. Fertilizer		2	2	4	2
4. Manure		0	0	0	0
5. Transplan/sowing		16	17	33	16
6. Thinning		0	0	0	0
7. Weeding		131	34	165	82
8. Spraying		0	2	2	1
9. Staking		0	0	0	0
10. Tying + Desuckering		0	0	0	0
11. Irrigation		32	32	64	32
12. Harvesting + Packing		90	78	168	84
13. Transportation	1000/	4.05	2.5	6.55	3.3
b) MATERIALS					
1. Seed	Kg	74	300	374	187
2. Fertilizer					
DAP	Kg	0	0	0	0
20:20:0	Kg	0	0	0	0
Urea	Kg	0	0	0	0
CAN/ASN	Kg	205	840	1045	522
3. Manure	Ton	0	0	0	0
4. Chemical					
Dithane M-45	Kg	0	0	0	0
Ambush	L	0	1.5	1.5	0.8
c) YIELD	Ton	5.4	5.2	10.6	5.3
d) GROSS OUTPUT	1000/=	40.5	37.8	78.3	39.2

Table C11 Beans + Maize interplanted

a) LABOUR OPERATIONS	MD	FARMS RT1	RT2	RT3	ROWTTL (RT1..RTT3)	$\bar{X}_1$	FARMS RT1	RT2	RT3	ROWTTL (RT1..RT3)	$\bar{X}_2$	$\bar{X}_1 + \bar{X}_2$
1. Land Prep + Harrow		50	62	50	162	54	0	0	0	0	0	54
2. Furrow/Holes		20	5	30	55	18	0	0	0	0	0	18
3. Fertilizer		0	0	3	3	0	0	0	0	0	0	0
4. Manure		20	10	0	30	10	0	0	0	0	0	10
5. Transplan/sowing		10	3	20	33	11	20	25	20	65	22	33
6. Thinning		0	0	0	0	0	0	0	0	0	0	0
7. Weeding		--	--	--	0	--	190	200	60	450	150	150
8. Spraying		0	3	4	7	4	0	0	0	0	0	0
9. Staking		0	0	0	0	0	0	0	0	0	0	0
10. Typing + Desuckering		0	0	0	0	0	0	0	0	0	0	0
11. Irrigation		0	0	0	0	0	0	0	0	0	0	0
12. Harvesting + Packing		20	10	50	80	27	50	48	30	128	43	70
13. Transportation	1000/=	0	0	0	0	0	0	0	0	0	0	0
b) MATERIALS												
1. Seed	Kg	40	30	20	90	30	100	200	60	360	120	150
2. Fertilizer												
DAP	Kg	0	0	30	30	10	0	0	0	0	0	10
20:20:0	Kg	0	0	0	0	0	0	0	0	0	0	0
Urea	Kg	0	0	0	0	0	0	0	0	0	0	0
CAN/ASN	Kg	0	0	0	0	0	0	0	0	0	0	0
3. Manure	Ton	3.5	0.8	0	4.3	1.4	0	0	0	0	0	0
4. Chemical												
Fungicide	Kg	0	0	0	0	0	0	0	0	0	0	0
Insecticide	L	0	2	2.4	4.4	1.5	0	0	1.3	1.3	0.4	1.9
Other	Ksh	0	5	10	15	5	0	0	0	0	0	5
c) YIELD	Ton	1.4	1.1	3.3	5.8	1.9	0.9	3	2.2	6.1	2.0	
d) GROSS OUTPUT	1000/=	3.4	3	6	12.4	4.1	5	19.2	16.8	41	13.7	17.8

APPENDIX D: MATHEMATICAL FORMULAE OF DISCOUNTED MEASURES OF PROJECT WORTH.

1. NET PRESENT WORTH (NPW)

$$NPW = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1 + i)^t} = 0$$

2. INTERNAL RATE OF RETURN (IRR)
   It is the discount rate i such that:

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

3. NET BENEFIT-INVESTMENT (N/K) RATIO

$$\frac{\sum_{t=1}^{t=n} \frac{N_t}{(1 + i)^t} = 0}{\sum_{t=1}^{t=n} \frac{K_t}{(1 + i)^t} = 0}$$

Where B_t = benefit in each year

C_t = cost in each year

N_t = Incremental net benefit in each year after stream has turned positive

K_t = Incremental net benefit in each year after stream has turned negative

t = 1, 2, ..., n

n = number of years

i = discount rate

Source: Gittinger (1983).

4. LITERATURE REVIEW

4.1 Smallholders

The Ministry of Economic Planning, Kenya, adopts three categories of farmers for planning purposes, based on the sizes of their farm holdings (F.A.O., 1983). Small farmers have upto 2 ha., medium farmers,2-8 ha., and large farmers have farm holdings above 8 ha.

The Ministry of Agriculture, and the Ministry of Co-operative Development, Kenya, on the other hand, have two classes of farmers, also based on the size of their agricultural holdings. Smallholders Have upto 8. ha and large farmers over 8 ha. (M.O.A.,1975). Small "h"

4.2 Financial Analysis of Irrigation Development

The purpose of financial analysis is to identify the actual year by year costs and benefits which can be expected after starting the irrigation development (Thompson et al., 1983). The analysis assesses the financial conditions that would be encountered in