To the Graduate Council:

I am submitting herewith a dissertation written by Hezron Omare Nyangito entitled "Economic Evaluation of Alternative Livestock Disease Control Methods in Kenya." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Agricultural Economics.

Steven D. Mundy, Major Professor

We have read this dissertation
and recommend its acceptance

Accepted for the Council:

Associate Vice Chancellor
and Dean of The Graduate School

ECONOMIC EVALUATION OF ALTERNATIVE LIVESTOCK DISEASE CONTROL METHODS IN KENYA

A Dissertation

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Doctor of Philosophy

Degree

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ABSTRACT

Economic analysis is an important prerequisite in the development of new technologies before they are transferred to farmers for adoption. In Africa, new technologies are being developed for the control of East Coast Fever (ECF). However, economic analysis for the ECF control methods have been limited to economic estimates using budgeting techniques that do not adequately account for production and price risks associated with the technology.

ECF is a cattle disease caused by the protozoan parasite *Theileria parva* and transmitted by ticks. ECF is conventionally controlled by controlling ticks using acaricides and by treating the sick animals. A new technology involving immunizing cattle against the disease has been developed, tested and found to be feasible under research conditions. However, controlling ECF disease alone using the new technology may not be adequate because the presence of ticks also causes stress on cattle and can transmit other diseases. This study focused on the evaluation and prediction of farm-level financial and economic impacts of using alternative ECF control methods.

A whole farm simulation model, the Technology Impact Evaluation Simulator (TIES), was used to evaluate five alternative ECF control methods. The model included all the production and disposal activities on the farm as well as off-farm activities. Production and price risks were estimated within the model using multivariate probability distributions for yields and prices. The study used both primary and secondary data. A total of 12 farms in Uasin Gishu District and Kaloleni Division in Kenya were analyzed.

The TIES model was used to simulate annual production, marketing, financial management, and family consumption activities of representative farms over a 10-year planning horizon. The key output variables from the simulation model were net present value, net worth, benefit cost ratio, internal rate of return, and average annual cash and net farm income. The simulated output results from the alternative ECF control methods were used to analyze the financial and economic performance of farms, the probability of survival, and the probability of

economic success of the farms. The alternative ECF control methods on farms were also evaluated using the stochastic dominance criterion to determine the most preferred alternative by farmers and to estimate the associated confidence premiums.

The results from the analysis indicated that the improved alternative ECF control methods were financially and economically superior than the currently practiced methods on all farms. The most preferred alternative ECF control method was the adoption of the new technology, immunization or the "Infection and Treatment Method" with a 75-percent reduction in acaricide use. The highest financial and economic benefits were realized with exotic cattle breeds and crosses between the exotic breeds and the indigenous Zebu cattle (Grade cattle). The most preferred ECF control method was stable over a wide range of cattle mortality rates, immunization and acaricide cost levels. However, the method was sensitive to changes in cattle productivity, particularly milk production.

The results demonstrated that whole farm simulation, based on a model such as TIES, offers a flexible method for economic analysis of new technologies on farms. Risks associated with stochastic yields and prices are easily incorporated in the model using probability distributions. With stochastic simulation, probabilities associated with net present value, internal rate of return, benefit cost ratio and other key output variables are generated that can be used to select among alternative technologies. The generated probabilities indicate the chance that the new technology or investment will attain the required selection criteria as opposed to the traditional selection criteria which rely on absolute values only. Thus, with this particular model, the economic survival and success of farms from the use of alternative technologies can be assessed. The probability distributions for the output variables also allow for the alternative technologies to be ranked using the stochastic dominance criteria and to estimate the confidence premiums or convictions associated with the most preferred technology or investment alternative. The calculated confidence premiums indicate the shadow prices that might be attached to alternative technologies or practices.

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CHAPTER I

INTRODUCTION

This Chapter includes an outline of the background to this study, the statement of the problem and the objectives of the study. The importance of livestock in Africa and the constraints that limit livestock production are reviewed. The emphasis on disease constraints is on East Coast Fever, a tick-borne disease which plays an important role in affecting cattle production in Africa. The economic problem of this study was essentially, the need for economic analysis in evaluating new technologies and the development of methodologies that can be used for the analysis. The research problem was the need to determine the financial and economic viability of a newly developed East Coast Fever cattle disease control method in Africa. The overall objective of the study was to evaluate the financial and economic impacts of alternative East Coast Fever control methods in small-scale farming in Kenya.

Background

Livestock perform a wide variety of economic and social functions in the households of Africa. Jahnke et al (1988) classify the functions into four main categories: output, input, wealth and socio-cultural functions. The output function includes the use of livestock products such as milk, meat, hides, skins, and wool for subsistence and sale of the surplus in the monetary economy. The input function includes the use of livestock for animal traction for agricultural fieldwork and transport and the use of manure as fertilizer and fuel. The wealth functions include the use of livestock as capital for investment, and their use as a means of storing and increasing wealth. Socio-cultural functions include the use of livestock for ritual exchanges among families and their use in feasts and ceremonies, as well as for social and cultural rewards to reinforce family and social ties.

Livestock also play an important role in the overall economic development of most countries in Africa by contributing to the Gross Domestic Product (GDP). The average share of in research station and field trials is the "Infection and Treatment Method" (ITM) which is described by Radley (1981). The ITM was initially developed by the former East African Veterinary Research Organization (EAVRO), now under KARI, and supported financially by the Food and Agriculture Organization (FAO) and United Nations Development Program (UNDP). The procedure has been further refined by KARI in collaboration with ILRAD (ILRAD 1990).

The ITM is an immunization control procedure whereby the animal is simultaneously infected by a live parasite of the disease (*Theileria parva*) and simultaneously treated using chemotheraptic antibiotics. This enables the animal to develop an immune response which protects the animal against the disease for its entire life. The ITM has proven to be technically efficacious under field trials in different regions of East, Central and Southern Africa (Robson et al 1977, Dolan 1985, Morzalia 1989, Berkvens et al 1989, Musisi et al 1989, Nambota 1989, and Young et al 1989). Several studies have included estimates of the cost of applying ITM. For example, Radley (1981) estimated that the cost of immunizing one animal in Kenya could be Kshs. 50. Kiltz (1985) and Irvin (1985) have also estimated the cost of the method for Burundi and Malawi, respectively. Mukhebi et al (1992c) estimated a comprehensive cost and a sensitivity analysis for Kenya and indicated that the cost of immunization, including field delivery, could be Kshs. 544. A financial assessment has shown that the approach is economically feasible (Mukhebi et al 1989). Consequently, governments in East, Central, and Southern Africa are planning to introduce extensive use of the method in the future.

Studies on economic assessment of ITM are limited to financial analysis of localized immunization trials (Morzalia et al 1988 and Mukhebi et al 1989). Furthermore, the analyses are simplistic estimates of physical and sometimes financial losses due to mortality, drug treatments, or acaricidal applications. Some studies have also attempted to estimate costs of the disease in terms of losses in milk and beef and the costs of dipping (Ongare and Wilson 1981). Mukhebi et al (1992a) estimated the total direct economic cost of Theileriosis and assessed the potential economics of its control using ITM. This is the only comprehensive economic analysis that considered morbidity and mortality losses in milk, beef, animal traction, and manure besides disease control costs. Their study indicated that ITM was an economically feasible ECF control method that could be used in the region. However, the analysis was concerned with the economics of using the method on a country-wide basis in the whole region rather than assessing the financial and economic feasibility of the method at the farm level.

Statement of The Research Problem

Governments in eleven countries in Eastern, Central and Southern Africa, which include Kenya, intend to introduce ITM for use by farmers. ITM has proved to be technically and economically feasible under research station trial conditions. However, successful widespread adoption of such a technology will require *ex-ante* epidemiological, economic, social, and environmental assessment to determine circumstances under which it can be successfully applied on a sustainable basis.

Economic analysis and assessment to identify the alternatives that generate optimum benefits to farmers and society at large are required to allow for selection among the available technologies. Analysis is also needed to determine the economic viability of the whole farm or ranch as a result of adopting or using the new technology. Furthermore, economic analysis would help policy makers to determine economically viable technologies that need to be encouraged for adoption.

Although economic analysis is usually an important prerequisite in the development of new technologies before they are transferred to farmers for adoption, the evaluation and assessment is complicated by the fact that the analysis is generally an *ex-ante* problem. That is, the benefits, costs, and the impacts of the technology are in many cases evaluated before the technology is actually introduced on the farm or ranch. Consequently, the actual results on the farm or ranch are not actually known but are instead based on experimental research trials.

Gittinger (1982) points out that " the effectiveness of a new technology on farms should be realistically assessed and the technological assumptions checked to ensure that they reflect on-farm conditions but not those of an experiment station." The evaluation of a new technology based on research results does not usually reflect the economic viability of the technology on the actual farm because the conditions on the farm, particularly resource endowments, may be quite different from those on research stations.

Although the benefits from research expenditures, particularly from improved agricultural technologies, are generally high, *ex-ante* benefits to specific research projects are usually difficult to measure. For example, while the development of improved livestock disease control technologies are being emphasized in Africa, available economic analyses on the new and existing control methods (particularly ECF control methods) are limited to costs, financial, and economic estimates. Some analyses are available on assessments of regional economic losses from the disease and the economics of its control (Mukhebi et al 1992a). However, there is no economic study which has comprehensively evaluated the new improved ECF control method while taking into consideration associated price and production risks. Furthermore, the economic viability of farms or ranches due to use of new or existing technologies has not been analyzed using methodologies that systematically consider the whole farm or ranch and its environment.

To bridge the gap that exists between technical development and economic evaluation of livestock disease control methods in Africa, the Socioeconomic Program (SEP) at ILRAD is developing methodologies for economic analysis. One such methodology is a firm level simulation model known as the Technology Impact Evaluation Simulator (TIES) developed by Richardson, Mukhebi and Zimmel (1991). TIES is a computerized simulation model which quantifies the economic impacts of both livestock and crop technologies on farms in developing countries. TIES can be used to simulate and identify impacts on costs, yields and risks from livestock technologies such as changes in types of breeding stocks, grazing systems, herd management practices, disease control methods, and immunization procedures. The model can also be used to evaluate technologies that affect crop production, such as alternative crop mixing and varieties, fertilizer and herbicides use, and mechanization. This study uses TIES to assess *ex-ante* financial and economic impacts of livestock disease control methods in Africa. The focus of the study is on ECF control methods in Kenya.

Objectives of The Study

The overall objective of this study is to evaluate and predict farm-level financial and economic impacts of alternative ECF disease control methods under different cattle production systems in Kenya. The specific objectives are:

1) To describe the cattle production systems and identify current farm level ECF disease control methods.
2) To evaluate the financial and economic impacts of ECF control methods on selected farms according to size and type of cattle kept.
3) To determine the most preferred strategy for ECF control by farmers under different risk circumstances.

CHAPTER II

OVERVIEW OF THE AGRICULTURAL SECTOR IN KENYA

This Chapter includes a discussion of the importance of the agricultural sector in Kenya. The important agricultural activities and their relative importance in the economy of Kenya are outlined. The structure of agricultural production to indicate the importance of small-scale farming is also discussed. The practiced cattle production systems which are the focus of this study are discussed to indicate the constraints that producers face. Demand and supply of milk and beef products in the country are reviewed to indicate the current situation. Finally, constraints that limit increased cattle production with a special emphasis on the role of diseases, particularly ECF, and the efforts the government is undertaking to overcome the constraints are discussed.

Importance of The Agricultural Sector

Agriculture is the mainstay of the economy in Kenya and provides the basis for the development of the other sectors. The sector contributes about 30 percent of the gross domestic product (GDP), compared to about 13 percent for the manufacturing sector and 47 percent for other sectors including commercial and government services sectors (Kenya 1988). The agricultural sector also provides about 75 percent of the total employment and is also the leading earner of foreign exchange. According to the 1989-1993 development plan, "the agricultural sector is expected to continue playing an important role in feeding the population, generating employment and incomes to the majority of the people, contribute to foreign exchange earnings and induce growth in the other sectors of the economy."

Agricultural Production

Agricultural production in Kenya is considerably diversified, as indicated in Table 2.1. The leading crops are the permanent and temporary export crops. Permanent crops are those

Table 2.1. Gross Marketed Agricultural Production at Constant (1982) Prices, 1980-1987

Commodity	1980	1981	1982	1983	1984	1985	1986	1987
				K£. Million				
Cereals								
Wheat	20.4	20.2	22.0	22.8	12.7	18.2	21.0	17.7
Maize	11.7	25.3	30.8	34.0	30.0	31.2	36.0	35.1
Barley	4.1	3.1	3.9	2.8	1.2	3.3	3.5	3.8
Paddy Rice	2.8	2.9	2.9	2.5	2.7	3.0	1.6	2.3
Sub-total	39.0	51.5	59.5	61.1	46.6	55.5	62.1	58.9
Industrial Crops								
Pineapples	1.2	2.1	2.2	2.6	2.9	2.3	3.1	3.1
Pyrethrum	9.3	13.4	14.8	5.0	2.0	3.0	4.3	4.3
Sugar - Cane	37.7	36.2	29.4	28.0	30.7	29.4	30.2	31.4
Cotton	6.7	4.5	4.3	4.5	4.0	6.7	4.5	4.2
Tobacco	1.6	2.1	3.0	3.8	4.8	3.0	3.2	4.0
Sub-total	49.8	58.3	53.7	43.9	43.5	44.4	45.3	47.0
Other Temporary Crop	8.6	10.0	10.6	11.9	10.7	12.0	13.4	15.0
Permanent Crops								
Coffee	127.0	126.1	122.9	132.5	164.7	134.3	159.7	145.9
Sisal	11.8	10.4	12.6	12.5	12.9	11.3	10.4	9.3
Tea	87.2	88.3	93.2	115.8	112.7	142.8	139.1	151.2
Cashew-Nuts	8.1	3.8	1.7	4.8	8.4	3.0	1.7	1.9
Others	2.4	1.6	1.2	1.3	1.3	3.1	1.5	1.8
Sub-total	236.5	230.2	231.6	266.9	300.0	294.5	312.4	310.1
Livestock and Produce								
Cattle for Slaughter	49.0	59.5	52.3	56.8	59.0	70.0	70.5	73.0
Dairy Products	81.2	95.9	91.7	99.3	94.8	109.0	118.8	126.8
Sheep and Goats for Slaughter	1.5	1.1	1.6	1.8	3.0	2.0	2.2	2.6
Pigs for Slaughter	1.7	1.6	1.7	1.9	2.8	1.7	2.2	2.3
Poultry and Eggs	1.6	2.8	3.0	1.2	1.3	2.0	1.6	1.8
Hides, Skins, and Wool	5.2	4.6	4.6	4.8	5.5	6.2	4.1	5.2
Sub-total	140.2	165.5	154.9	165.8	166.4	191.7	197.2	211.7
Grand Total	423.0	447.1	449.0	485.4	493.6	517.3	557.3	560.9

Source: Republic of Kenya, Statistical Abstract, 1988.

that are cultivated for more than two years (perennial). The permanent crops include coffee, tea, sisal, cashew nuts and some horticultural crops. Temporary crops are those that are cultivated for one or a few years, annuals or biennials. They include pyrethrum, cotton, pineapples and some horticultural crops. Cotton is grown both for export and domestic consumption. The other temporary crops that are used domestically for industrial processing include sugar cane, barley and tobacco. The most important food crops are maize and wheat. Other food crops include; rice, pulses, potatoes, cashew nuts and cassava. Cattle and dairy products are also produced for export and domestic consumption. Other livestock such as sheep, goats, pigs and their products, are produced for local consumption.

The shares of marketed agricultural commodity groups in total marketed output are shown for recent years in Table 2.2. In terms of marketed value, the share of permanent perennial crops at about 53 percent, is more than any other group. The share of livestock and livestock products estimated at about 23 percent is the second most important commodity group. The food crops, mainly maize, wheat, and pulses, contribute about 10 percent of the marketed production. However, Table 2.2 does not include the marketed output that passes through the local and informal markets. If these were included, food crops would appear more important than is suggested in Table 2.2. The total marketed value of livestock and livestock products are underestimated in the same manner as for food crops. Most of the livestock and livestock products are marketed in local and informal markets rather than through formal market channels where there is more adequate recording of sales.

Although agriculture is the main stay of the Kenyan economy, increased agricultural production through expansion in the available land area is limited. Only about 7 percent of Kenya's total land area of approximately 569,000 kilometers can be described as good agricultural land in the sense that it has adequate and reliable rainfall and good soils for crop production. An additional 4.5 percent is suitable for crop production, but is in areas where rainfall is inadequate in most years and, therefore, must be irrigated. About 28 percent of the land is suited to stock raising, particularly ranching, at varying levels of intensity depending on rainfall and soils. However, about 60 percent of the land is best described as semi-arid and arid land which is not suitable for crop production and is mainly used for pastoral nomadism.

The diversity of the land resource in Kenya would be suitable for specialization in crop and livestock production. However, about 80 percent of the total agricultural production comes from only one fifth of the land where mixed agriculture is practiced. These land areas are referred to as the medium and high potential areas. Medium and high potential areas include regions of the country that receive an annual rainfall of 750 to 1000 millimeters and over 1000 millimeters, respectively, while low potential areas receive an annual rainfall that is below 750 millimeters.

Table 2.2. Share of Commodity Groups in Gross Marketed Agricultural Production 1986-1990.

Year	Cereals	All other Temporary Crops	Permanent Crops	Livestock and other Products	Total
			percent		
1986	11.4	12.8	58.8	17.0	100.0
1987	12.0	15.0	50.0	23.0	100.0
1988	10.5	11.2	53.0	25.3	100.0
1989	11.6	12.6	50.8	25.0	100.0
1990	8.2	13.6	51.8	26.4	100.0
Average	10.70	13.0	53.0	23.3	100.0

Source: Republic of Kenya, Economic Survey, 1991.

The outlined potential classification of land in Kenya largely determines the various agricultural enterprises for the farmers in any given region of the country. For example, the main activity in the low potential areas, which cover about 80 per cent of Kenya's land, is livestock production involving indigenous breeds with low productivity. Consequently, aggregate livestock production from the use of land and labor resources in these zones is much lower. The Ministry of Livestock Development (Kenya 1990b) estimates that the low potential areas produce between 25 and 35 percent of the total milk and beef production, respectively, compared to 75 and 65 percent of the milk and beef production, respectively, from the medium and high potential areas. Furthermore, in smallholder livestock production in the medium and high potential areas, land and labor resources are used more intensively as shown in Table 2.3 and, thus, contribute significantly to generating employment in the economy.

Table 2.3. Land and Labor Requirement for a Tropical Livestock Unit[a] by Type of Farming in Kenya

Type of Farming	Labor Man-days/year	Land Hectares/year
Small-scale	55	0.35
Rancher	5	1.40
Pastoral Nomads	35	10.43

Source: Stotz, (1983), Table 1.1, Page 2.
[a] A tropical livestock unit is an animal of about 250 kg of live weight.

In Table 2.3, land and labor required by a tropical livestock unit for a typical small-scale livestock producers, ranchers (large-scale livestock producers) and pastoral nomads are compared. Small-scale livestock producers raise a few animals on their privately owned farms while large-scale livestock producers raise a large number of animals on their privately owned farms as well. Pastoral nomads on the other hand, raise animals on communal land and they move from one place to another in search of pastures. As shown in the table, small-scale livestock farming is more markedly labor intensive than ranching and pastoral nomadism. Land use intensity is also high for small-scale farming. Small scale farms are located in the medium and high potential agricultural areas where pasture productivity is higher than in the low potential and the semi-arid areas where ranching and pastoral nomadism are practiced.

Structure of Agricultural Production

Discussions about agricultural production in developing countries usually make a distinction between the "modern" and "traditional" sectors, between large-scale and small-scale farmers, or between commercial and subsistence farming. The distinctions often refer to characteristics such as the use of modern techniques for farming, type of ownership, size of farm holdings, and whether production is largely for the market or for subsistence. Agricultural production in Kenya cuts across all of the above distinctions. However, a significant characteristic is the dichotomy between small-scale and large-scale farmers on one hand, and pastoral nomads on the other. Pastoral nomads occupy the semi-arid and arid areas of the country. They operate a complex system of exchange and control of livestock under very harsh environmental production conditions. The pastoral nomads keep livestock for subsistence needs and for cultural reasons, mainly as a source of wealth as well as a source of security in times of food scarcity. Due to the complexity of production practices by pastoral nomads and the marginal contribution of livestock products from pastoral areas to the monetary economy, very few agricultural production development programs have been put forward by the government in these areas. Because pastoral nomads move from place to place in search of pastures for their livestock, they rarely practice high levels of animal husbandry practices such as purchase of feeds for livestock and disease control.

Agricultural production in small-scale and large-scale farm holdings is the focus of agricultural developments in Kenya. Small-scale farms in Kenya's context are those which are less than 12 hectares even though there are some farms that lie outside this range (Kenya

1988). A distinct feature of small scale farms is that they are family farms and they, by and large, practice mixed farming. The average size of the large scale farms is 700 hectares, although again there are some farms that are relatively small units (Kenya 1988). The distinct feature of large-scale farm holdings is that they are operated as commercial farms rather than as family farms. Large-scale farms include plantations of the major industrial and export crops, ranches, and mixed farms, where dairying and the production of cereals is predominant. The classification of farms into small-scale and large-scale according to the hectarage sizes tends to ignore the medium-scale farms. However, for most accounting and planning purposes, small-scale farms include farms that are up to 100 hectares in size as long as they are family farms.

The smallholder agricultural sector has grown rapidly since national independence in 1963 and the sector continues to contribute significantly to the monetary economy. The importance of smallholder production relative to the large scale sector is shown by the contributions of each sector to the gross value of marketed output over the years in Table 2.4. Before independence in the 1950s, the aggregate average share of the value of marketed output for small farms was about 17 percent with an average value of Kenya pounds (K£) 6.65 million compared to the large scale sector's share of 83 per cent with an average value of about K£. 32 million. By 1989, the share for small scale producers of the value of marketed output was about 48 percent, valued at about K£. 430 million. The increase in smallholder marketed output is attributed to an increase in production as a result of adoption of improved crop and livestock production practices and expansion in the area under small-scale farming in response to price and marketing incentives (Kenya 1986). The decrease in the relative marketed output from large scale farms is largely attributed to subdivisions of the farms into small holdings which started soon after independence in 1963 and continues to date (Kenya 1991a). The policy of the Government on the development of small-scale farms is to develop technologies that will be appropriate for small-scale farming so that smallholder agricultural

Table 2.4. Average Value of Marketed Agricultural Output From Large and Small Farms and Their Relative Shares, 1954 to 1990.

	Large Farms		Small Farms	
Period	Value K£. Million	Share Percent	Value K£. Million	share Percent
1954-1959	32.0	83.0	6.7	17.0
1960-1964	37.4	74.6	11.1	25.4
1965-1969	34.9	51.7	32.9	48.3
1970-1974	53.1	49.4	56.5	51.6
1975-1979	139.1	47.4	154.1	52.6
1980-1984	244.2	48.0	264.7	52.0
1985-1989	460.4	51.7	430.2	48.3

Sources: Republic of Kenya (1991a), Economic Survey, Republic of Kenya (1970, 1983, and 1988), Statistical Abstracts.

production can continue to play an important role in the economy of the country (Kenya 1986).

The characteristic feature of smallholder farming is that the farmers grow temporary and/or permanent export or industrial crops and food crops as well as raising livestock, which may be cattle, goats, sheep, poultry or pigs. The type and number of livestock kept is closely related to the available feed, particularly forage the main feed for cattle, sheep, and goats which are the most important livestock that are raised. For example, Stotz (1983) reports that increased grazing land availability appears to be closely linked to farm size. Larger smallholders appear to keep more cattle than smaller sized holders. On the other hand, Sands et al (1982), as reported by Stotz, found that the smaller the farm size, the higher the number of livestock units kept per land unit. Such farms rely heavily on forage supplied by crop residues such as maize stover, straw, and by-products of harvested crops, and off-farm forage such as grazing by the roadside.

Livestock farming is generally integrated with cropping activities in the smallholder farm system. Livestock production serves the overall objective of providing food and cash income for the farm family. Food and income objectives are achieved through drawing on the available common pool of resources: land, labor, capital, and management. Interactions generally exist between cropping and livestock activities; therefore, various enterprises are generally interdependent within the whole farm system as shown in Figure 2.1. Consequently, any change in one activity will affect the other activity and, hence, farmer decisions on a change in one activity have to take into consideration the effects on the other activity.

As shown in Figure 2.1, the available farm resources are used for production activities such as crop, livestock, and forage production. Other inputs which are not produced on the farm are purchased for use in crop, forage, and livestock production. The outputs from the farm activities are used to provide food for family use and to generate farm income. The outputs are also used in the production of the crop and animal products. In Kenya, the integration of crop and livestock farming relates mainly to cattle feed. Stotz (1983) indicates that crop by-products and residues, mainly maize stover, provide an average of 35% to 45% of the total digestible energy for cattle.

Livestock produce manure which is applied to crops to increase yields. However, direct application of manure to crops is rarely practiced on most farms, but the benefits are realized from rotational farming practices. Livestock also provide traction power to prepare fields for crop production. The use of animal power for cultivation is not common in the very small farms in the high potential areas, but livestock, particularly cattle, provide a considerable amount of traction power on the relatively larger farms, particularly in regions of the country with marginal crop production.

Livestock Production Systems in Small Scale farming

Livestock production on small farms is one of a number of activities involving crops and fodder production. Consequently, to define a livestock production system, the activities that are specific to livestock production need to be separated from activities related to crop

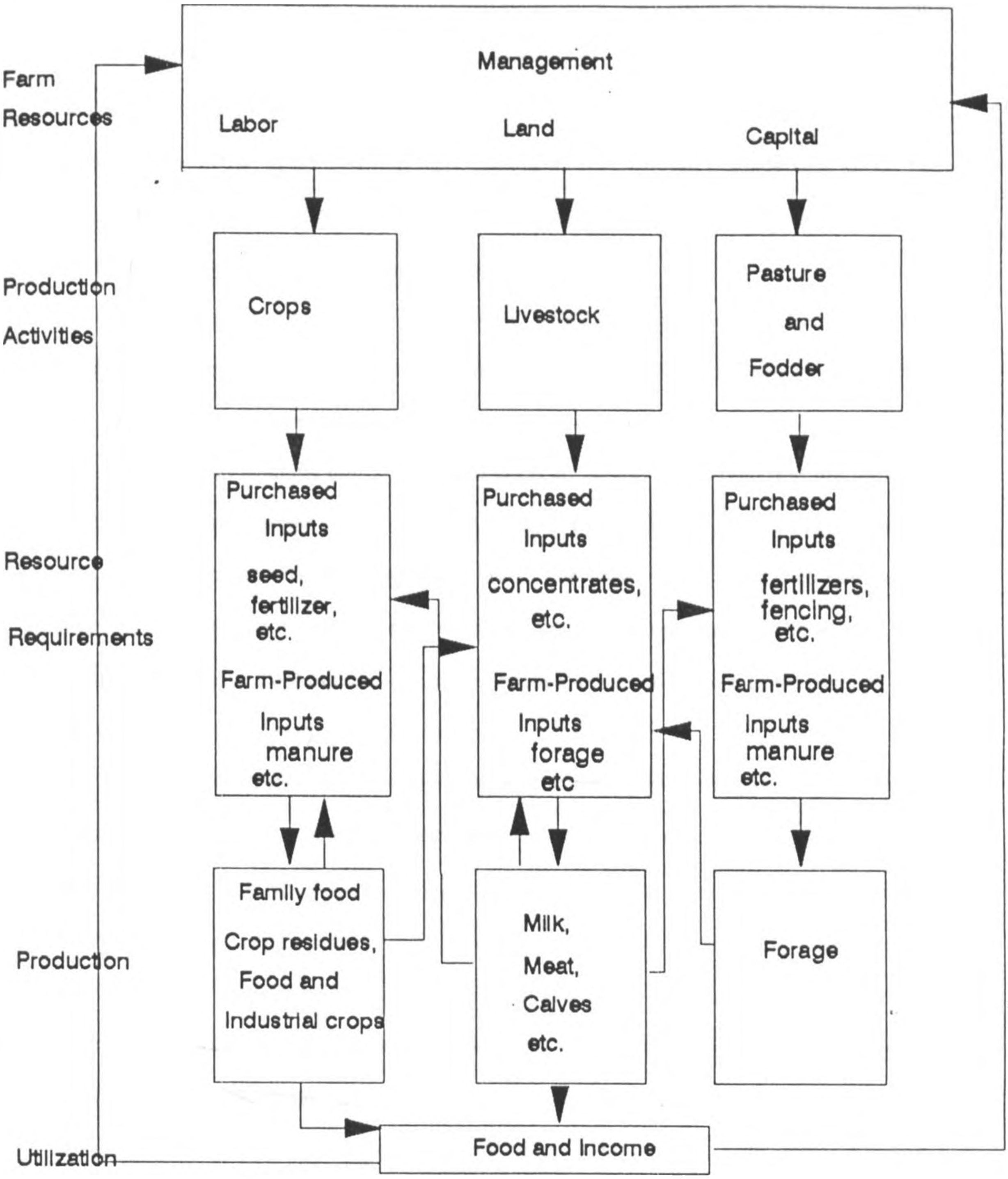

Figure 2.1: Interactions Between Crop and Livestock Activities on Smallholder Farms

Source: Adopted from Stotz (1983)

production. The livestock production system consists of resource requirements for livestock and the related livestock outputs and the interdependence between the inputs and outputs as characterized by the production process itself. In its simplest sense, Stotz (1983) defines a livestock production system as a group of similar interdependent management units. The similarities are brought about by the type of livestock produced, the types of product, and by the types of resources required by the system.

Based on the definition by Stotz (1983), smallholder livestock production systems in Kenya can be divided broadly into ruminants and non-ruminants. Ruminant systems include dairy cattle, beef cattle, sheep, and goats, while the non-ruminants include poultry and pigs. These production systems can further be divided according to the type and amount of inputs used to produce a certain output. Finally, livestock production systems can be differentiated by products such as milk, beef, eggs and wool. The differentiation becomes relevant as intensity of production increases and decisions have to be made about the level of production required to achieve best results. Intensity of production usually refers to the level of application of particular inputs in a production process.

The outlined discussion on a livestock production system suggests the difficulty in exhaustively discussing all livestock activities under one production system. Because of the diversity in livestock types produced by smallholders and the differences in their products, each livestock activity usually must be considered individually. However, because the focus of this study is on cattle, only the cattle production systems are discussed in detail. The discussion emphasizes dairy production because small scale farmers in Kenya keep cattle mainly for milk production. Beef cattle become available mainly as a by-product of dairying through sales and home consumption of cull cows, heifers, steers, bulls and bull calves.

Cattle Production Systems

The main types of cattle in Kenya are the indigenous breeds, *Bos indicus*, which are commonly referred to as Zebu cattle; the exotic breeds, *Bos taurus*; and crosses between the two breeds. The *Bos taurus* breeds and the crosses are commonly referred to as Grade cattle. Grade cattle are more productive but are more susceptible to diseases than the Zebu, which in turn are low producers but are more resistant to tropical diseases and are well adapted to the environmental conditions.

Cattle production by most smallholders relies heavily on natural pastures for forage. Pasture quality and quantity vary with seasons. During the rainy season pasture is plentiful while during the dry season, often there is not enough. Some farmers try to offset this problem by growing fodder crops which can be used for dry season feeding. Farmers also use crop residues and by-products to feed cattle while others buy industrial by-products and manufactured feeds.

Small scale cattle production systems can be distinguished by grazing systems and arable fodder production systems. Grazing systems can further be divided into unregulated and regulated pasture systems. Unregulated grazing is based on natural pastures which naturally regenerate after several years of crop cultivation or infrequent plowing to allow for natural reseeding. Pasture management practices, such as fencing, weeding the grass paddocks, fertilization, and rotational grazing, are rarely carried out. Regulated grazing is based on growing pastures and fodder crops through regular rotations between arable cropping, pasturing, and fallowing. During the fallow, pastures are planted with natural or improved grass species and they are fenced and weeded, while fodder crops tend to be cultivated intensively. In regulated grazing, cattle are allowed to graze on the natural or improved pastures during the day and are stall fed using fodder crops and crop by-products.

Grazing systems also vary with the type of method used to feed the cattle. The three common methods of feeding cattle are free range grazing, semi-zero grazing, and zero grazing. Free range grazing is a system in which the animals are allowed to graze pasture fields without supplementary feeding of fodder crops. Semi-zero grazing is a system in which cattle are allowed to graze pasture fields but are also fed fodder crops and crop by-products in stalls. Zero grazing is a system in which cattle are not allowed to graze on pasture fields but are fed entirely on fodder crops, hand chopped grasses, crop by-products, and manufactured feeds in stalls or in enclosed areas on the farm. Zero grazing is the most intensive cattle production system and is common in areas where farms are very small and the competition for arable land for growing crops is very high.

The different grazing systems are part of the husbandry practices that describe the various cattle production systems in Kenya. However, there are many other production features that define the production systems. The features are cattle breeds used, calf rearing practices adopted, and disease control measures used. Using these production features, numerous production system combinations are possible, but under smallholder conditions that prevail in Kenya, four main production systems occur.

The four main cattle production systems in Kenya classified according to the type of cattle kept and the grazing system used are:

(1) Zebu cattle grazing on natural pastures (System I)

(2) Cross bred cattle grazing on natural pastures (System II)

(3) Grade dairy cattle kept under semi-zero grazing (System III)

(4) Grade dairy cattle kept under zero grazing (System IV).

The features of the four systems which are discussed next are based largely on discussions by Stotz (1983):

Zebu cattle grazing on natural grass or System I is the most widely practiced production system in the low and medium potential areas of the country. The main grazing system is free range grazing, but the cattle can be supplied with concentrates or mineral salts and water. Disease control measures are rarely practiced, but they are usually done when it is made compulsory by the government to control diseases such as Rinderpest or Foot and Mouth disease. Cows are generally milked for the first 3 to 5 months of lactation. The annual milk yield is about 600 Kgs. Calves join their dams during milking and feed by suckling the dams, after which they are separated and confined away from the cows. Calves are usually weaned at 5 to 7 months but the mortality rate is usually high. The rate is estimated at about 25 percent and is usually due to tick-borne diseases and malnutrition.

Under this system, a cow requires about 3700 kg of forage matter (FM), 1,650 kg of total digestible nutrients (TDN), and 210 kg of digestible crude protein (DCP) per year. About 330 hours of labor are required per year per cow. The average calving interval is about 18 months. Most heifers are underdeveloped because of poor nutrition and are served at an age of about 32 months old. Based on 1983 prices, Stotz found that this production system gave a negative gross margin when the imputed values for labor and capital were deducted from the gross value in addition to all the other variable costs.

Cross bred cattle grazing natural pastures or System II is an intermediate between the traditional and the intensive production systems and is most prevalent in the medium and high potential areas of Kenya. The typical cow herd consists of crossbred cattle which are acquired by upgrading zebu cows using exotic breed bulls. Cattle graze natural pasture fields which are usually fenced. The husbandry practices with respect to feeding and calf rearing are similar to those in System I. However, in this system, cattle are regularly dipped or sprayed to control tick-borne diseases. The average milk yield under this production system is about 1400 kgs. The cow requires about 5000 kg of FM, 2500 kg of TDN, and 300 kg of DCP per year for production and maintenance under this system. The labor requirement per cow is about 370 hours per year for forage production, calf rearing, milking and feeding. The calving interval is about 17 months and the mortality rate for calves is about 20 percent. The estimated gross margin for this production system is Kshs 141 per cow per year (Stotz 1983).

Grade dairy cattle kept under semi-zero grazing or System III is a system where pure exotic breeds or crosses are kept and are grazed for some time during the day and stall fed in the evenings or at night. Usually, the cattle are rotationally grazed in pasture paddocks that are frequently cleaned and weeded. At the stalls, the cattle are fed fodder crops such as napier grass, crop rèsidues, or purchased feeds. The fodder crops and crop residues are usually carried to cattle as opposed to System I and II where the fodder crops and crop residues are predominantly grazed. Lactating cows are also fed concentrates at the time of milking. Calves are separated from the dams and are bucket fed or hand reared. Tick-borne diseases are usually controlled by spraying acaricides or dipping the animals.

In this system, the average milk production is about 2,200 kg per cow per lactation. The calving interval ranges from 12 to 16 months. The mortality rate of calves is about 15 per-cent. Under the system, a cow requires about 6,300 kg of FM, 3,100 kg of TDN, and 360 kg of DCP. This system is fairly labor and capital intensive. About 460 hours of labor per cow per year are required for forage production, milking, and feeding the cow and calf. The estimated gross margin for this production system is Kshs. 839 per cow per year (Stotz 1983).

Grade dairy cattle kept under zero grazing or System IV is the most intensive milk production system and is the focus of government development efforts under the dairy development program which started in 1980 (Kenya 1991a). The system is characterized by keeping high yielding Grade cattle permanently under a cow shed in which they are fed and milked. Smallholders who practice zero grazing are predominantly commercial producers whose main concern is milk production; therefore, male calves are sold out at the age of 2 to 3 weeks. Female calves are bucket fed with whole milk for a period of about ten weeks. The calves are raised for replacement; after weaning the heifers are also kept in the cow shed. The cows are usually hand sprayed with acaricides once a week to control ticks and tick-borne diseases.

Zero grazed cattle are fed on fodder crops, crop residues, and manufactured feeds. Under this conditions, the cow produces about 2,800 kg of milk per year with an average calving interval of about 14 months. For production and maintenance, a cow under this production system requires about 7,200 kg of FM, 3,500 kg of TDN and 420 kg of DCP. The system is labor and capital intensive and requires high levels of management. Productivity of the cows is also high while calf mortality is low at about 10 percent. The high productivity is possible, however, only under effective disease control measures, particularly tick control to avoid tick borne diseases.

The importance of the existing cattle production systems is to indicate the performance of the current management levels and the prevailing constraints. The production systems show that the zero grazing system is the most productive cattle production system but it is also the most intensive user of resources. Consequently, System IV is the most costly cattle production system. The system is not used by most farmers because most farmers lack the capital to invest in it. The system also requires high nutrition and disease control levels to ensure that the producer does not incur losses once the investment has been made. On the other side, the Zebu cattle production system requires very few resources, but has the lowest milk production levels. The government has emphasized the development of the livestock sector to ensure an adequate supply of livestock products to meet the increasing demand and to generate employment opportunities (Kenya 1981). However, increased production of cattle products will depend on the availability of new technologies and the decision of farmers to adopt the technologies.

Supply and Demand of Cattle Products

About 80 percent of the total milk and 64 per cent of the beef produced in Kenya comes from smallholders (Kenya 1991b). Although, no accurate supply and demand estimates of milk and beef products are available, the government of Kenya widely acknowledges that the quantities of beef and milk demanded outstrips the quantities supplied (Kenya 1981, 1986, and 1989). The estimation of the supply of milk and beef is made difficult because there is no accurate recent census of livestock. However, most estimates of the supply of milk and beef are based on estimates of cattle numbers by the Ministry of Livestock Development. These estimates are compiled from annual district reports by livestock officers. According to the 1990 estimates, there were about 3 million Grade cattle and 9.7 million Zebu cattle as shown in Table 2.5.

The contribution of each type of cattle to milk and beef production varies. The estimated milk production from Grade cattle is about 75 percent of the total, while the Zebu herd produces the remaining 25 percent. On the other hand, the Zebu herd produces about 67 percent of the total beef production, while the Grade cattle produce the remaining 33 percent.

The supply of beef and milk in Kenya is usually estimated from the sales of these products. The estimated sales of beef are based on the recorded sales by abattoirs in urban and rural areas and sales by the Kenya Meat Commission, the formal government institution which buys livestock from producers and then processes and sells meat products to consumers. For example, the Ministry of Livestock Development estimated that in 1990 about 228,000 metric tons of beef were sold. On the other hand, the demand for beef products in 1990 was estimated at about 330,000 metric tons. Thus, comparing the estimated quantities supplied and the quantities demanded, there was a deficit of beef in 1990 and this situation has prevailed in the country for most years.

Various government agencies notably the Ministry of Livestock Development, the Ministry of Economic Planning and National Development, and Kenya Creaminary Cooperative (KCC), give rough estimates of the supply and demand for milk. The estimates for supply are usually based on milk sales in the country with the assumption that all milk produced is consumed domestically. The estimates are based on the amount consumed at home by farm families and marketed quantities. The estimated milk consumption in 1981 and 1990 and the respective growth rates are shown in Table 2.6 to show the changes that have occurred

Table 2.5. Estimated Cattle numbers in Kenya by Province in 1990.

Province	Grade Cattle	Zebu Cattle	Total
		(Thousand head)	
Rift Valley	1666.88	3282.03	4948.91
Eastern	261.49	1745.55	2007.04
Nyanza	122.26	1443.57	1565.83
Coast	30.87	1187.01	1217.88
Western	103.29	983.08	1086.37
North Eastern	0.40	1065.60	1066.00
Central	794.68	82.93	877.61
Total	2994.55	9704.29	12698.84

Source: Kenya, (1990a), Ministry of Livestock Development, Animal Production Division Annual Report.

Table 2.6. Estimated Milk Consumption and Growth Rates in Kenya.

Type of Consumer	Consumption 1981	Consumption 1990	Annual Growth Rate
	Million Liters		Percent
Home Consumption	668	790	1.88
Marketed Consumption			
KCC	191	350	8.32
Others	290	378	3.03
Total	1,149	1,518	3.21

Source: Kenya (1991b), Ministry of Livestock Development, Unpublished Report.

during the decade. As shown in the Table, about 728 million liters of milk were available for sale in 1990, from a total consumption of 1,518 million liters compared to 481 million liters that were sold in 1981 from a total consumption of 1,149 million liters.

The amount of milk sold to KCC, the government institution which has the monopoly to purchase milk from producers to process, and to sell to consumers in urban areas, represents only 20 percent of the total milk production. The rest of the milk is consumed on farms or is sold through informal markets in rural areas and in local market centers. For most small scale producers, KCC is a residual buyer or "buyer of the last resort" in the sense that producers sell their milk to the organization only when they are unable to sell milk elsewhere at a higher price. The main reason is that KCC buys milk at the regulated government price, while milk prices in the local markets are determined by the forces of supply and demand.

Although the estimated amounts of milk consumed gives an indication of the amount of milk that is produced domestically, the estimate does not give an accurate indication of the quantities that are demanded in the country. The estimated demand for milk depends on incomes, population, and prices of milk, among other things. Based on estimated income elasticity of 0.58 and 1.01 for urban and rural, areas respectively; an own price elasticity of 0.43; and a population growth of 3.5 per cent; the Ministry of Livestock Development (Kenya 1991b) estimated the quantity of milk demanded in 1990 to be about 798 million liters. The estimated quantity demanded does not take into account the amounts required for home consumption but considers only the market demand. However, the estimate indicates that there was a deficit in domestic production at the prevailing government set prices which is usually the case for most years.

The deficits in milk production are not uniform throughout the country; some districts are surplus areas while some have deficits. The estimated average milk per capita requirement in Kenya is 64 kilograms (Kenya 1991b). Based on this estimate the Ministry of Livestock Development designates a district as milk deficit or surplus if it has a per capita estimate below or above the average, respectively. According to this classification, about 50 percent of the 41 districts in Kenya are surplus milk producing areas, while the remaining are milk deficit areas. Most of the surplus milk producing districts in the country are in Rift Valley and Central provinces. The two provinces have the largest numbers of grade cattle and, hence, there is a positive relationship between the number of Grade cattle and milk surpluses. This relationship is plausible because Grade cattle are high milk producers while the Zebu are low milk producing cattle.

Strategies to Increase Cattle Production

The discussion on the supply and demand situation of milk in Kenya indicate that the country is not self sufficient in this important foodstuff. Therefore, the country is forced to import milk and milk products. However, because of the scarcity of foreign exchange required to import such products, the government emphasizes the development of the livestock sector so that production can be increased to meet at least the domestic demand (Kenya 1990b). The strategies are to encourage farmers to improve animal husbandry practices which include high feeding standards and disease control measures. Another strategy in improving milk production is to improve the genetic potential of the dairy herd. This strategy is crucial because the Zebu cattle, which currently comprise 80 percent of the national herd, are low producers, while the high milk producing Grade cattle comprise only 20 percent of the national herd.

Although a potential exists to increase milk production by improving the genetic potential by crossing the Zebus and the exotic breeds, the low abilities of the grade cattle to resist tropical diseases limits the exploitation of the potential. The most important cattle diseases in Kenya are Trypanosomiasis which is transmitted by tsetse flies, East Coast Fever which is transmitted by ticks, and the bacterial diseases; Rinderpest and, Foot-and-Mouth disease. The importance of these diseases is acknowledged by the government in its policy paper for development, Sessional Paper No 1 of 1986 on **Economic Management for**

Renewed Growth Specifically the paper states that:

> " Diseases have been a major obstacle to increased livestock production in many parts of the country. Rinderpest is a potentially devastating disease that is kept under control by regular vaccination of yearlings and cattle near the country's borders. Foot-and-mouth disease, which can sharply reduce dairy production among the improved stock, is controlled by a combination of vaccination and cattle movement restrictions **whenever the disease breaks out**[1]. For every shilling of increased production due to control of the disease, the Veterinary Department spends only Kshs. 0.22. Tick-borne diseases are controlled by dipping cattle, but the costs are high and some farmers show a reluctance to dip their cattle, especially if fees are charged Consideration will be given to the development of an immunization program to control tick-borne diseases and eventually to replace dips" (Kenya 1986, page 76).

Thus, of all livestock diseases, the government attaches great importance to tick-borne diseases. The next sub-section reviews the status of tick-borne diseases in Kenya to indicate their economic importance in cattle production and the efforts the government is undertaking to control the diseases.

Importance of Tick and Tick-Borne Cattle Diseases in Kenya

The prevention of ticks and tick-borne diseases in cattle is regarded as being of greatest importance in Kenya. The importance is reflected in Kenya laws by the Cattle Cleansing Ordinance (Cap. 358) which empowers the Minister of Agriculture and Livestock Development to declare "proclaimed areas," and enforce regular, usually weekly, cleansing of cattle in these areas through the use of approved acaricides. "Proclaimed areas" are those in which tick-borne diseases, particularly East Coast Fever (ECF), are present and cattle cleansing is compulsory. The major tick-borne diseases of cattle in Kenya and the tick species

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[1] Bold type is addition by the current author

that are vectors of the diseases are: 1) ECF caused by *Rhipicephalus appendiculatus*; 2) Babesiosis caused by *Boophilus, Ixodes, Haemaphysalis, Rhipicephalus* and *Hyalomma* species; 3) Anaplasmosis caused by *Boophilus* species; and 4) Heartwater caused by *Amblyomma* species.

The ticks constrain livestock production in two main ways. By themselves they can cause damage to hides and skins of the host animals and cause lower productive performance through exsanguination, toxicosis, irritation and secondary infection of the wounds on cattle. Other than the direct effects, ticks cause more severe losses by acting as vectors of the various diseases which can cause the death of cattle and reduce productivity. Although the levels of losses caused by the listed tick-borne diseases vary, they have certain factors in common in their epidemiology. First, the diseases are generally more severe in Grade cattle breeds and crosses than they in breeds that are indigenous to tick-infested areas. Second, in situations where there are sufficient numbers of vector ticks to guarantee frequent transmission of the disease in question, a stable "endemic" situation may be created. That is, cattle become infected with the disease as calves, suffer a generally mild or inapparent infection, and then become immune to further disease attack upon recovery. This immunity is continually reinforced as the result of repeated challenges from infected ticks. However, the immunity is not genetically transmitted from cows to calves.

Comparing the various tick-borne diseases with respect to creating endemic stability, the Department of Veterinary Services (Kenya 1985), indicates that endemic stability is easily established for anaplasmosis and babesiosis. The reason is partly because of the efficiency with which the vector ticks transmit the diseases. Endemic stability can be established with little or no loss in affected cattle populations, even in instances where the population densities of the vector ticks are relatively low. As for the case of heartwater, the disease has a short infective period in the host. The short infective period in the infected host usually results in low infection rates by the *amblyomma* vector tick. Consequently, endemic stability is possibly farmers, then he or she uses the local communal dips built by the government or by a group of farmers on a co-operative basis. The objective of applying acaricides to control ticks and tick-borne diseases is to reduce direct losses caused by their infestation on cattle. At the same time tick control should reduce infection of tick-borne diseases.

Before 1977 the Veterinary Department was responsible only for the supervision of the Cattle Cleansing Ordinance but had no responsibility for the actual management of cattle dips or spray races that were widely used to apply acaricides. However, concern over escalating cattle losses due to tick-borne diseases and the emergence of acaricide resistance by ticks due to inefficient acaricide application, led the Department of Veterinary Services to assume responsibility for the management of communally operated dips. The responsibility was undertaken through a government tick-control program in proclaimed areas. Under this program, the government provided acaricides for the communal dip tanks and levied a fee, about Kshs. 0.30 in 1985 and Kshs. 2.00 in 1990, for each animal immersed in the dip. By 1985 when the government tick-control program was finishing its first phase, there were about 3330 dips and over 6 million cattle in the program, one third of which were exotic or Grade cattle in the proclaimed areas.

Under the government tick-control program, each communal dip had a committee composed of elected representatives from local livestock producers. The committee was responsible for working with the Veterinary Services in managing the dip and for providing labor when required. The choice of the acaricides used was subject to government policy. Acaricides to which ticks have been proven to be resistant were banned. However, owners of private dips or spray races would use acaricides of their own choice. In areas that are not proclaimed, tick control is voluntary and at the discretion of the livestock owner.

The government tick-control program seemed to have been successful in reducing ECF incidence in its first years of operation as shown in Figure 2.2 which shows the annual incidence of ECF in Kenya in 1969 to 1987. As shown in Figure 2.2, there was a reduction in

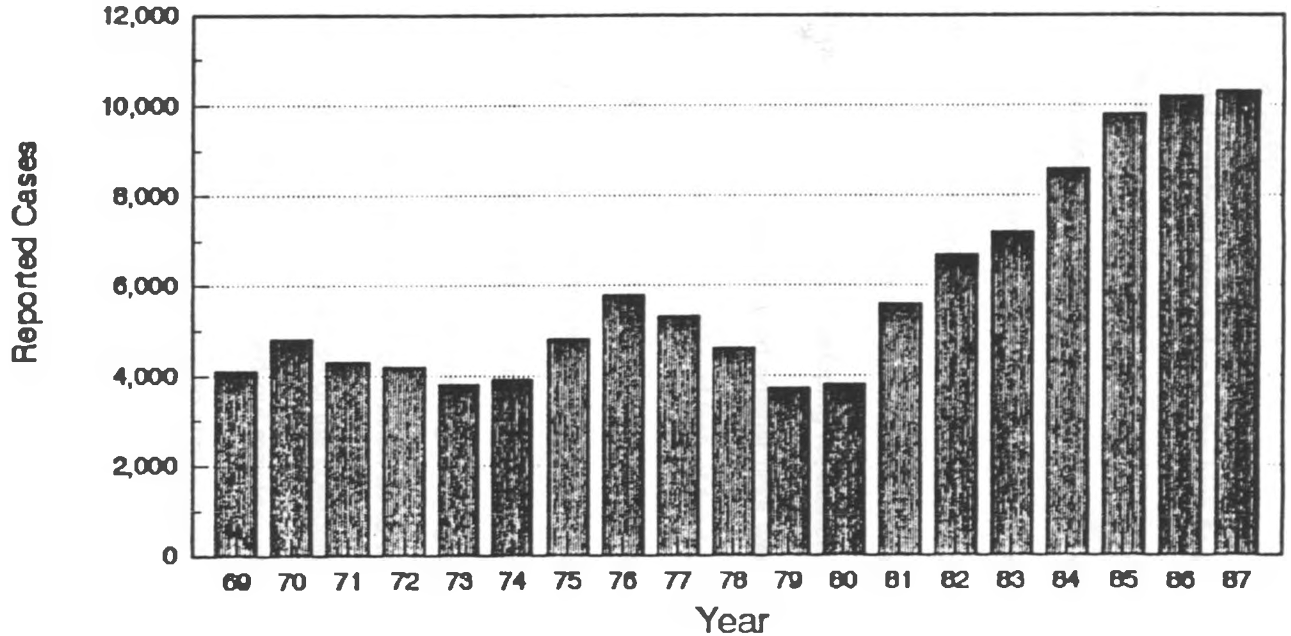

Figure 2.2: Annual Incidence of East Coast Fever in Kenya
Reported and Suspected cases 1969-1987

Source: Norval et al. 1992

the number of reported ECF cases from 5800 in 1976 to 3700 in 1979. However, beginning in 1982, the number of reported ECF cases surpassed the reported cases in 1977. The main reasons for the increases in ECF cases are attributed to two main constraints, financial and managerial (Kenya 1985).

The financial constraint arose due to the high financial requirement of the program for the purchase of acaricides that was estimated at K£. 390,000 in 1985. Because the government has commitments in other development programs, there was generally an acute shortage of funds to purchase acaricides. As a result, dips were not replenished adequately with acaricides and were under-strength most of the periods. In addition, emptying and refilling of dips had to be delayed. The effects of these factors were to reduce the efficiency of the dipping procedure and led to ticks developing resistance to some acaricides. Consequently, the degree of protection of cattle dipped against ticks was reduced. A further problem with financing was the maintenance. Because of lack of funds, adequate maintenance was often not carried out and dips sometimes were closed for considerable periods while awaiting necessary repairs. This also added to the ineffectiveness of dipping as a method of controlling ticks.

The problems resulting from lack of funds were often accentuated and complicated by poor management. The existence of two management groups, the dip committee and the Veterinary Services Department caused confusion as to the exact responsibility of each group, particularly over maintenance and the use of the collected dipping fees. The Veterinary Department collected the fees and carried out maintenance with labor provided by the dip tank committees but usually strife arose over who should control the collected funds. In 1988 the government made a decision to leave the management of dips to the committees, while the role of the Veterinary Services Department was left to provide advisory services like checking the strength of acaricides used.

A further problem in using communal dips is the risk livestock farmers face when they expose their cattle to other herds. The cattle face the risk of contracting contagious or or infectious diseases when herds from different farms are mixed. Adverse effect on milk production also occurs as a result of walking animals to and from communal dips. The trauma of the dipping procedure also forces farmers to prefer to dip or spray their cattle privately. However, private costs can be higher than the subsidized charge at the communal dips.

Under the government tick-control program, the recommended frequency of dipping cattle was once a week. But the frequency with which acaricides are applied could be governed by the economic considerations such as the gains in productivity when compared to the costs of applying acaricides. Losses, particularly on Grade cattle as a result of failure to control ticks are usually acknowledged to be high. If the ticks are not adequately controlled, the alternative to control tick-borne diseases is the use of therapeutic drugs to treat the sick animals. The most effective and recommended drug is clexone. However, the cost of a course of treatment, estimated at about Kshs. 2 per kilogram of live weight of an animal, is high and unaffordable by most small-scale farmers. Besides, effective treatment requires early diagnosis of the disease which small-scale farmers are usually unable to do. The problem is compounded by accessibility of the veterinary health officers to treat the animal as soon as the farmer diagnoses the disease. The ratio of animal health assistants and the Veterinary Officers to farmers is very low. In most districts one Veterinary Officer covers an administrative division that has about 10,000 small-scale farms or more while, an animal health assistant covers an administrative location or sub-location with 500 small-scale farms or more.

An alternative ECF control method that the government of Kenya intends to introduce for use by farmers is the "Infection and Treatment Method," the immunization procedure that has been described in Chapter I. The government of Kenya, through the Department of Veterinary Services, has been involved in the development of the method from the initial stages. Currently, the government is undertaking on-farm field trials in Kaloleni Division of Kilifi District with the intention of making the method available for use by farmers in all the proclaimed areas. Although the method has been proven to be technically and economically viable in research trials (Mukhebi 1991), no economic analyses have been undertaken to evaluate the alternative tick and tick-borne diseases in conjunction with the new methods to determine their impacts on small-scale livestock farms. This study was undertaken to contribute partly toward narrowing this information gap.

CHAPTER III

THEORETICAL BACKGROUND AND LITERATURE REVIEW

This Chapter includes a discussion of the technical and theoretical background for this study and a review of the relevant literature. First, the methods used for economic analysis are reviewed to indicate their suitability and limitations. The main methods are budgeting techniques, programming, and simulation modelling. This study uses simulation modelling to undertake an economic analysis of alternative livestock disease control methods. Consequently, studies that have used whole-farm simulation are reviewed to indicate the applications of simulation modelling. Finally, a theoretical background and review on risk, risk analysis, and decision making under risk is discussed. The background information is used to show the importance of risk in economic analysis and the various aspects of risk analysis that are important in decision making under risk as well as the procedures that are used in risk analysis.

Economic Analysis

Quite often the financial and economic results of a new technology are assessed using farm budgets that quantify the costs and returns associated with the technology to indicate its profitability. Barry, Hopkin and Baker (1988) define budgeting as orderly approaches of assembling and analyzing information and choosing among financial alternatives. Barnard and Nix (1973) on the other hand indicate that farm budget techniques are primarily concerned with organizing resources on the farm to achieve a given set of objectives. The objective can be profit maximizing or family satisfaction.

Economic analysis of new technologies or farm plans using budgets can be based on income or investment analysis. Farm income analysis is generally used to evaluate the performance of a farm or a group of farms within a prescribed period, usually one year (Boehlje and Eidman 1984, and Kay 1986). The analysis measures the profitability of the business. Farm investment analysis, in contrast, is taken to determine the financial or economic attractiveness of a proposed investment to the producer and other participants including society as a whole (Gittinger 1983). Farm investment herein is broadly defined as addition of durable assets to a business (Barry et al 1988). In agriculture, farm investments include annual operating inputs such as feed, seed, fertilizers, and fuel, and capital assets such as land, machinery, buildings, permanent crops, and breeding stock. Consequently, new farm technologies are investments which can be evaluated using both farm income and investment analysis.

Farm investment analysis involves the use of cash flow and capital budgets. Cash flow budgets are important in establishing inflows and outflows of funds and in managing liquidity in light of seasonal patterns in farm production and marketing. Capital budgets on the other hand enable producers or managers to compare new alternative investments under different financing methods using various decision criteria. The widely used criteria for comparison are: net present value (NPV), benefit-cost ratio (BCR), and internal rate of return (IRR). The criteria provide a method for ranking, accepting or rejecting various investment alternatives.

NPV is a criterion whereby the projected future cash flows of an investment are discounted to determine the current present value. Mathematically, NPV is calculated using the following equation:

$$NPV = -INV + \frac{P_1}{(1+i)} + \frac{P_2}{(1+i)^2} + \ldots\ldots + \frac{P_N}{(1+i)^N} + \frac{V_N}{(1+i)^N}$$

Where;

INV = initial investment costs

P_n = annual net cash flow at period n

V_n = salvage or terminal value at period n

N = length of planning horizon

i = interest or discount rate

Each projected net cash flow is discounted to its present value and then summed to yield a net present value for the investment over its entire life. Any terminal investment value is included as a cash flow in the last year of the planning horizon. The projected cash flow in any year can be either positive or negative. Hence, a projected operating loss in any year enters the cash flow with a negative sign and is discounted to its present value. The initial investment cost or value (INV) is negative, since it reflects a cash outflow.

The sign and size of the net present value of an investment determines its ranking and acceptability. Acceptability of each investment depends on whether the NPV is positive or negative. The decision rules are: if NPV exceeds zero, then one accepts the investment; if NPV equals zero, one is indifferent; if NPV is less than zero, then one rejects the investment. Acceptance of an investment implies that the investment is profitable relative to the required rate of return which is implied by the discount rate. Rejection of an investment based on a negative NPV implies that the alternative investment with a rate of return implied by the discount rate (i) is more profitable than the investment being evaluated. Ranking of investments is based on the largest positive NPV. The investment which gives the largest positive NPV is favored, with the next NPV being second favored, and others follow accordingly.

Internal rate of return (IRR) of an investment, which is also referred to as the "discounted-rate-of-return", the "marginal efficiency of capital", or the "yield of an investment" (Barry et al), is the rate of return (or interest) which equates the net present value of the projected series of cash flow payments to zero. Mathematically, IRR is calculated using the following equation;

$$0 = -INV + \frac{P_1}{(1+i)} + \frac{P_2}{(1+i)^2} + ... + \frac{P_N}{(1+i)^N} + \frac{V_N}{(1+i)^N}$$

IRR is calculated by solving for the interest rate (i) that satisfies the equation. In effect, IRR equates the present value of the projected cash flows to the initial investment cost (INV).

consequently, the equation above can be rearranged to the following:

$$INV = \frac{P_1}{(1+I)} + \frac{P_2}{(1+I)^2} + ... + \frac{P_N}{(1+I)^N} + \frac{V_N}{(1+I)^N}$$

Investments are ranked and accepted or rejected using IRR on the basis of their relative sizes. The investment that gives the largest IRR is ranked first, followed by the second largest and the rest accordingly. Acceptability of each investment depends upon the comparison of its IRR with the required rate-of-return (RRR) of the investor. Acceptability is based on the following decision rules: if IRR is greater than RRR, one accepts the investment; if IRR = RRR, one is indifferent; if IRR is less than RRR, one rejects the investment.

The benefit-cost ratio (BCR) is the ratio of the present values of cash inflows to the present values of the cash outflows. Mathematically, the ratio is estimated as follows:

$$BCR = \frac{\sum_{i=1}^{n} \frac{B_i}{(1+I)^n}}{\sum_{i=1}^{n} \frac{C_i}{(1+I)^n}}$$

where;

B_i = Returns in year i

C_i = Costs in year i

Investments are ranked and accepted or rejected using BCR on the basis of the size o the values just as is the case for the other decision criteria that have been discussed. The decision rules for acceptability or rejection are: if BCR is greater than 1, one accepts the investment; if BCR = 1, one is indifferent and; if BCR is less than 1, one rejects the investment.

Either of the criteria, NPV, IRR or BCR can be used to rank alternative investments. In most cases, however, NPV and IRR are frequently used. Although in most circumstances IRR and NPV give the same rankings for alternative investments, occasional differences can arise due to the different assumptions about the rate of return on reinvestment of the net cash flows. The IRR method implicitly assumes that net cash flows from an investment are reinvested to earn the same rate as IRR of the investment under consideration. The NPV method, on the other hand, assumes the funds are reinvested at the firm's interest rate. Barry et al (1988) indicate that NPV is widely used as the criterion for selecting among alternative investments because it has the advantage of being consistent for all investments and it may be more realistic if the interest rate is determined by the opportunity cost of capital. However, IRR also offers an advantage in comparing alternative investments against a common RRR and present profitability in percentage terms. Consequently, either of the criteria can be used to select among alternative investments.

A major limitation with the use of NPV is that ranking acceptable alternative non-mutually exclusive investments is not possible because NPV is an absolute criterion but not a relative measure. A small, highly attractive investment may have a smaller net NPV than a large, marginally acceptable investment (Gittinger 1982). The selection criterion is to undertake both since there will be sufficient funds if the opportunity cost of capital is correctly estimated. If there are insufficient funds to undertake both, the implication is that the opportunity cost of capital has been estimated to be too low. The NPV is the most preferred selection criterion to choose among mutually exclusive investments. Mutually exclusive investments are investments such that if one is implemented the other one is precluded from implementation. The alternative ECF control methods are examples of mutually exclusive investments.

IRR is a widely used criterion in financial and economic analyses in developing countries. The IRR has distinct advantages over other investment selection criteria. First, its calculation does not depend on assumptions about the opportunity cost of capital because the assumptions are not necessary for the calculation of IRR. Second, unlike NPV, IRR is a relative measure that can be used to compare alternative investments. The rate of return represents the average rate of interest at which an investment pays back the investment over its lifetime (Brown 1979). A major limitation of IRR is that its calculation is tedious. The estimation of the discount rate that make the incremental stream of benefits equal to zero is done by trial and error procedures. Furthermore, if all the values are positive, no discount rate can make the net present value of the stream of benefits equal to zero (Gittinger 1982). IRR can also lead to erroneous ranking of mutually exclusive investments when they are directly compared. The reason is because undertaking a small, high-paying investment may preclude generating more wealth through a moderately renumerative but larger alternative. This problem can be avoided by using the NPV criterion or by discounting the differences in the cash flows of the alternative investments and then calculate an IRR. The calculated rate of return is the marginal return for the resources required to implement the larger investment as opposed to the smaller one.

BCR is generally used to indicate how much costs could rise without making the investment unattractive. For purposes of selecting among mutually exclusive investments, BCR can also lead to erroneous results just as IRR does. BCR discriminates against projects with relatively high gross returns and operating costs, even though these may be shown to have greater wealth-generating capacity than that of alternatives with higher BCR (Gittinger 1982). A further problem with the use of BCR is that different results can be obtained depending on how costs and benefits are calculated for various investments. Gittinger indicates that usually analysts working in one country should follow a common netting-out convention to derive cost and benefit streams. Otherwise, NPV is commonly used because it not affected by the problems of using IRR or BCR except for the problem of choosing the proper discount rate.

The ranking of investments using the three criteria cannot be relied upon because of the outlined problems. Although the criteria are useful in deciding whether or not to reject or accept given investments they are not adequate in selecting among alternative investments. Yet in many instances it is convenient to have a reliable measure to rank projects to determine the order in which investments should be undertaken. Hence, a need arises for a criterion that can be used to rank alternative investments adequately.

Although budgeting techniques are useful and provide the basis for evaluating new farm plans and technologies, several criticisms are levelled against them (Barnard and Nix

1973, Anderson et al 1977, and Brown 1979). A major criticism is that budgeting techniques usually assume that stochastic variables such as price and yields are known with certainty. Thus, price and production risks are usually not adequately accounted for in the analyses (Barnard and Nix, Anderson et al, and Brown). Risk, however, has been shown to be an important factor that affects farmer response to economic incentives as well as decision making in developing countries (Behrman 1968, Wolgin 1975, Moscardi and de Janvry 1977, and Dillon and Scandizzo 1978).

Risk is usually accounted for in investment analysis using budgeting techniques by adding a risk premium to adjust discount rates or use of expected values as actual ones for the stochastic variables (Anderson et al 1977, Barry et al 1988, and Kay 1986). Sensitivity analysis is then undertaken to compare how risky the investments are. Sensitivity analysis is a procedure in which the values of stochastic variables (such as prices and yields) are varied over some ranges in the analysis to recalculate the decision criterion and determine how sensitive the investment is to the changes.

Sensitivity analysis gives an indication of how risky an investment is as a result of changes in prices or yields. However, the analysis has two major disadvantages. First, it is incomplete because it is not designed to cope with all possible circumstances. Second, it is ambiguous because it does not specify the likelihood of alternative outcomes (Brown 1979). A comprehensive approach to include risks in investment analysis is use of probability distributions to measure the associated risks in price or production (Reutlinger 1970, Polinguen 1970, Anderson et al 1977, and Barry et al 1988). The procedure commonly referred to as risk analysis in agricultural economics literature involves expressing the expectations of stochastic variables in probability terms. The purpose of risk analysis is to eliminate the need for restricting one's judgement to a single "best" value but to allow judgement on the possible range of each variable around this value, and to determine the likelihood of each value within the range (Reutlinger 1970). One of the methods that are used for risk analysis is simulation.

Methods Used to Evaluate New Technologies

The evaluation of new technologies is aimed at providing information to various groups, most immediately to the developers and purveyors of the new technology, then to the policy makers and various communicators, and ultimately to users of the technology. Consequently, evaluation of new technologies can be undertaken in different contexts, depending on who is undertaking the analysis, for what purpose, and the stage of development of the technology (Valdes, Scobie, and Dillon 1984).

The stage of development of the technology will affect the complexity to which evaluation will be related to the farming environment. Evaluation of new technologies that are under development in research stations and which have not proven to be technically sound need not be related to the realities and complexities of the farming environment. However, developed technologies that are ready for adoption need to be carefully evaluated in relation to the circumstances of the target group of farmers. The reason is that farmers, and particularly small farmers, are characterized by different patterns of resource endowments, production opportunities, skills, beliefs, and preferences. Consequently, evaluation of new technologies for small-scale farmers requires taking into account the resource endowments of individuals, alternative uses of the resources, and their preferences and beliefs. The evaluation is important to ensure that the new technologies are relevant to the needs of the farmers and can hence be applied on a sustainable basis. Therefore, whole-farm decision models are required for the analysis.

Whole Farm Planning Techniques

The whole-farm planning techniques that exist for evaluating new technologies include budgeting, mathematical programming and simulation. Budgeting techniques are probably the most widely used techniques to evaluate new technologies because they are easily adaptable Budgeting techniques, as discussed earlier, are thought of as accounting procedures for assessing the profitability of some change in farm methods or organization. Budgeting can also be used to assess the feasibility of such changes. Thus, budgeting can be used to account for limited resource availabilities and interrelationships between farm activities. However, the analyst must use judgement in deciding which relationships will be accounted for explicitly and which will be handled more subjectively or intuitively.

A major disadvantage of budgeting techniques when compared to other whole-farm planning techniques is lack of any formal optimizing algorithm. Because the optimality of any budgeted plan cannot be guaranteed, analysis must proceed on a trial-and-error basis. The alternative methods used to search for ways to identify the optimal farm plans or "best" portfolio of technologies for particular farming circumstances are mathematical programming methods. These methods have been used mostly by academic researchers and to a lesser extent by practitioners (Valdes, Scobie and Dillon). Linear programming (LP) has been the most widely used of these methods.

Mathematical Programming Methods

The LP model allocates the available resources among the competing activities and determines the mix of efficient activities that gives the optimal plan as specified by the objective function. The principal outstanding criticism levelled against the use of LP for whole-farm planning relates to the embodied assumption that all planning coefficients are known constants. Consequently, LP does not adequately take into account risks which are inherent in farming. Nevertheless, examples of studies that have used LP to analyze farm planning in developing countries as cited by Valdes, Scobie and Dillon include: Clayton (1965), Heyer (1971 and 1972), Johnson (1969), Langham (1968), and Wills (1972). To overcome the problem of not adequately accounting for risk in LP models, extensions are usually made to the basic LP model. The extensions essentially involve models with stochastic net revenues and models which recognize risk in the constraints.

The simplest way of incorporating risk in LP models is to change the objective function to maximization of expected net revenue, subject to the usual constraints. The chief disadvantage of this model, apart from the exclusion of stochastic constraints, is that no account is taken of the possible risk aversion by the farmer. Risk aversion is usually dealt with by use of quadratic programming (QP). QP is a technique similar to LP but the objective function is not necessarily linear. The objective function corresponds to a quadratic function which incorporates expected income and variance of income. The risk attitude of the decision maker is expressed by a risk aversion parameter which is also incorporated in the objective function. The principle behind QP is the mean-variance (EV) analysis criterion of selecting among risky prospects using the means and variances of the distributions. The concept originated in portfolio selection as a means of explaining diversification as a rational choice by decision makers (Markowitz 1959).

Freund (1956) was the first to apply QP to a farm firm problem. The application of QP is a two-stage process. In the first stage, solutions are required for the objective function which incorporates risk. The objective function is optimized subject to the usual technical constraints and a minimum expected income constraint. The second stage is to determine the optimum plan from the "efficient set". This may be done by direct inspection of the data results by the farmer, or the optimum can be located analytically using a Taylor series expansion of the farmer's utility function for income.

For the application of QP to a farm planning problem, a covariance matrix of activity net revenues is required. In most applications, these data are obtained from farm records. Specification of the required covariance matrix either from past records or by use of subjective probabilities seems to be very difficult in most small-farm contexts. Moreover, the usual quadratic risk programming models do not provide an appropriate means of accounting for risk in subsistence crop or livestock products whose output is not converted to cash. A further problem in using quadratic programming in whole-farm planning which is often cited in most risk analyses is the specification of the risk aversion coefficient. Specification of the risk aversion coefficient is usually arbitrary, yet critical for determining a risk efficient farm plan (Mapp and Helmers 1984). One approach is to derive an entire efficient frontier and present the set of farm plans to the farmer. The farmer can then reveal his degree of risk aversion through selection of an optimal plan from the risk efficient set. However, this approach is only valid with a model that fully captures the relevant risk responses for the decision maker. Brink and McCarl (1978) cited by Mapp and Helmers also indicate that the risk aversion parameter can be varied until the difference between a farmer's actual plan and a farm plan on the efficient frontier is minimized.

Despite its problems and limitations, quadratic programming has had a number of applications in empirical risk analysis. Studies that have used quadratic programming as cited by Mapp and Helmers (1984) include Scott and Baker (1972) in which they derive a risk efficient set of farm plans for a cash grain farm and Lin et al (1974) in which they develop risk efficient sets for a panel of California farms. Johnson (1979) also used a multiperiod quadratic programming model to integrate short-run production and long-run investment and financial decisions into a common framework. The model allowed responses to risk through variations in farm size, diversification of crop and livestock production, and adoption of alternative cash selling and hedging conditions.

Although, budgeting and programming techniques can be modified to accommodate some recognition of the impact of risk and uncertainty, both models are reliant on the neoclassical paradigm of profit or utility maximization. In recent years, there has been a swing away from the neoclassical paradigm toward paradigms that highlight the multidimensional nature of farmer goals and preferences. Some of the perceived dimensions include subsistence, consumption, leisure, and attitudes toward risk and credit (de Janvry 1975, Hazell and Scandizzo 1973, Lipton 1968, and Sen 1966). Addition of these dimensions to the objective function greatly increases the difficulty of modelling programming algorithms. One possible way out of the dilemma that has emerged is the use of systems simulation.

Simulation Modelling

Simulation is a technique that involves setting up a model of a real situation (system) and then performing experiments on the model (Naylor 1971). The technique is a flexible procedure which allows complex processes, such as whole farm planning and growth, to be represented and described realistically. The basic features of simulation are modelling and experimentation. In modelling, a real system is replaced by an analogous but abstract system using a mathematical model. Experimentation involves using the model to study problems for which the model was designed. The aim of the experiment might be to explore and to describe the response of the system to some variables, or it might be to optimize the response over some operable region of the system (Naylor 1971).

Simulation makes the study of the potential or probable effects of certain changes on the operation of a system possible by making alterations in the model of the system and by observing the effects of these alterations on the behavior of the system. A major advantage of the simulation approach is its ability to incorporate realistically the important stochastic elements of a system. By representing over time the essential characteristics of the system under study, simulation allows the investigator "to view problems as they exist rather than as some predetermined analytical structure admits" (Johnson and Rausser 1977).

A simulation model may have many attributes: it may be deterministic or stochastic; involve single or multiperiod events; programmed to maximize or minimize a linear or non-linear objective function, search for an optimal solution, or be non optimizing; represent part or all of a complex process; and be behavioral or mathematical. Thus, simulation is flexible in design, but the flexibility is both an advantage and a disadvantage. The system and design of the model are determined by the researcher. Consequently, simulation models rarely have a pre-existing structure, as occurs with the coefficients, constraints, and objective functions of linear and quadratic programming. Each problem is uniquely modelled but the model can sometimes be adapted to solve or analyze other problems. However, few simulation models that have been developed in agricultural economics are generalized and documented adequately for modification and re-use. An exception is the Firm Level Income Tax and Policy Simulation Studies Simulation Model (FLIPSIM) (Richardson and Nixon 1983 and 1986) which has been used widely in the United States.

The basic steps in simulation modelling are: (1) model formulation, (2) synthesis, (3) verification or validation and (4) experimentation. In the formulation stage, the problem is identified and research hypotheses are formulated. The structure of the mathematical model is determined including its input and output requirements, its decision rules and feedback loops. Stochastic variables are identified at this stage. The model output should also be designed to yield key measures for risk analysis. The simulation model need not have an objective function to be optimized, however, decision rules can be specified to determine the organization of production (Mapp and Helmers 1984).

In the synthesis step, the model is specified in detail, including the stochastic variables such as prices, yields and climatic variables, the choice of distributions, collection of data, examination of serial dependence, and estimation of covariances. Risk analysis in a multi-period model will require specification of future economic events. The assumptions used in the projection of such economic events should be clearly specified.

Verification or validation considers the technical accuracy of the model and realistic portrayal of the system under simulation. Verification includes the "debugging" of apparent inconsistencies and determining if subroutines are performing correctly. A major validity test is to compare the model results with observed behavior. For example, the yields, prices, or net returns generated by the model should have proper maximum, minimum, mean, and standard deviations. Validation often requires subjective appraisal, gauging results against historical changes, or checking the model's performance against expected theoretical changes.

The experimentation stage subjects the model to a range of values of the key variables. For example, the potential impacts on net farm income, net worth, or consumption from various combinations of stochastic yields or prices for crop and livestock activities can be simulated. The probabilistic results generated from simulation can then be evaluated and used to select desirable outcomes.

A Review of Simulation Studies

Simulation modelling has had a marked influence on agricultural economics, particularly on firm-level studies in recent years. For example, Baum and Richardson (1983) and Cole and English (1990) indicate that several studies have been done using simulation techniques in the United States. The techniques have been used extensively to quantify the impacts of alternative management practices, policies, and technologies on the economic viability of farms and

One of the earliest studies involving whole-farm simulation analysis was to evaluate management policies under uncertainty on a large-scale ranch (Halter and Dean 1965). The study indicated that simulation offered a promising tool of analysis involving decision making where numerous stochastic and time related interrelationships among variables existed. The Halter-Dean simulation model was essentially a mathematical model of decision rules, information sources, and other interactions among the components of the organization (ranch). The model considered the returns and costs of enterprises to determine net income which was used to evaluate management policies. However, the model used did not include other information such as balance sheets, cash flow, debts, and taxes.

Baum and Richardson (1983), discussing some of the developments in firm-level modelling using simulation techniques, indicate that later models such as the Hutton and Hinman (1971) models which include balance sheets, cash flows, debts, and taxes, were essentially improvements on the Halter-Dean model. The Hutton-Hinman type of models were replaced by a third generation of farm level simulation models in the late seventies and early eighties. These models include those developed by Boehlje and Griffin (1979), Richardson and

Nixon (1980), and Richardson and Condra (1981). The third generation models incorporate options such as farm programs, farmland disinvestment, stochastic prices and yields, family consumption functions, tax laws, machinery replacement, flexible inflation rates, and optimization routines to determine the annual enterprise mix and resource use.

Most whole-farm simulation models are developed for analyzing specific research problems and are rarely adaptable for use by other researchers. However, the results of the studies suggest that simulation is a useful tool in agricultural research. These studies include analyzing production strategies (Blackie and Dent 1976, and Mapp and Eidman 1976), farm firm growth processes (Chien and Bradford 1976), and evaluating the impacts of new agricultural technologies (Mann and Paulsen 1976). A general problem with specific whole-farm simulation models is that a wider use of the models is limited. This observation may be attributable largely to researcher enthusiasm for model building aspects of simulation which is not matched by corresponding guidance of real world decision making (Dobson 1974). In recent years,owever, some generalized whole farm simulation models such as FLIPSIM have been developed to analyze a wider range of agriculture research problems.

FLIPSIM has been used extensively to quantify alternative management practices, policies and technologies in the United States. The model is a firm level, recursive computer simulation model that simulates the annual production, farm policy, marketing, financial management, growth, and income tax aspects of a farm over a multiple-year planning horizon The computer program is capable of simulating a case farm situation for 1 to 10 years. The model recursively simulates a typical farm by using the ending financial position for year 1 as the beginning position for the second year, and so on. Although the model has an option to use a programming algorithm to select an optimal (profit or utility maximizing) plan for each year, it is a simulation model as opposed to a programming model. The model does not include an overall objective function to be optimized but rather analyzes the outcome of a given set of input data and assumptions of a typical farm.

Studies that have used FLIPSIM to analyze alternative management practices include Richardson, Lemiux and Nixon (1982), Bailey and Richardson (1985), Leatham et al (1987), and VanTassel et al (1989). Studies on alternative policies include Richardson and Condra (1981), Lemiux, Richardson and Nixon (1982), Duffy, Richardson and Smith (1986), Knutson et al (1987), and Richardson et al (1991). Studies on quantifying the effects of alternative technologies include Richardson and Smith (1985a and 1985b), Lemiux and Richardson (1989), and Office of Technology Assessment (1986 and 1991). The studies indicate that FLIPSIM is a generalized simulation model that can be used to evaluate economic impacts of a wide range of agricultural research problems.

Some of the recent studies that used FLIPSIM to analyze the economic impacts of a new technology on producers are by Lemieux and Richardson (1989) and Office of Technology Assessment (1991). Lemiux and Richardson analyzed three representative grain-hog farms in Midwestern United States by simulating the farms for a period of five years to estimate the economic impacts for adopting porcine somatotropin (PST), a biotechnology developed to stimulate faster growth in pigs. Each farm was simulated under alternative assumptions for PST and hog price response to indicate annual production, marketing, finance, income tax, machinery replacement, herd maintenance, farm program participation, and family consumption activities of the farm.

The economic impacts on producers and the economic success of the farms were evaluated using estimated net present values, ending net worth and cash income, and probability of success for each farm. The model was also used to incorporate production and price risk by use of multivariate empirical probability distributions. The results indicated that large-scale operations garnered greater increases in income from PST adoption than small-scale and medium-scale operations that adopted PST. Furthermore, the economic benefits from adoption would be merely sufficient to cover the costs of adoption if there was no carcass premium. The results from this study suggest that simulation techniques can be used to evaluate new technologies to indicate economic impacts from adopting the technology.

The Office of Technology Assessment study used FLIPSIM to analyze farm-level impacts of Bovine Somatotropin (BST), a dairy biotechnology which has been developed to increase milk production in the United States but has yet to be released for adoption by producers. The analysis was used to determine the economic viability of farms based on the probability of survival and, economic success (probability of earning a targeted internal rate of return and increasing equity). Using different price policy scenarios such as fixed price-support, trigger price, and quotas, the researchers found that the payoffs from adoption of BST were substantial regardless of the region under consideration. The analysis further indicated that non-adopters of BST would find it difficult to survive and would more likely exit dairy farming.

The analysis was also used to rank the capability of the policies to enhance the adoption of BST. The quota program was found to perform poorly compared to the trigger price and fixed price support policies because restrictions on output would curb expansion and raise production costs. To maintain dairy farm income under a quota system, the price objective would be required to be sufficiently higher to offset the effects of lower production. All the representative farms in the analysis showed at least a 20- to 40- percent decrease in economic payoff under a quota compared to the trigger price policy. Hence, adoption of BST would be slowed by imposing a quota as opposed to the trigger price policy. The results from this study indicate that besides analyzing the *ex-ante* economic impacts of a new technology, simulation analysis can be used to indicate the payoffs of alternative strategies or technologies and to rank them accordingly.

In developing countries, the use of simulation as a planning and policy-making tool is limited by lack of trained personnel and availability of descriptive information about the interrelationships that exists in the economies (Hayenga, Manetsch, and Halter 1968). However, a study by Crawford and Milligan (1982) in Nigeria indicates that simulation offers advantages in evaluating farm technologies. Using a multi-year, stochastic farm simulation model, they were able to examine income growth prospects for small scale farms. One of the conclusions from their study was that testing new technologies via on-farm trials is an essential process, but is a slow and expensive evaluation method. However, where manpower and computational resources are available, simulation modelling can be used along with on-farm trials to assess the performance of a new technology under different assumptions. Furthermore, simulation improves the dependability of evaluation and will be particularly useful where many marginal farmers are present.

A recent study which uses simulation modelling and the FLIPSIM model in particular in a developing country was undertaken by Binamira (1991). He analyzed the impacts of agricultural price policies on the adoption of integrated pest management (IPM) by subsistence farmers in the Philippines. The FLIPSIM model was used to analyze the economic survival of farms from the adoption and non adoption of IPM based on two price scenarios: high rice price and low chemical prices, and low rice price and high chemical prices. The probability of survival and the net present value (NPV) for the farm enterprises were used as criteria for evaluating farm level impacts of alternative price policies. The analysis indicated that low rice and high chemical prices enhanced full adoption of IPM among irrigated rice farmers.

Binamira also used the FLIPSIM model to generate simulated NPV cumulative distributions that were analyzed using stochastic dominance criteria to identify preferences of farmers with different attitudes towards risk. He concluded from the analysis that confidence premiums as measures of farmer conviction indicated that a strong preference for full adoption was held by intermediate and non-adopters whose incomes came strictly from rice farming. However, under low yield rice regimes, the benefits arising from different IPM adoption strategies were not apparent when rice prices were also low although full adoption continued to benefit farmers with low yields as long as rice prices were high.

The results from Binamira's study indicate that FLIPSIM is a generalized model that can be used to analyze the economic impacts of changes in policies as well as new technologies in a developing country as much as it has been used in a developed country. Mitchell (1985) indicates that an ideal model for simulating the economic performance of subsistence farms should include the technical and behavioral relationships governing farm production and consumption activities that are unique in developing countries. FLIPSIM does not explicitly consider the unique farm production and consumption relationships in developing countries, but the study undertaken by Binamira indicates that the model is valid model for any type of farm. The analysis is possible because FLIPSIM is an accounting model whose equations remain valid regardless of geographic location. As an accounting model, the model can place limits on the technical and behavioral relations of subsistence farms even when these cannot be quantified (Binamira 1991).

FLIPSIM as originally developed considers some issues such as taxation and price supports which are prominent in developed countries but not so prominent in developing countries. In the same vein, the model does not consider some issues such as reliance on farm production for family nutrition and self-sufficiency in food stuffs which are prominent in developing countries but are of minor concern in a developed country. Consequently, the model needs to be modified to take into account the unique behavioral relationships that exist in each environment so as to reflect the system to be modelled as accurately and realistically as it can. The Technology Impact Evaluation Simulator (TIES) model that was used in this study has this advantage over FLIPSIM. TIES was developed specifically for use in developing countries to take into account the technical and behavioral production and consumption activities that are characteristic of farm families in developing countries. The TIES model, however, maintains flexibility just like FLIPSIM and can be useful for applications under varied environments in developing countries.

Risk and Decision-Making Under Risk

Methods of analyzing decision making under risk and attitudes towards risk have been the focus of agricultural economists for a long time. Jensen (1977), in his survey of farm management and production economics literature, indicates that numerous studies on risk have been undertaken since Heady's 1949 observation that risk and its dynamics on the farm were neglected areas of research. Jensen indicates that the studies that were undertaken covered areas such as the quality of farmer expectations, measuring risk attitudes and managerial characteristics, and responding to yield and income variability.

Barry (1984) gives a review of developments in risk studies and indicates that the studies were stimulated in 1950s and 1960s in research on the growth processes of family-size farms and the consequences of greater financial leverage. The studies were stimulated partly because risk responses by many farmers are strongly expressed through financial choices in managing liquidity (Barry and Baker 1977). Developments in decision analysis in agriculture under risk in 1970s are illustrated by Anderson, Dillon and Hardaker (1977). Their approach to decision analysis under risk based on subjective probabilities of the decision makers about the occurrence of uncertain events and evaluation of potential consequences is widely used in agricultural risk analysis. Barry et al (1984) also provide a comprehensive coverage of risk concepts, methods of analysis and practical applications of the methods over the years.

Risk Analysis Theory

In economic theory, risk concepts originated in Bernoulli's postulate in 1730s that investors maximize expected utilities or, in his terminology, "moral expectations" rather than expected income (Barry 1984). Traditional risk analyses made a distinction between risk and uncertainty based on Knight's work in 1921. Knight defined risk as a situation in which the decision-maker knows both the alternative outcomes and the probability associated with each outcome. Uncertainty on the other hand referred to situations where the alternative outcomes and the probability of occurrence are not known. In modern decision theory, however, risk and uncertainty are used interchangeably to refer to uncertain alternative outcomes. The decision maker may not know the full range of alternative outcomes, but possible outcomes and probabilities of their occurrence can be estimated subjectively (Boehlje and Eidman 1984).

Since Knight's pioneering work, substantial developments have occurred in economic theory to analyze decision making under risk. Von Neumann and Morgenstern (1947) revived and extended the expected utility approach and demonstrated how to predict choices of individuals under risky situations. Friedman and Savage (1948) and Savage (1954) introduced subjective probability concepts in analyzing utility and their relationship in decision making. Markowitz (1959), Baumol (1963), Hanoch and Levy (1969), and Hadar and Russell (1969) developed risk efficient criteria which are used to partially order risky choices for decision makers. Pratt (1964) and Arrow (1974) developed risk aversion measures which allow for interpersonal comparison and analysis of risk attitudes.

In agriculture, the risks farmers face can be divided broadly into business and financial risk (Boehlje and Eidman 1984). Business risk is the inherent uncertainty the firm faces independent of the way it is financed. The major sources are production and marketing uncertainty. Production risk can be biological due to diseases and pests or physical due to climatic factors. Major causes of market risk are product and input price changes. Financial risk is the variability of net returns to owner equity that results from financial obligations associated with debt financing. The different sources of risk make the analysis of risk complex. Young (1984) points out that different concepts of risk found in the literature range from probability of loss, variance, and size of the maximum possible loss. These concepts result in different procedures for measuring risk or eliciting expectations.

Incorporating Risk in Economic Analysis

Incorporating risk in economic analyses is a subject of controversy because risk is not easily quantified. The probability distributions from which the alternative risk concepts such as variance, chance of loss, or maximum loss are computed can originate from either objective or subjective sources. The terms, "objective" and "subjective", refer to probability measures computed from historical observations or elicited from the decision maker, respectively. Young (1984) indicates that although no theoretical linkage exists between specific risk concepts and sources, theoretical relationships may exist between some decision models and the probability sources.

Most firm-level behavioral studies use subjective estimates of expected returns and variances from farmers to incorporate risk in the analyses. The studies include technology adoption by peasant farmers (Roumasset 1976 and O'Mara 1971) and livestock stocking rates and crop disease control (Franscico and Anderson 1970 and Carlson 1970, respectively). Other researchers, however, such as Wolgin (1975), Moscardi and de Janvry (1977), and Conklin et al (1977) have used objective measures. The measures were risk indices computed from historical data. Consequently, both objective and subjective measures of risk are often used in firm-level risk studies. However, little evidence exists as to whether or not objective or subjective probability measures are superior.

At the industry level, risk studies, particularly models of supply response, generally rely on moving variance or moving standard deviation of variables computed from historical data. Studies that have used this approach include Just (1974), Lin (1977), and Ryan (1977). However, most of the supply analysts generally acknowledge that risk variables are proxies for subjective expectations of producers.

Although incorporating risk in economic analyses continues to be controversial and is an area of focus for research, Reutlinger (1970) and Richardson and Mapp (1976) indicate that risk can easily be included in simulation studies using Monte Carlo methods. Monte Carlo simulation involves generating a large number of values of a stochastic variable from a specified probability distribution and then using sampling to select the value to use in the analysis. By repeating the process many times, a probability distribution of the evaluation criterion (net present value, net worth, or cash income) is generated, thus allowing the risk associated with the technology to be evaluated.

A major difficult in using Monte Carlo simulation is ensuring that the distribution of the values of the variable, as the value emerges from the random selection, is consistent with the distribution for that chosen for the analysis (Reutlinger 1970). In most cases, the theoretical distribution that describes the process is unknown or is difficult to obtain. However, VanTassel, Richardson, and Conner (1989) indicate that most researchers avoid this problem by using actual data obtained from a historical series to generate the required empirical probability distribution.

Decision Making Under Risk

Decision making under risk can be based on three main classes of decision rules. The decision rules are: (1) no probability information rules, (2) safety-first rules, and (3) expected utility maximization. The decision rules requiring no probability information are discussed by Halter and Dean (1971). They include (1) minimax loss or maximin gain, (2) minimax regret, (3) Hurwicz α index, and (4) La Place principle of insufficient reason. These rules are rarely used in modern decision analysis due to their theoretical weaknesses and practical naivety (Young 1984 and Halter and Dean 1971).

Modern decision making emphasizes the use of probabilities in analyzing decision making under risk; hence, safety-first rules and the utility maximizing criteria are frequently used. Safety-first decision rules specify that a decision maker first satisfies a preference of some goal such as adequate food supply for the farm family or minimizing risk when selecting among action choices before following a profit oriented objective. Safety-first decision rules are based on lexicographic utility analysis. Lexicographic utility refers to sequential ordering of multiple goals. The highest priority goal must be achieved at a threshold level before considering the second goal, and so on. Thus, attaining a higher priority goal serves as a constraint on goals with successively lower priorities. Over achievement of goals has no effect on total utility, but an infinite disutility is associated with under achievement.

Lexicographic utility analysis is essentially an empirical method, no theoretical base or set of axioms is required to guide the ordering. However, the sequential ordering concept has much intuitive appeal and appears consistent with a hierarchy of goals suggested by other behavioral disciplines (Maslow 1943). Three types of safety rules have been suggested for risk analysis. The first rule (SF_1) was put forward by Telser (1955). The safety-first rule (SF_1) states that a decision maker maximizes expected returns (E) subject to the constraint that the probability of a return less than or equal to a specified amount (E-min) does not exceed a stipulated probability (P). SF_1 is expressed as:

Maximize E

subject to $P(E \leq E\text{-min}) \leq P$

The decision maker first determines a threshold level of income and the probability with which incomes must exceed this level. These values are the key indicators of risk attitudes under SF_1 rule. The threshold income might, for example, cover future obligations for living expenses, debt repayments, operating needs, or household food consumption needs. The decision maker then considers various actions that satisfy the constraint, and finally chooses among the actions based on the highest expected value.

The second safety-first rule (SF_2) was put forward by Kataoka (1963). The rule states that a decision maker will choose a plan that maximizes income at the lower confidence limit (L) subject to the constraint that the probability of income being less than or equal to the lower limit does not exceed a specified value of P.

SF_2 is expressed as:

Maximize L

subject to $P(E < L) \leq P$

The third safety-first rule (SF_3) was developed by Roy (1952). SF_3 states that a decision maker chooses a plan with the smallest probability of yielding a return below some specified level. That is,

Minimize $P(E < E\text{-min})$.

The expected utility decision rule is based on the principle of maximizing utility or the expected utility model (EUM). The EUM provides a single-valued index that orders choices according to the preference or attitudes of the decision maker. The EUM requires information on a set of action choices, a set monetary of outcomes (X_{ij}) associated with each action choice for each state of nature, and probability density functions $P(S_j)$ indicating the likelihood of outcomes in the respective states, for an action choice. The utility value for each possible outcome of an action choice is weighted by its probability and summed. The resulting expected utility is a preference index for the action choices. The alternative outcomes are ranked on the basis of the levels of expected utility and the action choice with the highest value is the most preferred.

Mathematically, the goal function is given as:

$$Max\ EU(x) = \sum_{j=1}^{n} U(x_{ij})\ P(s_j), \qquad j = 1,2,\ldots,n$$

The EUM is based on a theorem derived from a set of axioms about individual behavior. The approach was developed by Von Neumann and Morgenstern (1947). The axioms are based on the classical utility theory and the general assumption is that people are rational and consistent in choosing among risky alternatives. The set of axioms can be summarized as follows:

(1) Ordering choices

For any two actions, A_1 and A_2, the decision maker either prefers A_1 to A_2, prefers A_2 to A_1, or is indifferent between the two.

(2) Transitivity among choices

If A_1 is preferred to A_2, and A_2 is preferred to A_3, then A_1 must be preferred to A_3

(3) Substitution among choices

If A_1 is preferred to A_2, and A_3 is some other choice, then a risky choice $PA_1 + (1 - P)A_3$ is preferred to another risky choice $PA_2 + (1 - P)A_3$ where P is the probability of occurrence.

(4) Certainty equivalent among choices

If A_1 is preferred to A_2, and A_2 is preferred to A_3, then some probability P exists that the decision maker is indifferent to having A_2 for certain or receiving A_1 with probability P and A_3 with Probability (1 - P). Thus A_2 is the certainty equivalent of $PA_1 + (1 - P)A_3$.

The expected utility model (EUM) is the basis for much of decision theory under uncertainty. The model provides the expected utility maximization choice criterion that integrates information about the preferences and expectations of a decision maker in order to identify preferred choices under uncertainty. The model, however, is associated with difficulties in measuring preferences, for a decision maker. The most direct way to measure preferences is to estimate a utility function for a decision maker. A utility function relates the possible outcomes of a choice to a single-valued index of desirability. It is an exact representation of preferences but for practical purposes estimating an accurate utility function is not possible because of several reasons. The reasons given in studies cited by King and Robinson (1984) include lack of knowledge about preferences of an individual (Zadeh 1973), shortcomings in interview procedures (Officer and Halter 1968 and Binswanger 1980), and problems in statistical estimation (Knowles 1980).

Some of the problems of estimating utility functions are overcome by using an efficiency criterion to order choices. An efficiency criterion is a preference relationship which provides a partial ordering of choices given specified restrictions on the preferences for a decision maker and, in some cases, the probability distributions of the choices being considered (King and Robinson 1981) Levy and Sarnat (1972) point out that an efficiency criterion divides the decision alternatives into two mutually exclusive sets, an efficient set and an inefficient set. The efficient set contains the preferred choice of every individual whose preferences conform to the restrictions associated with the criterion. No element in the inefficient set is preferred by any of the concerned decision makers. Thus, an efficiency criterion can be used to eliminate some feasible choices from consideration without requiring detailed information about the preferences of the decision maker.

King and Robinson (1984) indicate that efficiency criteria are useful in situations involving one or several decision makers whose preferences are not known but which conform to a specific set of restrictions. They are also useful in analyzing policy alternatives or extension recommendations that affect many diverse individuals. The efficiency criteria that are frequently used include stochastic dominance, mean-variance, and mean-absolute deviation.

Stochastic dominance has been used in various studies to compare insurance, marketing, and production strategies and to compare and select among alternative technology options. Crop insurance studies that have used the criterion include Lemiux, Richardson and Nixon (1982). Marketing and storage strategies studies include Rister, Skees, and Black (1984) and Bailey (1983). Studies to compare crop and livestock production alternatives include McBride (1989), Lee et al (1988), and Zacharias and Grube (1984). Studies on comparing alternative technology options include Lee et al (1985), Lemiux et al (1982), Lemiux and Richardson (1989), and Massey and Williams (1991).

CHAPTER IV

RESEARCH PROCEDURES

This Chapter includes a description of the conceptual framework of analysis and research procedures. The conceptual framework outlines the theoretical and research model that were used in this study, selection of the unit of analysis and the sources of data. Data collection procedures including the study areas, data types, and collection procedures are described. The methods of analysis used in this study encompassing the analytical model, the techniques used to evaluate the impacts of alternative ECF control methods and to compare and select among alternative ECF control methods are also discussed in detail. The data development assumptions outlined include estimation of the important cattle productivity and disease epidemiological parameters and the generation of stochastic yields and prices. Finally, the alternative ECF control methods that were analyzed are discussed.

Conceptual Framework of Analysis

Whole farm simulation was selected as the model of analysis in this study. Simulation modelling was used because it provides the flexibility for dealing with the dynamics and stochastics that are too complex to be represented by rigid mathematical models such as linear and quadratic programming. Simulation also offers the capability for adequate handling of risk faced by smallholder farmers. The other advantages of simulation are: (1) avoids gross aggregation of results over many farms, (2) allows for the contribution of experts from different disciplines to contribute in the evaluation of technologies, (3) allows for the incorporation of risk (price and production) faced by farmers in the analysis, (4) allows for sensitivity analysis, (5) incorporates information from decision makers, and (6) it can be used in the delivery of final research products; that is, results can be used by extension specialists to evaluate technologies for producers.

Because of the flexibility and advantages of simulation models, they are widely used in evaluation of farm practices and technologies as discussed in Chapter III. Furthermore, simulation models are appropriate for farm evaluation studies because of their capability to generate probabilities of survival and other pertinent financial and economic information of interest to policy makers (Perry et al 1986a). Simulation models also accurately approximate the decision making processes of farmers because the assumptions of profit maximization and perfect knowledge are unnecessary (Patrick and Eisgruber 1968). Since the output data of stochastic simulation models are themselves random, stochastic dominance can be used to rank stochastically generated observations to identify the strategies preferred by individuals with different risk attitudes (Hadar and Russell 1969). In addition, non-economic costs and returns influencing subsistence behavior can be considered with relative ease.

Research Model

The Technology Impact Evaluation Simulator (TIES) model was used in this study. The model was developed by Richardson, Mukhebi and Zimmel (1991) and was tested, refined, and validated with data from farms in Kenya. The TIES model has attributes similar to the FLIPSIM model that has been widely used in the United States as outlined in Chapter III. However, TIES was developed specifically for use in developing countries by incorporating farm production and consumption aspects that are characteristic in these countries. The TIES model provides a consistent method for evaluating the financial and economic impacts of technology changes on a whole farm basis which explicitly incorporates risk. The model also includes a family nutrition component which projects the impacts of technology and management on the quantity and quality of food in the diet consumed by the household. The components of the TIES model are described under the analytical methods sub-section that follows later in this Chapter.

TIES is a Monte Carlo computer simulation model designed to assess and predict the financial and economic impacts of alternative technologies, production practices, and policies on representative or typical smallholder farms in developing countries. Whole-farm simulation is the core of the model. The model simulates annual production, consumption and marketing activities of a farm over a 1 to 10-year planning horizon. TIES is a Monte Carlo model in that exogenous variables influenced by weather (such as crop yields and milk production per cow) and market forces (crop and livestock prices) are drawn at random to simulate the uncertainty and risk faced by farmers.

The TIES model incorporates farm production activities, such as crop mix, yield, production, family consumption, livestock feeding, and marketing. The livestock production activities in the model include breeding, calving, culling cows, raising cow replacements, bull replacement, family consumption, milking, and marketing. The annual economic activities included in the model are calculation of variable and fixed costs, debt repayment, machinery depreciation and replacement, family consumption, off-farm income, marketings and total receipts, income taxes, government payments, and balance sheet values (assets and liabilities). Risk associated with crop yields, livestock production (calving rates, rate of gain for calves, and milk production per cow), crop prices, and livestock prices are estimated within the model from empirical probability distributions.

The computation components of the model include accounting equations, identities, and table look-up functions. No econometric relationships with fixed parameters are included in the model. Accounting equations are used to calculate crop production, crop sales and crops used on the farm both for livestock feed and household consumption. Identities are used to calculate crop and livestock receipts and herd dynamics due to death loss and off-take. Table look-up functions are used to generate stochastic crop prices and yields, as well as livestock production and prices from multivariate empirical probability distributions. Accounting and time delay equations are used to calculate livestock production, household consumption and calf growth to replacement age for oxen and cows. Similar identity and accounting equations are included for sheep, goats and pigs.

Selection of Unit of Analysis.

The diversity of small farms, not only in Kenya but in most developing countries creates special problems in undertaking analyses that can be generalized for a wide region. The small-farm systems are characterized by different patterns of resource endowments, production opportunities, skills, beliefs and preferences. Generalized solutions for such systems are almost impossible to achieve, while the number of farms is generally too large to permit analysis of individual cases (Valdes, Grant, and Dillon 1984). However, analysts use various ways to overcome these problems. The three main approaches are case studies, representative farms, and sample surveys.

In the case study approach, a few farms are chosen, not as much as for their representativeness but for being typical and suitable for analysis. For example, farmers who keep records or who are more articulate than most are selected. The justification for the case study approach is that it allows an intensive study of one or a few typical farms from which insights of general or widespread relevance to the population of farms may be gained. Any unusual features of a particular farm studied are accepted and accounted for in interpreting the results.

The representative farm approach, by contrast, involves real or hypothetical farms that are selected to "represent" the population of farms in some characteristics. However, lack of data in most cases means that the representativeness is very limited. Hence, the extent to which the results from analysis of such farm models can be generalized for the population of farms in an area remains questionable, especially, when hypothetical average farms are used.

The sample survey approach involves random sample farms that are drawn from a target population of farms. In principle, the issues under consideration are investigated for each farm selected in the sample. The results are then related using statistical methods to generalize for the population. If the survey method is based on appropriate stratification of the target population, it is somewhat similar to the representative-farm approach. The distinguishing feature however, is that more farms are investigated in the sampling method. This is however, a major disadvantage because a relatively large sample will often be needed to represent the farms for conventionally accepted statistical precision. Furthermore, the implied analytical load requires substantial resources to investigate the farms and analyze the data.

The problems associated with the approaches that can be used to select farms for analyzing smallholder farming practices compounds the problem of analysis. However, the method used is usually based on the focus of analysis. The sample survey approach is usually appropriate for descriptive and statistical analyses. Case and representative farm approaches are appropriate for detailed investigations, particularly for farm planning and evaluation of technologies or management practices on farms. The case study approach was used in this study.

Sources of Data

This study used primary and secondary data. Primary data were collected from farm surveys in Uasin Gishu and Kilifi Districts of Kenya (Figures 4.1 and 4.2). The survey data were supplemented with secondary data from surveys undertaken by ILRAD and other existing records, particularly from the Ministry of Livestock Development reports. The emphasis on secondary data collection was on ticks and tick-borne disease control practices. These data included the costs of tick and tick-borne disease control technologies and the technical coefficients on cattle productivity associated with alternative control methods.

Data Collection Procedures

The Study Areas

The study areas were Uasin Gishu District in the Rift Valley Province and Kaloleni Division of Kilifi District in Coast Province which are shown in Figures 4.1 and 4.2. Uasin Gishu

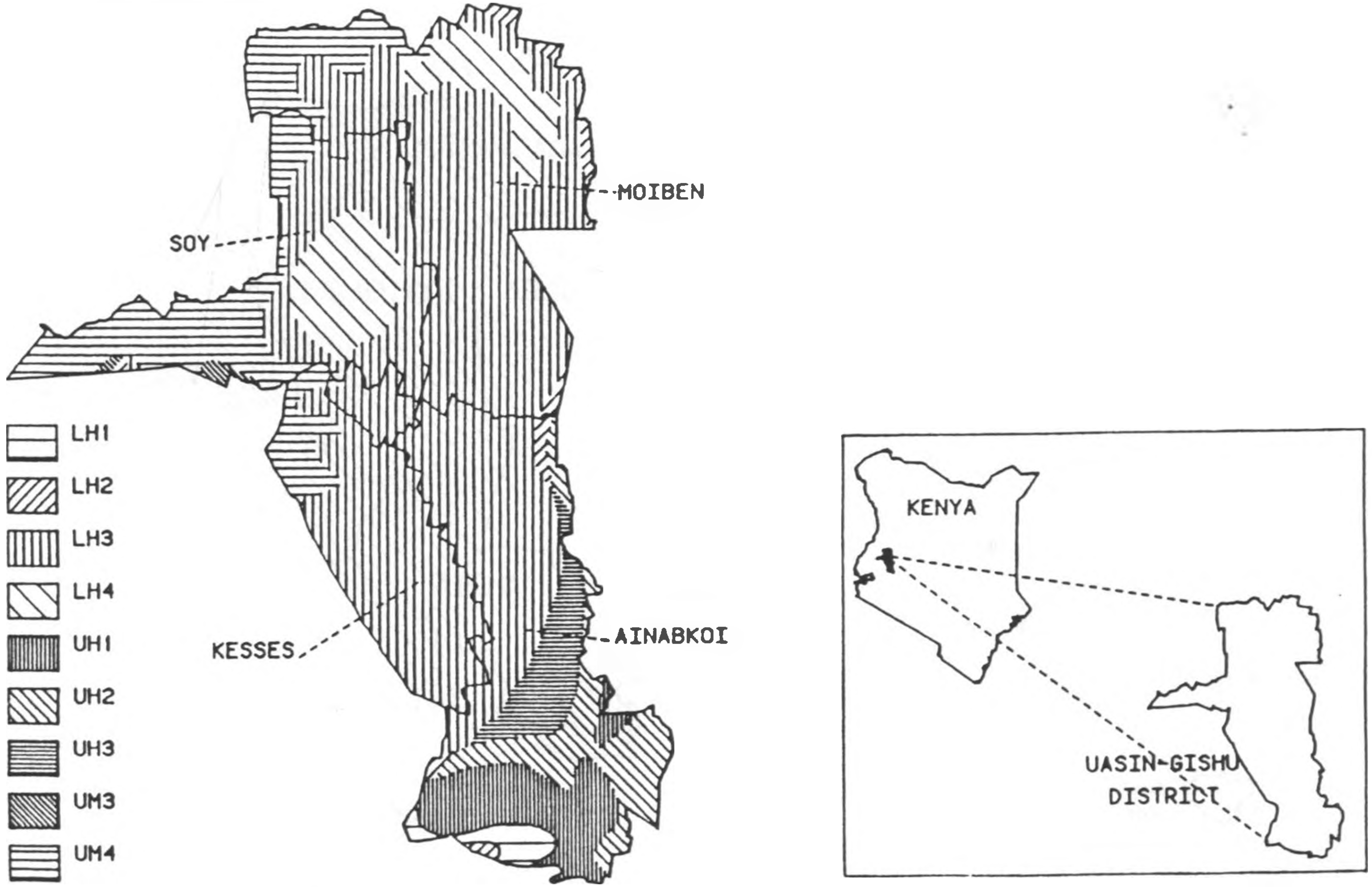

Figure 4.1: Divisional Administrative Boundaries and Agro-ecological Zones for Uasin Gishu District, Kenya.

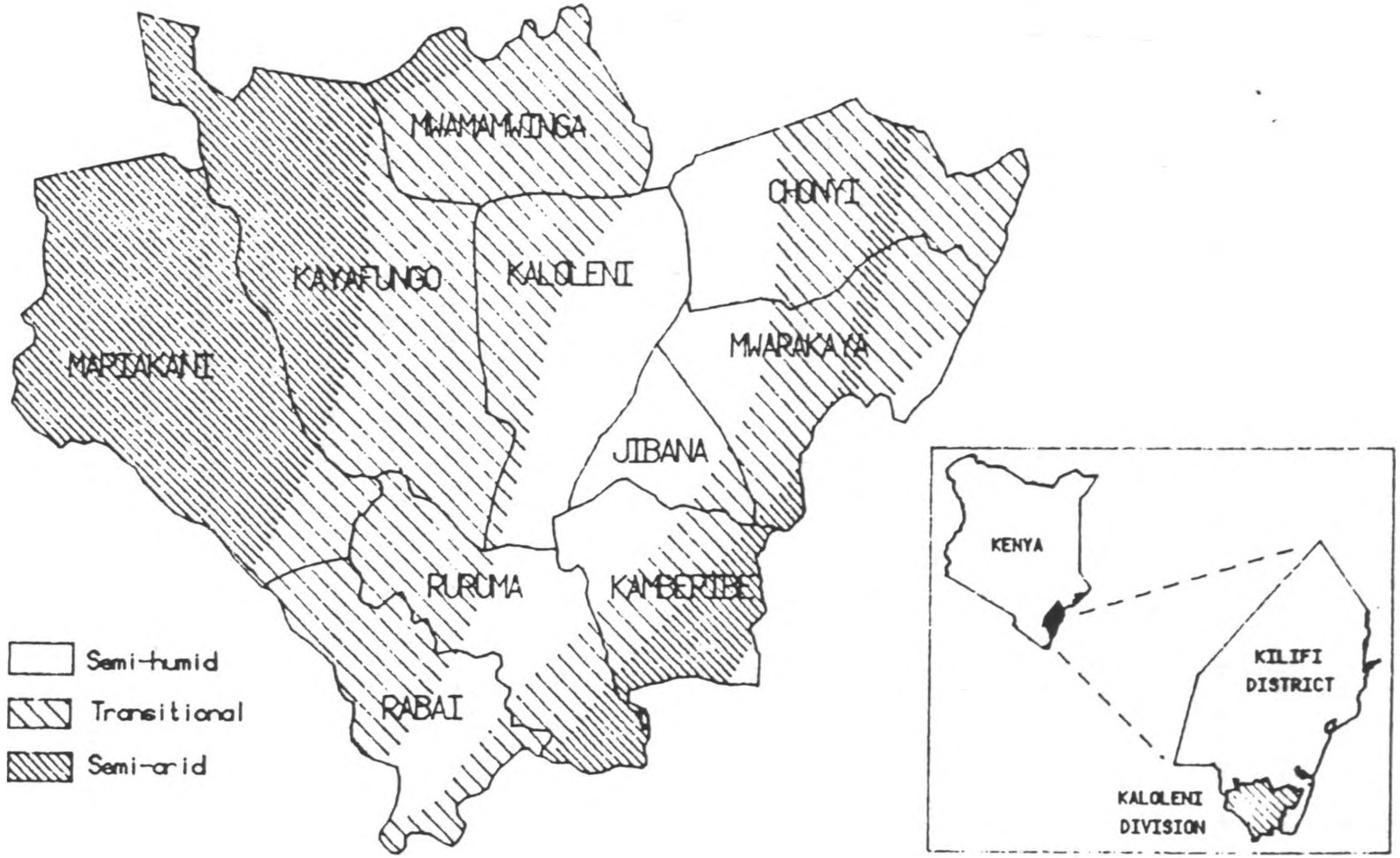

Figure 4.2: Administartive Locations and Agro-ecological Zones for Kaloleni Division, Kilifi District, Kenya.

District lies in the high potential highland areas of the country. The climatic conditions are cool and wet which makes the area suitable for the keeping of Grade cattle. Kaloleni Division on the other hand, lies in the medium potential coastal areas of the country. The climatic conditions are warm and humid. Although Grade cattle are kept in the area, the climatic and environmental conditions are not as suitable for keeping Grade cattle as they are in the highlands. The two areas were chosen for the study to provide a comparative analysis of the impacts of alternative tick and tick-borne disease control methods on small-scale farms under different environments. Furthermore, the two areas are targeted for pilot immunization of cattle against ECF by the Kenya Agricultural Research Institute.

Uasin Gishu District

Uasin Gishu District is comprised of four rural divisions and one urban division as shown in Figure 4.1. The divisions are Anaibkoi, Kesses, Moiben and Soy, and the urban town of Eldoret. The District occupies an area of 3,478 km^2 and has a population estimated in 1979 at 300,766 persons (Curry et al 1991). The population density was estimated at 89 persons per km^2 although it varies from division to division ranging from 62 persons in Moiben Location to 92 persons per km^2 in Kaptagat Location.

Most of the district of Uasin Gishu is situated on the Uasin Gishu plateau, which ranges in altitude from 1900 to 2700 meters above sea level. Maximum temperatures vary from 19^0 to 24^0 C, and minimum temperatures range from 13^0 C to 16^0 C. The average annual rainfall ranges from 900 to 1100 millimeters and has a bimodal distribution pattern with peaks occurring in April and August (Jaetzold and Schmidt 1983). Because of the climatic variation, the district can broadly be classified into three clusters of agro-ecological zones (AEZ) as shown in Figure 4.1. The clusters are: the upper midland zones (UM3 and UM4) which cover most of the western and northern parts of the district; the lower highland zones (LH1, LH2, LH3 and LH4) which cover much of the central parts of the district; and the upper highland zones (UH1 and UH2) which cover the southeast parts of the district.

The agro-ecological zones are important in delineating the dominant farm activities. For example, in Uasin Gishu District, although maize growing and dairying are dominant farm enterprises in all parts of the district, different farm activities are also best suited to each agro-ecological.zone. The upper midland zones (UM_s) are marginal coffee areas dominated by sunflower and maize growing. The lower highland zones (LH_s) are dominated by wheat, maize and barley growing as well as sheep and dairy cattle keeping. The upper highland zones (UH_s) are dominated by wheat, maize and pyrethrum growing and keeping of sheep and dairy cattle

Kaloleni Division

Kaloleni Division is one of ten administrative units in Kilifi District as shown in Figure 4.2. Kaloleni Division occupies an area of 915 km^2. The population of Kaloleni Division in 1989 was estimated at 200,000 persons with a population density of 218 persons per km^2 (Kilifi, 1991). The division is mainly rural but it is at the proximity of Mombasa town which is the second largest city in Kenya, with an estimated population of 700,000 people. The city provides a ready market for agricultural products from the division and it also provides opportunities for off-farm employment for most people in the area.

Kaloleni Division is dominated by the coastal uplands with a range in altitude of 250 to 350 meters above sea level. The mean annual rainfall is between 800 mm to 1350 mm and is generally bimodally distributed. The rains are highly variable both in annual quantity and distribution. The first rains occur in March to May while the second rains occur in October to November. The second rains are particularly variable and are unreliable for crop production (Thorpe et al 1991). The mean monthly temperatures range between 28^0 and 33^0 C, while the mean monthly minimum temperatures vary from 14^0 to 21^0 C. Relative humidity is generally high at about 70% throughout the

Kaloleni Division is divided into three main agro-ecological zones as shown in Figure 4.2. These are; the semi-humid zone (CL3); the transitional zone (CL4); and the semi-arid zone (CL5). The semi-humid zone (CL3) has the highest average annual rainfall ranging from 1000 mm to 1250 mm and is the area best suited for keeping grade cattle in Kaloleni Division. The zone has also the highest potential for crop production in Kaloleni Division. The major crops grown include cashew nuts, citrus fruits, mangoes, coconuts, cassava, sorghum, maize and a variety of vegetables.

The transitional zone (CL4) has an average annual rainfall which ranges between 850 mm to 1100 mm and is the transitional zone between zones CL3 and CL5. The same crops grown in zone 3 are also grown here but the production potential is low. Both Grade and Zebu cattle are also kept in this zone. The semi-arid zone (CL5) has an average annual rainfall which ranges between 750 mm to 860 mm. The rains occur for a very short period during the rainy season in March to May and, consequently the length of the season for growing crops is very short. The zone is predominantly a livestock area and Zebu cattle are dominant here. The environmental conditions, particularly the high temperatures, are not suitable for the keeping of Grade cattle.

Study Design

The unit of analysis for this study was the household farm. A household as used in this study refers to a group of individuals who operate a farm as a unit under one household head, and whose production and consumption decisions are made within the unit. Consequently, a household farm is a family farm whereby production and consumption decisions are made under one household head. In selecting the case farms for study, two steps were undertaken.

The first step was to select the areas within the study regions where the case farms were selected. Selection of these areas was based on stratification of the study sites by the major factors considered to be important in causing significant variation in cattle production and disease epidemiology. The stratification was based on previous surveys in the two regions for studies related to application of the infection and treatment method of immunization against ECF (Huss-Ashmore and Curry 1991, Curry et al 1991, and Mukhebi et al 1991). The main factors that were found to be important for stratification in both regions were size of the farm hectarage, type of cattle kept and agro-ecological zone.

Farm size represents resource endowments of farmers with large farms having more resources than small farms. The size of small farms varies from region to region. For example, the size of small-scale farms in Uasin Gishu are larger than those in Kaloleni. Hence, the classification of farms in Uasin Gishu and Kaloleni was different. In Uasin Gishu, small farms were those less than 4 hectares, medium farms were those between 4 and 20 hectares, while large farms were those over 20 hectares but less than 40 hectares. In Kaloleni Division, small farms were those less than 4 hectares, medium farms were those between 4 and 8 hectares, while large farms were those over 8 hectares but less than 40 hectares. Farms larger than 40 hectares in both Uasin Gishu and Kaloleni were considered to belong to the category of large-scale farms which were not considered in this study.

Classification according to cattle types was based on the proportion of Grade and Zebu cattle in the herd. A Grade cattle farm was one in which the number of non-Zebu cattle (exotic breeds and crosses) was predominantly in the herd. For a Zebu cattle farm, the type of cattle in the herd was predominantly Zebu (80% or more). Classification of areas by agro-ecological zones was based on the three main classes for each region; zones UH, LH and UM for Uasin Gishu; and zones CL3, CL4 and CL5 for Kaloleni as described before. The importance of classifying areas into agro-ecological zones was in relationship to the likely effects of climatic conditions on the incidence of ticks and tick-borne diseases. Zones were envisaged to differ in the incidence of the diseases because of the differences in temperatures and rainfall which affect the intensity of ticks in a given area. Wet areas are more likely to have a higher tick incidence than dry areas. Areas with a higher intensity of ticks require more intensive tick control methods. Otherwise, the mortality rates in cattle are higher. Thus, the costs of controlling ticks and the associated cattle losses vary from one agro-ecological zone to another in the same region.

Each region was stratified first into the different agro-ecological zones. Each agro-ecological zone was then stratified according to farm size. Finally, the farms were selected according to the type of cattle that was dominant on the farm. Thus, from each region there were 18 cells from which case farms were to be selected for detailed investigation. The cells from which farms were selected are three agro-ecological zones, three classes of farm size and two groups of cattle types. Data were originally to be collected from 18 farms in each region However, during the actual data collection phase in the field, farms with required characteristics, such as cattle types according to selected farm size, were not found for some cells within some of the delineated agro-ecological zones in the regions. Consequently, data were collected from 29 farms, 15 farms in Uasin Gishu District and 14 farms in Kaloleni Division.

The selection of farmers for interview was done using the available records from previous studies and assistance by field extension staff of the Ministry of Livestock Development in the regions. For Kaloleni, the records of 77 farm households from a previous study (Mukhebi et al 1991) were used. The farmers were selected on the basis of their knowledge and willingness for interviews. The selection relied in part on the experience of a technical research assistant[3] at ILRAD who had worked in the area before. In Uasin Gishu, farmers were selected from a list of land registration units in different agro-ecological zones in different divisions in the district that had been used for a previous study (Curry et al 1991). The final stochastic simulation analyses reported in this study used only 12 farms, six from each region (Uasin Gishu and Kaloleni). The farms for each region were three farms classified as small, medium and large for Grade cattle and three farms classified on the same basis for Zebu cattle.

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[3] Mohammed Baya assisted in the selection of farmers and also in carrying out the interviews.

Data Types and Collection

A structured and pretested questionnaire (appendix I) was used to collect data from the selected case farms. Individual farmers and members of their households were interviewed through single-day visits. Data collected included all of the farm resources and enterprises, yields, inputs, output and input prices, and production and management practices of the enterprises on the farms. Data on farm assets, liabilities, off-farm investments and income, crop and livestock sales, and consumption as well as food requirements by the household were also collected from the case farms.

Data measurements relied heavily on recall memory of the farmer and that of household members. Field and farm crop acreage, livestock numbers , production inputs, outputs and prices were given by the respondents. In cases where records were available such as title deeds for farms, payments for milk sales and other products, the recorded values were used. Annual crop hectarage and yields were based on previous year results. Respondents were also asked to provide the values of off-farm employment and off-farm investments and to estimate household expenditures on food items as well as non-food items.

Analytical Methods

The TIES Model

A systematic overview of the simulation steps in the TIES model is shown in Figure 4.3. A detailed description and documentation of the model is given in Richardson and Mukhebi (1992). Selected aspects of the simulation model including the main sections of the simulator are discussed in the following sub-section.

At the outset of the simulation, the TIES model reads and processes input data for the farm to be simulated. The input data are a complete description of the initial farm situation and its economic environment. Simulation can be deterministic or stochastic. Deterministic simulation is a multiple-year analysis in which the prices and yields are fixed at their means as

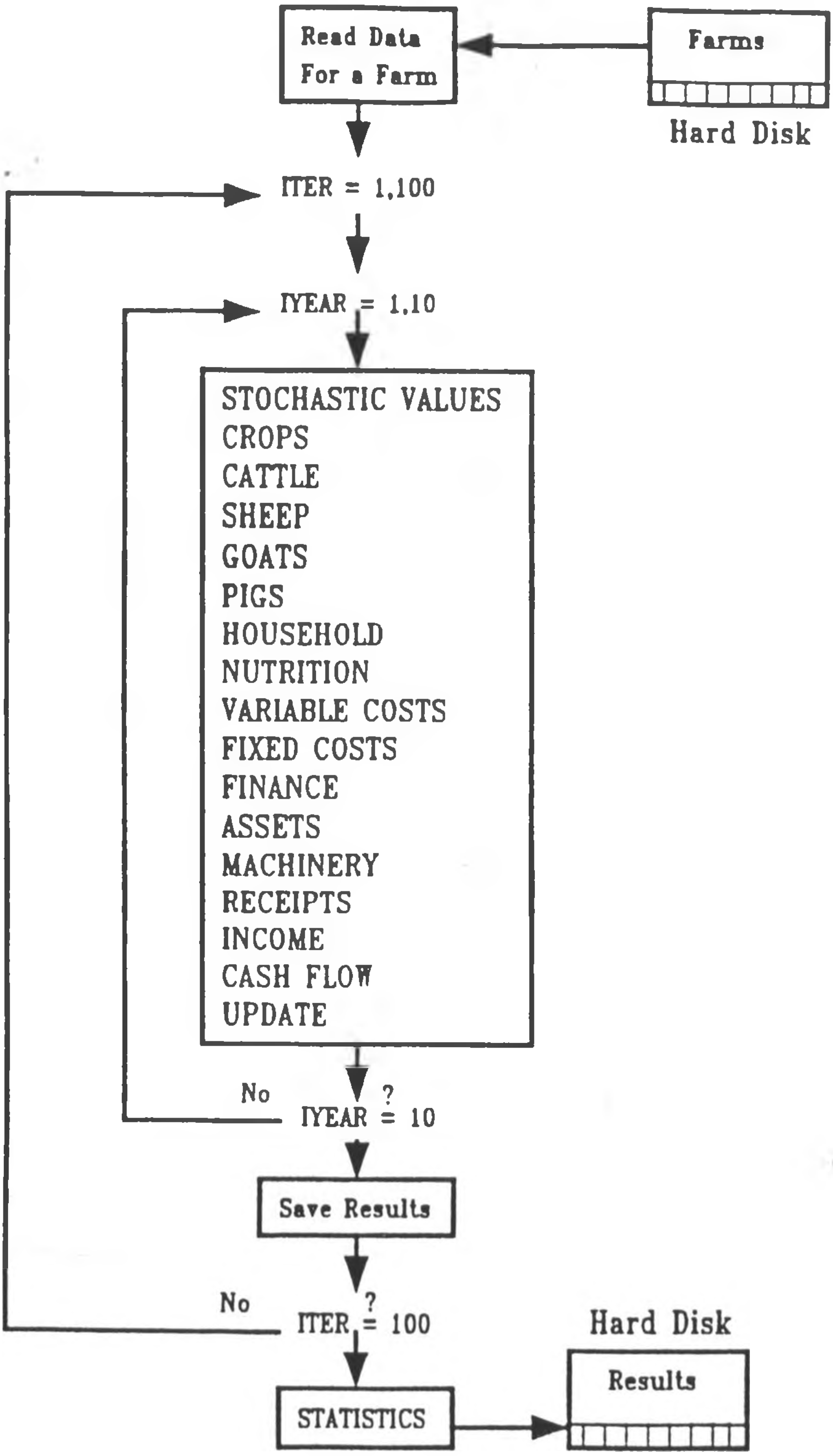

Figure 4.3. Schematic Diagram of the TIES Model

specified by the analyst. Stochastic simulation on the other hand is a multiple-year analysis in which yields and prices are drawn at random from multivariate empirical probability distributions. In this study, a deterministic simulation was first done to validate the model before using it for stochastic simulation which was the focus of the analysis.

Stochastic Values

In this stochastic simulation, a 10-year planning horizon was simulated recursively by using the ending year information for one year as the beginning information for the next year. For each year of the planning horizon, the model performs the same functions in the fixed order depicted in Figure 4.3. The first calculation determines crop and livestock prices and production levels (STOCHASTIC VALUES in Figure 4.3). The model uses a pseudo-random number generator to develop stochastic prices and production levels for crops and livestock. Information to generate stochastic values from empirical probability distributions for these variables is pre-defined prior to using the model. The use of a pseudo-random number generator insures that the same stochastic forces influence both the base and the alternative technology under consideration. At the end of each year, the results are summarized and saved for further analyses. The environment is returned to its initial state so the next iteration can be simulated with the same initial conditions.

Crops

The model is capable of simulating 20 different crops following stochastic or deterministic yields. Computation of the production of each crop is calculated using the number of planted and harvested hectares in the CROPS section. The produced crop output is then available for family use, cattle feed, or sale. Final disposition is based on family and livestock needs.

Cattle

The cattle herd is simulated assuming a specified herd size and structure (number of cows, oxen and bulls) to be maintained over time in the CATTLE section. The number of cows, oxen and bulls can decrease, remain constant, or increase from year to year based on the assumptions for the technology scenario being analyzed. The model maintains a pre-specified herd size by raising male and female calves for both sale and replacement.

The model calculates the number of female and male calves born based on the calving rate of the cows. The calves can be grown for replacements, sold or consumed on the farm depending on the desired herd and needs of the producer. The proportions in each use are specified by the analyst based on the information given by the farmer. The proportion of calves that die is calculated based on the specified technology and production practices on the farm If a surplus of cows and oxen exist after culling the adults and accounting for home consumption and death losses, the surplus adult animals are sold. The fraction of animals that die, the fraction consumed on the farm, and the fraction sold are specified according to the actual farm conditions and the technology being considered.

Cattle can also be culled if a drought occurs. A drought is defined to occur when forage production falls below defined forage levels. These levels are specified with respect to the ratio of forage demanded by cattle, sheep and goats relative to forage production. The specification of this percentage allows evaluation of different management strategies for defining and dealing with a drought. In the event of a drought, cattle are culled based on different culling percentages for each class (age group and sex) as desired by the producer. Similar culling percentages are provided for culling goats and sheep during a drought. Once forage production returns to the pre-defined range of normal production, the herd (or flock) is gradually rebuilt to its original level by retaining females.

Receipts

Cash receipts from cattle sales come from scheduled and unscheduled sales. Annual sales of calves and culled cows, replacements, bulls, and oxen account for scheduled sales. Unscheduled sales are forced sales brought on by drought. Receipts in both cases are calculated as the product of the number of head sold in each age group and the stochastic (or average) price for the respective age group. Cash receipts for sheep, goats and pigs are calculated in the same manner. Milk production for the farm is calculated based on the number of mature cows and the annual production of milk per cow. After subtracting family consumption of milk, the remainder is sold at the stochastic milk price (or average). Cattle which are consumed by the family produce hides in addition to meat. Animals that die also produce hides that are either used on the farm or sold. Surplus hides are sold. Manure production is calculated for each age cohort of cattle and any surplus, after meeting on-farm needs, is sold. Traction provided by oxen, less on-farm use, is another source of income. In the event that milk, hides, or manure production is less than the quantity needed on the farm, the deficit is purchased at prevailing market

Crop surpluses are sold in the CROP RECEIPTS section of the model. Receipts for each crop are calculated as the product of surplus production and the price of the crop. Surplus production is defined as total production less household and livestock demands. The value of crops, livestock, and livestock products consumed by the household are valued at current market prices, which are the per unit shadow prices for economic analysis

Sheep, Goats or Pigs

In addition to cattle, TIES is capable of simultaneously simulating a sheep flock, a goat herd and/or a pig herd. Information required to simulate sheep, goats and pigs need not be as detailed if the technology to be evaluated is for cattle. However, the number of each class (age and sex) of sheep, goats or pigs should be specified at the beginning of each year. Death losses, fractions of the livestock kept for breeding or consumed at home should be also be specified. Surplus sheep, goats and pigs are sold while, the breeding stock is maintained by raising replacements or purchases. Feed requirements for sheep, goats and pigs are calculated based on annual feed required per head. If feed shortages exist, sheep, goats or pigs, are culled based on the pre-defined rules for culling.

Household

Calculation of family demands for crop production as food are based on the specified values for the quantity of each crop eaten per adult consuming unit and the number of adult consuming units in the HOUSEHOLD section. If production of a crop is adequate to meet family needs, the surplus may be fed to livestock or sold at market prices. If production of a food crop does not meet family needs, the model attempts to purchase the needed food at prevailing prices. Deficit food needs are met by purchasing foods if adequate cash can be raised from the following: (a) cash reserves, (b) off-farm employment, (c) selling sheep, (d) selling goats, (e) selling hogs, and/or (f) selling cattle. Cash needs for food purchases are raised in the order listed. Selling livestock follows the rule of selling the youngest animals first and selling adult females last. If sufficient cash cannot be raised to meet food demands, the deficit is recorded and reflected in the index (nutrient sufficiency index) used to calculate the ability of the farm to meet food demands of the family.

Nutrient

The nutrient values for the family's diet are calculated based on the amounts actually consumed in the NUTRIENT section of the model. Total calories (kilocalories), protein (grams), calcium (milligrams), iron (milligrams) and Vitamin A (micrograms) in the diet of an adult consuming unit is calculated based on the quantity of each food crop and livestock product consumed and the nutrient properties of each food item. The model calculates two nutrient indices to determine both the qualitative and quantitative food adequacy of the household. The indices are the Index of Nutrient Quality (INQ) and the Index of Nutrient Sufficiency (INS). The INQ is an index that measures the quality of the diet in terms of the proportion of nutrients present relative to calories. The INS on the other hand, is a measure of the adequacy of the diet in meeting the minimum food nutrient requirement of an adult.

The INS is defined as an index of the proportion of the minimum recommended nutrients (calories, proteins, calcium, iron and vitamin A) for an adult provided by the diet:

$$INS = \left(\left[\sum_{i=1}^{5} \frac{\textit{Available nutrient } i}{\textit{minimum recommended nutrient } i} \right] / 5 \right) * 100$$

Available nutrients are estimated from the diet consumed by the farm family in each planning horizon. The recommended minimum level of the nutrients is the sum of the total nutrients required by the family members. The minimum nutrients required by the household are based on adult equivalent requirements as recommended by FAO for an adult in one year (FAO 1988). If the INS is greater than 100, then the diet meets the minimum recommended quantity of nutrients, and therefore, the family is self sufficient in food quantity. However, an INS less than 100 suggests a diet with less than the minimum recommended nutrients. An INS less than 100 can occur if the farm is unable to earn sufficient cash to purchase foodstuffs or disease and/or drought reduces the livestock herds.

The INQ is an index of the proportion of the nutrients (proteins, calcium, iron and vitamin A) available in the diet of an adult relative to calories. It is a measure of the quality of the diet. The index is calculated as:

$$INQ = \left(\left[\sum_{i=1}^{4} \frac{\textit{\% of Available nutrient } i \textit{ of minimum required}}{\textit{\% of available calories of minimum required calories}} \right] / 4 \right) * 100$$

An INQ of 100 implies a well-balanced diet in all nutrients. An index greater than 100 implies that the diet is low in calories when compared to other nutrients in the diet. On the other hand, an INQ of less than 100 implies that the diet is high in calories compared to other nutrients in the diet. Too much of the other nutrients in the diet compared to calories is nutritionally undesirable because it is a sign of carbohydrate malnutrition. Similarly, a diet with too much carbohydrates compared to other nutrients is nutritionally undesirable because it is a sign of malnutrition in proteins, vitamins and minerals. A quality diet should have a balance of nutrients. The INQ, however, does not indicate whether or not the diet provides adequate amounts of nutrients. Hence, both INQ and INS can be used to evaluate the potential impacts of a technology on farm family sustainability. However, in this study INQ and INS were not used as a criteria of evaluating the alternative ECF control methods.

Variable Costs

Variable costs of production are calculated for each enterprise and summed to obtain input costs in the VARIABLE COSTS section. The variable costs of production for crops include all production expenses, harvesting and marketing. Harvest costs are calculated by multiplying the production of each crop times its per unit harvesting cost. The variable costs for livestock include several expenses such as breeding, purchased feed, disease treatment, immunization, acaricide, Helminth and other health costs. The costs can be calculated separately for each class (age group and sex) of livestock on a per head basis or on a per herd basis, such as a cow herd. The per unit variable costs for crops and livestock are inflated annually using specified pre-determined annual rates of inflation. However, when the analysis is in constant prices the inflation rates are zero.

Fixed Costs

Fixed costs for un-allocated maintenance, bookkeeping, depreciation, interests on loans and permanent labor are calculated for the whole farm business in the FIXED COSTS section. The costs can also be inflated using pre-defined inflation rates or they can be held constant when constant prices are used.

Finance

All long- term and intermediate-term loans on the farm are amortized based on pre-defined loan life, initial loan amount, and annual interest rate in the FINANCE section of the model. All loans are amortized using the remaining balance formula. Variable interest rates are permitted for both existing and new loans. New loans can be obtained for machinery replacement, livestock purchases, and meeting cash flow deficits.

Assets

The market values of land, machinery, and other assets are estimated in the ASSETS section of the model. The values can be inflated using specified annual inflation rates or they can be kept constant for constant prices. The value of cattle, sheep, goats or pigs is updated annually based on market price and the number of head in each age cohort. Total assets are available cash plus the value of land, machinery, improvements, cattle, sheep, goats, pigs and crops held for sale or as livestock feed.

Machinery

Machinery on the farm is depreciated assuming a straight line depreciation schedule with 10-percent salvage value and the economic life specified by the analyst for each machine (MACHINERY section). Each machine is replaced at the end of its economic life if sufficient cash and borrowing capacity exist. Machinery replacement can be delayed one year if borrowing capacity is limited. Machinery can either be replaced by selling the old item or by trading it in for its replacement.

Total Receipts and Net Income

Receipts and expenses from all sources are summed to compute values for the income statement in the RECEIPTS and INCOME sections of the model. The sum of annual crop receipts, cattle receipts and farm income from other livestock enterprises constitute the total receipts in the income statement. Costs for the income statement calculated in other sections of the model include crop costs, livestock costs and fixed costs. Net cash farm income is calculated as the total cash receipts minus total cash expenses. Net farm income is equal to net cash farm income minus depreciation allowance plus the value of household consumption minus the value of non-cash costs.

Cash Flow

The household annual cash flow is calculated in the CASH FLOW section of the model. The positive components of the cash flow are net cash farm income from the income statement and off-farm income. Debits or the outflow are down payments for machinery and livestock, principal payments and family living expenses. Cash flow surpluses earn interest at a specified interest rate and deficits are met by borrowing against equity. If a farm is unable to meet a cash flow deficit by borrowing against equity in land, machinery, and livestock, it is declared insolvent and the iteration is terminated.

Household living expenses, excluding the value of crop and livestock consumption, are calculated using a bounded linear consumption function specified by the user. The lower and upper bounds for cash family living expenses are pre-defined by the analyst.
The marginal propensity to consume out of disposable income is also specified by the analyst for the farm family household being analyzed. Cash family living expenses are subtracted from cash income in the cash flow statement.

Balance Sheet

The farm balance sheet information is summarized at the end of each year. The market values of land, machinery, livestock, and crop stocks are estimated at the end of the planning horizon. Cash on hand is calculated from the cash flow statement. Liabilities on long- and intermediate-term assets are calculated as the remaining balances after amortizing existing loans and adding any new loans to cover cash flow deficits or livestock, machinery and food purchases. Net worth is the difference between assets and liabilities.

Update Function

The last activity of the model in each year updates the relevant values for the next year in the UPDATE section of the model. Ending debts at the end of the year become the beginning debts on the first date of the following year. Similarly, ending assets become the beginning assets. At the end of the last year simulated, the model summarizes the output values from deterministic or stochastic analysis.

Evaluating Impacts of Alternative Technologies

Evaluation of the economic impacts of alternative technologies on a farm using TIES is a two step process. First, the model simulates the base farm (without new technology) over the planning horizon period and calculates the results of the key output variables. The key outputs from the stochastic analysis include net present value, ending net worth, beginning net worth, cost-benefit ratio, internal rate of return, average annual cash receipts, average annual cash expenses, and average annual net farm income. The second step is to simulate the farm with appropriate changes for the new technology by changing the relevant variables in the model that will be affected by different alternative technologies.

Alternative technologies such as livestock disease control technologies must be defined and specified by indicating how epidemiological disease parameters, physical inputs and yields, and costs change from the base situation. The base situation is represented by the livestock production and management systems currently practiced by the farm being simulated.

In this study, the focus was on evaluating a new method of controlling ECF, the "Infection and Treatment Method." Consequently, the following procedure was adopted. First, the base farm was simulated with the current methods that are used to control ECF. The current control method on the base farm was the methods the farmers were actually practicing. The methods included either no control, or the application of acaricides by dipping, spraying or both dipping and spraying. Second, the farms were simulated with immunization (adoption of ITM). Changes attributable to immunization in epidemiological parameters such as mortality rates (by cattle age class), livestock input parameters such as acaricide and treatment costs, and output parameters such as live weight growth and milk yield were identified and quantified in the input data set. Because immunization against ECF does not control all of the tick-borne diseases nor does it control tick infestation, various combinations of current tick and tick-borne disease control methods with immunization were analyzed as alternative control methods or scenarios. Sensitivity analyses of key parameters such as the cost of acaricide application, cost of immunization, changes in productivity, and mortality rates were also undertaken.

Comparing Alternative Technologies

The specified alternative ECF control methods were compared for financial and economic performance using the key output variables in TIES. The compared parameters were the means, standard deviations, minimum and maximum values of simulated annual cash receipts, annual cash expenses, annual net incomes, net worth, internal rate of return, and benefit-cost ratio. To evaluate the financial and economical impacts of the alternative disease control methods, three major criteria were used. The criteria were probability of farm survival, probability of economic success, and stochastic dominance.

Probability of Farm Survival

Farm survival was evaluated using the probability of financial survival. Financial survival was determined by the probability that the farm remains solvent over the simulation period. Solvency is a financial measure that indicates whether or not the farm business assets cover the liabilities. For a farm to survive financially, it was expected to maintain an equity to asset ratio equal, or greater than a specified minimum for each of the planning horizons. The minimum is determined from the charge on borrowed funds for refinancing a cash deficit. Usually farmers are assumed to borrow funds from official credit agencies such as commercial banks or government lending institutions. The criterion for lending funds to farmers varies, but most importantly, is the capability of the farmer to repay the loan. The capability is reflected by the ability of the farmer to pay the annual interests on the loans and part of the principal.

In practice, most small-scale farmers rarely borrow from formal lending agencies but fund negative cash flows from other sources such as funds borrowed from relatives. The criteria for borrowing and the charge on the borrowed funds from informal sources varies according to the source. However in this study, the interest rate charged by commercial banks for borrowed funds was used as the minimum equity ratio required for borrowing. If the equity to asset ratio is equal or greater than the minimum financial ratio, the farm was assumed to be solvent. The assumption was that the farm would be able to borrow funds against its assets to refinance the cash flow and therefore it would not be declared insolvent. Consequently, the probability of survival refers to the probability that the farm would maintain an equity to assets ratio equal or greater than the minimum level for borrowing funds from commercial banks.

The solvency criterion used to assess the financial survival of the farm was based on the assumption that the farmer aims at satisfying family food needs before aiming at maximizing profits. The analysis was incorporated in the simulation model by giving household consumption needs of farm products a priority before selling them out for cash. Furthermore, if the farm was unable to produce the minimum required food supplies, the model allows the farmer to purchase the products using the available cash, selling livestock, or by borrowing. Refinancing assets to purchase food deficits is a major factor that can contribute to insolvency of the farm and, hence, its failure to survive.

Probability of Economic Success

The second criteria used to evaluate farms was the economic success of the farms. This criterion was evaluated using the net present value or NPV for alternative ECF control methods. The NPV was calculated as the present value of the ending net worth for the farm, plus the discounted annual family cash withdrawals less the farm beginning net worth and discounted annual off-farm income. In simple terms, this is equivalent to the difference between the present values of the benefit stream less the present values of the cost stream.

In traditional financial and economic analysis, a positive NPV denotes economic success because farm income, in addition to the capital gains on assets, generates a return greater than the discount rate or the return on alternative investments. The estimated NPV in the traditional analysis is assumed to be a deterministic value. However, in risk investment analysis, the estimated NPV value is an expected value which is estimated from a distribution of values with specified probabilities of occurrence. Given the discount rate used to calculate NPV, the probability of generating an expected value greater or less than the discount rate can be estimated. Because a NPV value greater than the discount rate denotes economic success, the probability of economic success can be calculated. Hence, the probability of economic success was defined as the probability that the farm will generate a rate of return greater than the discount rate used in calculating NPV. The higher the probability the higher the investment was ranked than the alternatives with lower probabilities.

Economic success of the farm was also analyzed using IRR, BCR and the ratio of ending net worth to beginning net worth. Economic success using IRR or BCR was calculated as the probability that the estimated value for each of these variables was equal or greater than the cut-off level for acceptance of the investment. Thus, economic success using IRR was estimated as the probability that the calculated IRR was equal or greater than the discount rate. For BCR, economic success was defined as the probability that the calculated BCR was greater than or equal to 1.0. Just as for the case of NPV, the higher the probability of success for the calculated IRR or BCR, the higher ranked the investment compared to investments with lower probabilities. Economic success using the ratio of ending net worth to beginning net worth was estimated as the probability of lowering real equity. Therefore, economic success on the basis of lower real equity was defined as the probability that ending equity to beginning equity ratio was less or equal to 1. The lower the probability the higher ranked the investment compared to the alternatives with higher probabilities.

The use of the probabilities of economic success in addition to using the traditional levels of accepting or rejecting investments using each of the criteria (NPV, IRR, BCR or equity ratio) indicates the conviction levels that the expected value would occur within the required cut-off levels. Estimation of the probabilities of economic success are important because in stochastic simulation analysis, the estimated values for the criteria under consideration may lie above or below the cut-off level. One or a few extreme values in the distribution might occur and cause the expected value to be higher or below the cut-off value for the criteria than is usually the case. Thus, the calculated expected value without an indication of the probability of occurrence might lead to an erroneous conclusion in accepting or rejecting the investment.

Stochastic Dominance Ranking

The third criterion used was to rank the alternative cattle ECF control methods and to calculate the associated conviction premiums. The NPV cumulative distributions from alternative disease control methods were ranked using the stochastic dominance criterion to identify the strategies preferred by farmers with different attitudes to risk. This risk analysis criterion has been used widely in investment portfolio studies and in appraising technological studies to delineate the efficient choice set. The preference of the producer rankings are also extended to calculate conviction premiums to determine shadow prices for the preferred alternative ECF control strategies for the farmers. The stochastic dominance criterion that was used to rank the strategies is discussed in the following section.

Stochastic Dominance Analysis

Stochastic dominance is a method used to screen out inefficient, risky choices (alternative technologies or any other production or marketing strategy) that can be considered by a decision maker. Stochastic dominance is an efficiency criterion which has been widely used in agricultural economics studies to compare and select among alternative risky choices of decision makers as indicated in Chapter III. The three forms of stochastic dominance that are commonly used are first degree (FSD), second degree (SSD), and stochastic dominance with respect to a Function (SDWRF) or general stochastic dominance (GSD).

FSD is the simplest and most universally applicable efficiency criteria. Under FSD an alternative with an outcome defined by cumulative probability distribution function F(y) is preferred to a second alternative with cumulative distribution G(y) for all decision makers who prefer more to less. Hadar and Russell (1969) define FSD as follows:

<u>Definition 1.</u>

The cumulative G(y) is said to be at least as large as F(y) in the sense of FSD, if and only if $F(y) \leq G(y)$ for all possible values of y and if the inequality is strict for some values of y.

Graphically, the condition implies that the cumulative distribution of the dominant function (F(y)) must never lie above the dominated distribution (G(y)).

FSD is a simple criteria to apply in selecting among alternative risky choices but it only eliminates a few choices from consideration because it is not able to discriminate between cumulative distributions that intersect. Thus, wide generality about preferences by FSD limits its usefulness (King and Robinson 1984).

SSD is an alternative to FSD and is more discriminating in selecting among alternative risky choices (Hadar and Russell, Hanoch and Levy 1969, and King and Robinson 1984). SSD holds for all decision makers whose utility functions have positive, non increasing slopes at all outcome levels. These individuals are said to be risk averse. SSD is defined as follows:

Definition 2

The cumulative function G(y) is said to be at least as large as F(y) in the sense of SSD if and only if

$$\int_{-\infty}^{y} F(y)\, dy \leq \int_{-\infty}^{y} G(y)\, dy$$

for all possible values of y, and if the inequality is strict for some values of y.

Under SSD, distributions are compared based on the accumulated area under the cumulative distributions. The cumulative distribution with less area under its function is said to dominate the distribution with a larger area. SSD is more widely used than FSD because SSD has more discriminatory power and the risk averse assumption seems reasonable for many situations (King and Robinson 1984). However, the risk averse assumption does not hold for all cases. For example, Officer and Halter (1968) and Conklin et al (1977) show that decision makers do at times exhibit preference for risk or are risk lovers. Meyer (1977a) also indicates that SSD can never reveal anything about a case where a certain action is preferred only by extremely risk averse producers. King and Robinson further indicate that SSD may not effectively reduce the number of alternatives to be ranked, particularly if some cumulative distributions have less areas at some low levels of y while the opposite occurs at high levels of y.

SDWRF or GSD is a more discriminating efficiency criteria that allows for greater flexibility in representing preferences (Meyer 1977a). SDWRF orders uncertain choices for decision makers whose absolute risk aversion functions lie within specified lower and upper bounds. The absolute risk aversion function is defined by Pratt's or Arrow's risk aversion coefficients. Pratt's or Arrow's risk aversion coefficient is defined as:

$$R_a(y) = \frac{-U''(y)}{U'(y)};$$

where; U represents the utility function, U' is the first derivative and U" is the second derivative with respect to y. R_a is a measure of an individual's attitude towards risk as risk averse, loving or neutral. Arrow defined an individual to be risk averse (loving), if when faced with uncertainty the individual is unwilling (willing) to accept a fair bet.

The attitude towards risk for a decision makers is inferred from the shape of the utility function as shown in Figures 4.4. A linear utility function implies risk neutrality. The assumption for a linear utility function is that the marginal utility of wealth for the individual is constant. A concave utility function implies risk aversion. The assumption is that the marginal utility of wealth for the individual is positive but decreasing. A convex utility function implies risk loving. The assumption is that the marginal utility of wealth for the individual is positive and increasing. These relationships between utility functions and risk attitudes imply that the sign of the second derivatives indicate risk neutrality, risk aversion and risk loving for linear, concave and convex functions, respectively. Thus, Pratt's or Arrow's aversion coefficient is assumed to be positive for a risk averter and negative for a risk lover.

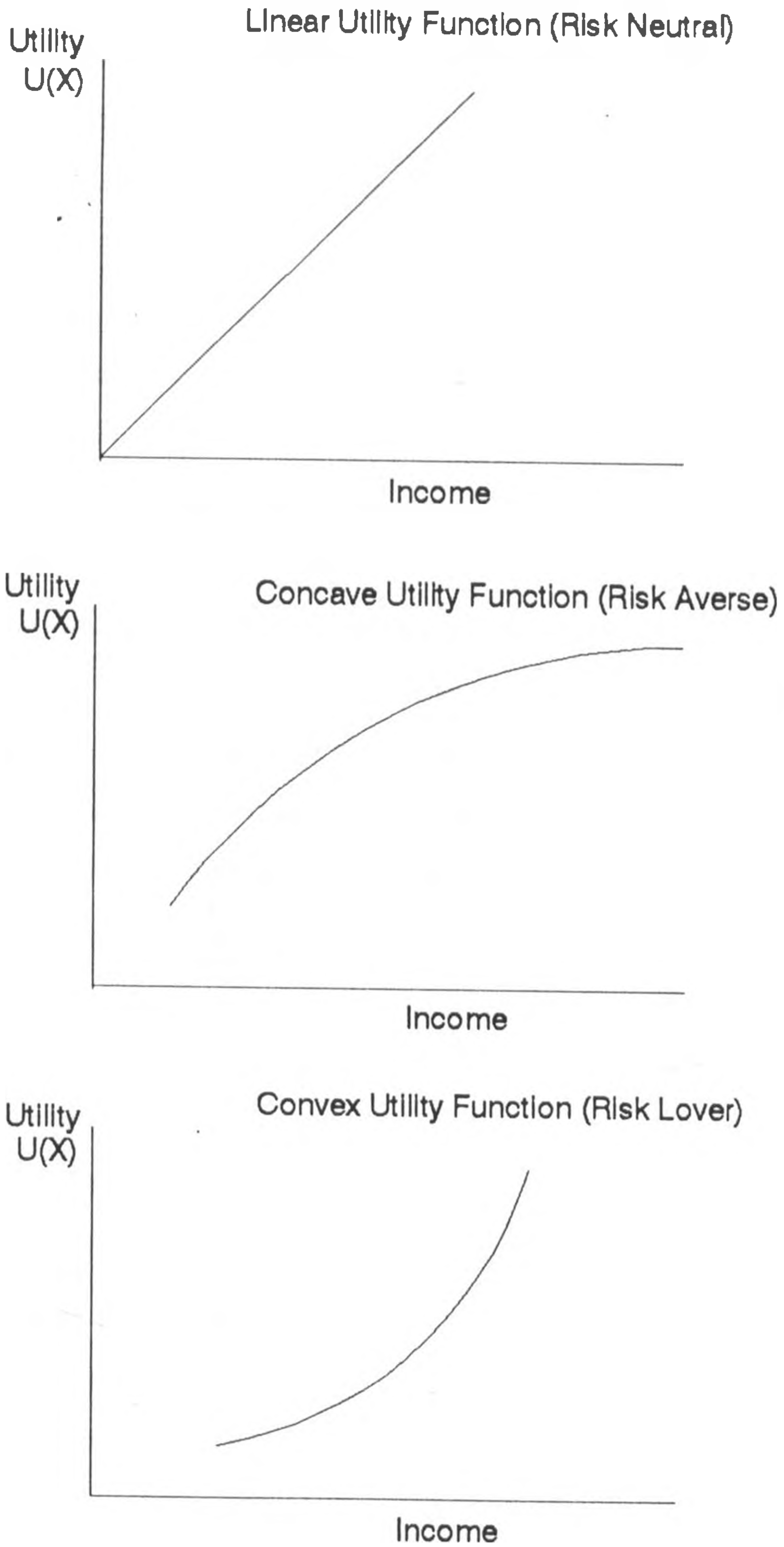

Figure 4.4: Graphs Showing Different Risk Attitudes

A risk averse decision maker, with a concave utility function, will prefer an action with a perfectly certain return to another action with an equal, but uncertain expected return. This preference occurs because the loss of utility from a monetary loss exceeds the gain in utility from a monetary gain when the monetary loss and gain are of equal magnitude and likelihood. On the other hand, a risk preferring decision maker, with a convex utility function, will prefer an action with an uncertain expected return to another action with an equal but certain return. This preference occurs because the expected gain in utility from a monetary gain exceeds the loss in utility from a monetary loss.

SDWRF establishes necessary and sufficient conditions under which the cumulative distribution function F(y) is preferred to the cumulative distribution function G(y) by all individuals whose risk aversions lie everywhere between lower and upper bounds $r_1(y)$ and $r_2(y)$. Consequently, SDWRF is a generalized stochastic dominance criterion which includes FSD and SSD. FSD requires that the decision maker only have a positive marginal utility (Hadar and Russell 1971). Therefore, no bounds need be placed on the decision maker's risk aversion coefficient. The lower and upper bounds $r_1(y)$ and $r_2(y)$ range from negative infinity to positive infinity. The requirement under SSD that marginal utility be decreasing as well as positive, on the other hand, implies that $r_1(y)$ and $r_2(y)$ are zero and positive infinity. Because of SDWRF's generalized nature and the associated advantages over FSD and SSD, the procedure is used in this study to compare alternative ECF control methods and to determine the preferred choices for farmers.

SDWRF Procedure

Meyer (1977b) developed a solution procedure to identify a dominant distribution using SDWRF as follows:

The solution procedure requires identification of a utility function $U_0(y)$ which minimizes

$$\int_0^1 [G(y) - F(y)]U_0'(y)dy \qquad (4.1)$$

subject to

$$r_1(y) \le -U_o''(y)/U_o'(y) \le r_2(y) \qquad (4.2)$$

where r_1 and r_2 are lower and upper bounds for Pratt's risk aversion coefficients, respectively. If the minimum of the difference of outcome distributions F(y) and G(y) in Equation 4.1 is positive, F(y) is unanimously preferred to G(y). If the minimum is zero, the decision maker is indifferent between F and G. If however, the minimum is negative, F cannot be said to be universally preferred to G. In that case the following expression must be minimized,

$$\int_0^1 [F(y) - G(y)]U'(y)\, dy \qquad (4.3)$$

subject to Equation (4.2). The equations are then used to determine if G(y) is unanimously preferred to F(y). There is a possibility that the minimum of both Equations (4.1) and (4.3) are negative. The implication of negative minimum for both equations is that neither F nor G is universally preferred. Thus, a complete ordering is not possible by this criterion.

Meyer (1977b) used optimal control techniques outlined by Arrow and Kurz (1970) to develop the necessary and sufficient conditions theorem. The theorem is developed as follows;

An optimal control $-U_0''(y) / U_0' y)$, which minimizes

$$\int_0^1 [G(y) - F(y)]U'\, dy \qquad (4.4)$$

subject to

$$r_1(y) \le [-U_o''(y)/U_o'(y)] \le r_2(y) \qquad (4.5)$$

and $U_0'(0) = 1$ is given by

$$\frac{U_o''(y)}{U_o'(y)} = r_2(y) \text{ if } \int_0^1 [G(y) - F(y)] U_o(y) dy \geq 0 \tag{4.6a}$$

and

$$\frac{U_o''(y)}{U_o'(y)} = r_1(y) \text{ if } \int_0^1 [G(y) - F(y)] U_o'(y)\, dy \leq 0 \tag{4.6b}$$

The theorem states that the value of the absolute risk aversion function which minimizes the objective function is determined at any particular point by the sign of the objective function to be integrated from that particular point forward to 1.0 using the optimal control (Meyer 1977b, p333). The theorem implies that the value of the absolute risk aversion is always either $r_1(y)$ or $r_2(y)$ (King and Robinson 1981).

The utility function associated with the lower and upper bound of the absolute risk aversion coefficient is shown by Pratt to be

$$U_i = -e^{-r_i y}; \quad i = 1,2 \tag{4.7}$$

where r_i is the lower or upper bound absolute risk aversion level.

Substituting for U′ in Equation 4.4, the equation becomes the following

$$\int_0^1 [G(y) - F(y)]\, r_i\, e^{-r_i y} dy \tag{4.8}$$

The function represented by Equation 4.8 can be integrated backward at each point of ordered cumulative distribution functions (CDF) from positive infinity to negative infinity for y. The value of each preceding integration is added to the current integration until each point is considered. If the value of the final integration is positive, F is preferred to G for decision makers with risk aversion coefficients bounded by r_1 and r_2 (King and Robinson 1981 pp 3-6).

Under SDWRF then, the choice distribution function F will dominate distribution function G, if and only if

$$\int [G(y) - F(y)]\ U'(r_1(y),\ r_2(y))\ dy \geq 0 \qquad (4.9)$$

for all U subject to

$$r_1(y) \leq r(y) \leq r_2(y) \qquad (4.10)$$

for all y. The function r(y) is defined as Pratt's absolute risk aversion coefficient described early.

In short, SDWRF states that members of a class of decision makers with risk aversion coefficients between r_1 and r_2 would prefer distribution F(y) to G(y), if and only if, the utility function $U(r_1(y), r_2(y))$ satisfies Equation 4.9. Hence, different classes of risk preferences or decision makers can be defined by varying the upper and lower bounds on r(y) without necessarily having complete knowledge of the decision makers' utility functions.

SDWRF imposes no restrictions on the width or shape of the relevant risk aversion interval. The absolute risk aversion functions that define the class of decision makers need not be constants; they can be placed anywhere in the risk aversion space (King and Robinson 1981). Thus, SDWRF can be used to order more choices than can be done with efficiency criteria such as FSD and SSD. King and Robinson (1981) further indicate that SDWRF has an additional advantage of not requiring an exact representation of the preferences of the decision maker to be specified as is the case for single-valued utility functions.

A computer program to implement the outlined procedure for practical use of SDWRF in analyzing risk decision making was developed by King and Robinson (1981). This program is incorporated in the TIES system and is used to rank the preferred ECF control strategies in this study. The only difficulty in using the SDWRF incorporated in TIES model is that it requires specific information on the lower and upper bounds of the absolute risk aversion functions for the decision maker or group of decision makers.

Estimating Risk Aversion Coefficients

Measuring and elucidating risk attitudes in agriculture has been the focus of many researchers and various approaches are documented in the literature (Robinson et al 1984). The procedures include: 1) direct elicitation of utility functions, 2) risk preference interval approach, 3) experimental methods, and 4) inferences from observed economic behavior. These procedures require estimation of the utility functions or personal interviews of individuals to estimate risk aversion coefficients. To avoid using any of these procedures to estimate risk aversion coefficients, McCarl and Bessler (1989) indicate that an upper bound risk aversion coefficient can be estimated from the coefficient of variation and standard deviation of risky prospects. Their method was used in this study and the procedure from which the method is derived is as follows:

Given Pratt's risk aversion coefficient ([r(x)] as given in Equation 4.11 and the risk premium [$\pi(X,Y)$] defined by Equation 4.12) Pratt (1964, P.125) cited by McCarl and Bessler, developed a relationship between risk aversion, risk premium and variance of a risky prospect as defined in Equation 4.13 below,

Pratt's risk aversion r(x) is given as

$$r(x) = -U''(X)/U'(X) \tag{4.11}$$

where U(X) is the decision maker's utility function of wealth, X is the decision maker's level of wealth, U'(X) is the first derivative of U(X) with respect to X, and U"(X) is the second derivative of U(X) with respect to X.

The risk premium is the amount that expected income differs from a certain income level with equal utility and is defined as

$$U[X + E(Y) - \pi(X,Y)] = E[U(X + Y)] \tag{4.12}$$

where $\pi(X,Y)$ is the risk premium at a level of wealth X and a risky prospect Y, and E(*) is the expectation operator.

The relationship between risk premium and risk aversion and variance of the risky prospect is given as

$$\pi(X,Y) = 0.5\sigma^2_Y r(X) + 0(\sigma^2_Y) \quad (4.13)$$

where σ^2_Y is the variance of the risky prospect and $0(\sigma^2_Y)$ are the higher order terms in the Taylor series expansion of the expected utility function around the mean of X.

When U(X) is unknown, Equation 4.13 can be manipulated to yield information about r(x) by solving for r(x) from Equation 4.13, which yields

$$r(x) = 2[\pi(X,Y) - 0(\sigma^2_Y)]/ \sigma^2_Y \quad (4.14)$$

Following Tsiang (1972) cited by McCarl and Bessler, the dispersion of the risk prospect is assumed small relative to wealth and the term $0(\sigma^2_Y)$ is neglected. Thus, r(x) is approximately given by

$$r(X) = 2\pi(X,Y)/\sigma^2_Y \quad (4.15)$$

An r(x) bound can be derived from Equation 4.15 using a non-negative certainty equivalent which restricts the risk premium to be no greater than the mean. The certainty equivalent ignoring wealth is given by

$$CE = E(Y) - \pi(X,Y) \quad (4.16)$$

In turn, if the certainty equivalent is non-negative, then

$$E(Y) \geq \pi(X,Y) \quad (4.17)$$

or

$$E(Y) \geq 0.5\sigma^2_Y r(X) = 0(\sigma^2_Y) \quad (4.18)$$

and a bound on r(x) is

$$r(X) \leq [2E(Y)/\sigma^2_Y] - [20(\sigma^2_Y]/\sigma^2_Y) \quad (4.19)$$

Assuming the last term in Equation 4.19 to be zero according to Tsiang, then the upper r(x) bound is given as

$$r(X) \leq 2E(Y)/\sigma^2_Y \qquad (4.20)$$

This bound is equivalent to twice the inverse of the coefficient of variation divided by the standard deviation.

Based on the outlined method, the risk aversion coefficients were calculated from the simulated NPV's for the base farms. The risk aversion coefficients were then used to rank the alternative ECF control methods.

Estimating Conviction Premiums

In decision analysis, a decision maker's willingness to pay for information or the premium (π), can be determined, given the specific utility function and the structure of the decision set and pay-off function (Anderson et al 1977). The premium is equal to the amount to be charged in each state of nature before becoming indifferent to buying information. The indifference point occurs when the expected utility of optimally using the information equals the expected utility of choosing the action without the information or paying the premium.

The theoretical approach of determining the value for information or premium can be extended to determine the premium of adopting alternative disease control methods. Based on a methodology developed by Mjelde and Cochran (1988), the lower and upper bounds on the premium can be obtained from an inexact representation of the utility function of the decision maker used in stochastic dominance analysis. These bounds, which are derived from stochastic dominance procedures, provide more information than the single point estimates in theoretical decision approaches.

According to Mjelde and Cochran, the lower bound on the value of information represents the minimum value of the premium, π, such that $F(x-\pi)$ no longer dominates $G(x)$. This is equivalent to a parallel shift in distribution $F(X)$. Mathematically, the lower bound is given by minimizing π such that

$$EU(F(x-\pi)) - EU(G(x)) \leq 0$$

for at least one U in u, where E is the expectation operator and u is the admissible class of utility functions. The upper bound on the other hand, is the minimum premium such that G(x) dominates F(x-π). Mathematically the bound is estimated by minimizing π such that

$$EU(F(x-\pi)) - EU(G(x)) < 0$$

for all U in u.

The range of the values of the premium associated with distribution F(x) is given by the upper and lower bounds based on information of risk preferences of the decision maker. Between the two bounds, stochastic dominance is unable to rank any two distributions for a given class of admissible utility functions. To rank the distributions between the bounds, additional information on the risk preferences is required. The necessary information is to narrow the class of admissible utility functions for generalized stochastic dominance.

The range of the values of premiums estimated in this study are used to determine the additional value of adopting a given ECF control method compared to the dominated one. These values can be considered as the shadow prices for preferences of alternative ECF control methods for the producers. The use of stochastic dominance to calculate premiums is facilitated by a computer program that is incorporated in the TIES system.

Data Development and Assumptions

This study uses farm-level data to simulate annual production, marketing, financial management and family consumption aspects of a farm with alternative ECF control strategies over a 10-year planning horizon. However, the availability of reliable data on farming activities that cover long periods of time on farms in developing countries is a major research constraint. Farmers, particularly small-scale farmers, rarely keep farm records; hence, for single visit data collection, researchers have to rely on the memory of the farmer. The alternative to collecting reliable data on farms is to undertake multiple visits to recordarming activities as they occur over a given period of time such as one cropping season or more. The resource demands in terms of money and time required for such an exercise are very high and are usually limiting for a study of this kind. Hence, researchers have to rely on using data collected on single visits supplemented by secondary data from government institutions and other sources.

The problem of data availability for analyzing small farms in developing countries is aggravated by the gaps that exist in records of secondary data that are collected by government agencies. The lack of farm records and gaps in secondary data collected over time make it difficult to use historical data to do any meaningful projections on important variables such as future prices and yields. Due to these limitations in data availability and quality, a number of assumptions were made and alternative approaches to data collection were applied. The assumptions used are discussed in this section.

Farm Resources

The major readily quantifiable farm resources are land, labor and capital. The three resources (in addition to the less readily measurable management resource) determine the level of activities in which farmers engage themselves. Allocation of these resources among alternative activities depends on the profitability of the enterprises. Theoretically, the allocation of the resources is determined by the principle of equal marginal returns. Results from a number of studies on small-scale farmers or "peasants" in developing countries show that farmers are efficient in allocating resources, in line with Schultz's hypothesis of the "efficient" but poor peasants (Schultz 1964). This study, however, was not concerned with analyzing the efficiency or optimal allocation of resources by peasant farmers among alternative enterprises. The assumption is that farmers allocate the available resources optimally. Therefore, the level of resource allocation in year 1 of the planning horizon on the base farm prevails throughout the planning horizon and for all alternative scenarios. Thus, the level of resource use among alternative activities on each farm was assumed to remain constant in all the analyses.

Yields and Prices

Crop yields, livestock weight gains, and milk output for cattle were assumed to be stochastic. The minimum, mean and maximum values derived from secondary data from the Ministries of Agriculture and Livestock Development were used to generate data used in specifying the distributions for these variables. The data that was used in this study is presented later in this section. Using the data values, a series of eight data point distributions were generated by dividing the range of the values proportionately. The eight data points were used to generate the stochastic values that were used during the simulation process. The generation of the probability distribution and the stochastic values that were used in this study is discussed later in this chapter.

The mean yields used for simulation during the 10-year planning horizon were kept constant. Forecasting the future values would have been more desirable; however, due to lack of adequate time series data, forecasting was not possible. By keeping the yields constant the assumption was that production technology remained constant during the planning horizon for all farms and alternative scenarios. However, this assumption was relaxed for the case of cattle production, the mean yields, live weight gains, and milk production were changed for different alternative scenarios. The relaxation was necessary to take into account the changes in productivity that accompany alternative ECF control scenarios; however, the minimum and maximum values of the variables were not changed with the productivity change.

The output prices for crops and livestock products used in the stochastic analyses were also generated from minimum, mean and maximum values derived for 1991 from the Ministries of Agriculture and Livestock Development secondary data. The producer prices for most of the major agricultural products in Kenya are controlled by the government. These include the prices of milk, maize, wheat, pyrethrum and cashew nuts. However, the prices of food products can vary in the local markets, particularly in deficit food producing regions of the country. For example, Kaloleni Division is a milk deficit area and most of the milk is sold in the local markets where the price is determined by the forces of supply and demand. Uasin Gishu District, on the other hand, is a surplus milk producing area and most of the milk is sold in the formal marketing channels at government controlled prices. Hence, the reported minimum, mean and.màximum prices for milk in the local markets in Kaloleni is used while, the government controlled price is used for Uasin Gishu.

The mean of the output prices used for simulation for each year during the 10-year planning horizon are assumed to be constant over the planning horizon. That is, real prices for the base year rather than nominal prices for each year of the planning horizon are used. Just as in the case for yields, forecasting future output prices was not possible because of lack of data. The use of constant prices is appropriate because the rate of inflation or deflation is assumed to be constant and equal for both output prices and costs. Hence, general nominal price changes will not affect the profitability of the enterprises. Tweeten (1980) points out that economic functions which determine the demand for output at farm level are homogeneous of degree zero in income and prices. Therefore, a general increase in the overall price level appears to increase nominal prices received and the farm demand in proportion to the general price level but leaves real farm demand and, hence, real demand prices unchanged.

The observed crop and livestock yields, associated average output prices and their respective ranges used in the simulation analysis for Uasin Gishu District and Kaloleni Division are shown in Tables 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6. The tables indicate the yields of the major crops and livestock in the two areas. Cattle production parameters are indicated in the tables according to the two main breed types, Grade and Zebu. As shown in the tables, the live weights for cattle and milk output per cow for all types are higher in Uasin Gishu than in Kaloleni. The difference was partly due to the higher feed availability as shown in Tables 4.3 and 4.6 and the more favorable highland cool climate in Uasin Gishu than the hot and humid coastal climate in Kaloleni.

Table 4.1. General Livestock Live Weights and Prices in Uasin Gishu District, Kenya, 1991

Animal class	Average weight (Kgs)	Weight range (Kgs)	Average price (Kshs/Kg)	Price range (Kshs/Kg)
A. Grade Cattle				
Cull cows	300	250-300	16.50	13.30- 20.00
Calves	100	80-100	15.00	8.00 - 20.00
Heifers 1-2 yrs	150	100-200	16.50	13.30 - 20.00
Heifers 2-3 yrs	250	200-250	32.00	24.00 - 40.00
Replacement cows	300	250-300	12500/head	10000-15000/head
Males 1-2 yrs	150	100-200	15.00	13.30 - 20.00
Steers	300	200-300	25.00	23.30 - 26.70
Cull bulls/oxen	350	300-400	25.00	23.30 - 26.70
Breeding bulls	350	300-450	11000/head	10000-12000/head
B. Zebu Cattle				
Cull cows	250	200-300	15.00	12.00 - 20.00
Calves	60	50-80	11.25	6.25 - 12.00
Heifers 1-2 yrs	100	80-150	13.30	12.00 - 20.00
Heifers 2-3 yrs	160	150-200	13.75	12.00 - 18.75
Replacement cow	250	200-300	4000/head	3000-5000/head
Steers	250	150-300	15.00	12.00 - 20.00
Cull bulls/oxen	300	250-350	15.00	12.00 - 20.00
Breeding bulls	300	250-400	5000/head	3000 - 6000/head
C. Goats and Sheep				
Weaners	20	15-25	10.00	150.00 - 250.00/head
Immatures	25	20-30	10.00	200.00 - 300.00/head
Mature females	30	25-35	10.00	250.00 - 350.00/head
Mature males	45	35-50	10.00	300.00 - 450.00/head

D. Livestock Products

Item	Unit	Weight Kgs	Range Price kshs./Unit	Average Price Kshs./Unit
Calf hide	1	1-2	36.00 - 96.50	65.50
Hides	1	3-5	36.00 - 96.50	65.50
Goat skins	1	1-2	11.00 - 22.00	16.50
Sheep skin	1	1-2	8.50 - 21.60	15.05
Milk	1	1.00	4.00	4.00

Source: Uasin Gishu District Agriculture and Livestock Annual Reports, 1991, and personal consultations with animal production and marketing officers

Table 4.2. General Yields and Output Prices for Major Crops in Uasin Gishu District, Kenya, 1991

Crop		Yields Kgs/Ha			Prices Kshs./Kg		
	Unit	Min.	Aver.	Max.	Min.	Aver.	Max.
Maize	1	963	3150	4500	2.00	3.30	4.00
Wheat	1	900	2250	3500	4.75	4.75	4.75
Potatoes	1	7500	18000	24000	1.50	3.00	4.30
Pyrethrum	1	560	850	1125	25.00	38.00	50.00
Beans	1	900	1800	2400	4.50	7.70	10.00

Sources: Ministry of Agriculture Annual Reports, 1991 and personal consultations with agricultural and animal production officers

Table 4.3. Estimated Average Forage Matter Requirement and Milk Yields Per Cow in Uasin Gishu District, Kenya, 1991

Type of Cow	Average Forage Matter Fed Kgs/Cow/Year	Milk Production Kgs / Cow / Year		
		Minimum	Average	Maximum
Grade	6300	1400	2400	2800
Zebu	5200	600	950	1400

Sources: District Annual Reports, 1991, and personal consultations with livestock officers.

Table 4.4. General Livestock Live Weights and Prices in Kaloleni Division, Kenya, 1991.

Animal class	Average Weight (Kgs)	Range of Weights (Kgs)	Average Price (Kshs/Kg)	Range of Prices (Kshs./Kg)
A. Grade Cattle				
Cull cows	270	200-300	15.00	11.00 - 20.00
Calves	65	60-80	6.00	5.00 - 7.00
Heifers 1-2 yrs	175	150-200	11.70	10.00 - 13.00
Heifers 2-3 yrs	250	200-300	16.00	32.00 - 44.00
Replacement cows	300	200-300	9500/head	9000 - 13000/head
Males 1-2 yrs	200	150-250	15.00	11.00 - 20.00
Cull bulls/oxen	350	300-400	15.00	11.00 - 20.00
Breeding bull	350	300-400	6500/head	5000 - 10000/head
B. ZEBU				
Cull Cow	200	150-250	15.00	12.50 - 20.00
Calves	45	40-50	6.00	4.00 - 8.00
Heifers 1-2 yrs	120	100-150	15.00	12.50 - 20.00
Heifers 2-3 yrs	160	150-200	15.00	12.50 - 20.00
Replacement cow	200	150-250	2500/head	2000-3000/head
Males 1-2 yrs	120	100-150	15.00	12.50 - 20.00
Steers/oxen	250	200-300	15.00	12.50 - 20.00
Breeding bulls	350	300-400	4000/head	3000 - 5000/head
C. Sheep and Goats				
Weaners	20	15-25	10.00	7.50 - 12.50
Immature	25	20-30	10.00	7.50 - 12.50
Mature female	30	25-40	10.00	7.50 - 12.50
Mature Male	40	30-50	8.00	7.50 - 12.50

D. Livestock Product Prices

Product	Unit	Weight Range Kgs	Range of Price Ksh./ Unit	Average Price Kshs./Unit
Calf hide	1	1-2	7.00 - 12.50	9.75
Hide	1	2-5	7.00 - 12.50	29.25
Goat skin	1	1-2	15.00 - 30.00	22.50
Sheep skin	1	1-2	10.00 - 25.00	17.50
Milk	1	1.00	5.00 - 10.00	7.00

Sources: Kaloleni Division Livestock Annual, Report 1991, and discussions with livestock officers.

Table 4.5. General Yields and Output Prices for Major Crops in Kaloleni Division, Kenya, 1991

Crop	Unit	Yields Kgs/Ha Min	Aver.	Max	Prices Kshs./Kg Min	Aver.	Max
Maize	1	800	1400	1600	2.00	3.50	5.00
Rice	1	300	500	700	N/A	10.00	N/A
Cow peas	1	300	400	900	6.00	10.00	13.00
Cassava	1	7000	10500	18000	0.50	1.00	1.50
Coconut	1	400	600	800	6.00	8.50	10.00
Cashew nuts	1	400	600	800	8.00	10.00	12.00
Citrus	1	4000	5000	6000	10.00	15.00	18.00

Source: Ministry of Agriculture (MOA), (1991) Kilifi District Farm Management Guidelines, and MOA (1991), Kaloleni Division Annual Report.

Table 4.6. Estimated Average Forage matter Requirement and Milk Yields Per Cow in Kaloleni Division, Kenya, 1991.

Type of Cow	Average Forage Matter Fed Kgs/Cow/Year	Milk Production. Kgs / Cow /Year Minimum	Average	Maximum
Grade	3700	900	1400	1800
Zebu	1800	300	600	900

Sources: Kaloleni Division, Annual Livestock Production Report, 1991 and discussions with animal production officer

Costs of Crop and Livestock Production

The costs of production for crops and livestock were estimated from the inputs used during the production process valued at 1991 market prices, but they were kept constant throughout the simulation planning horizon. Justification for the assumption of keeping costs constant throughout the planning horizon is the same as given for output prices. That is, inflation was assumed to have no effect on the real prices received and paid by farmers over the long run. The costs of production were estimated for each crop separately for each case farm. The costs for cattle were estimated on a per herd basis rather than for each cattle class. The unit of analysis for the herd was a cow. That is, the costs of all inputs for cattle were estimated in the aggregate for the whole herd and then divided among the number of cows in the herd to express the costs on a per cow basis. The costs were estimated on a per cow basis because most inputs, particularly feeds, are purchased and used on the whole herd. Therefore, breaking down the costs for the various classes (age groups and sex) of cattle in the herd is usually difficult. However, if there were any specific costs for a class of cattle other than cows, then the cost was considered accordingly for that class.

The cost components for cattle were breeding, purchased forage, purchased feeds, disease treatment, immunization, acaricide, helminth, and other health costs. Because the focus of this study was on disease control and specifically on evaluating alternative tick and tick-borne disease control methods, disease treatment costs were separated into two groups. These were treatment costs specifically due to tick-borne diseases and treatment costs for other diseases. Immunization costs were also considered specifically for the "Infection and Treatment Method", while immunization for any other diseases such as Foot-and-Mouth disease were specified under other health costs. The specification of the disease costs separately allows for the evaluation of alternative tick and tick-borne disease control methods without including the effects of other diseases.

Household Consumption Expenses and Food Nutrition

Household expenditures for each farm were determined from the responses of the farmers during the interviews. In TIES, the annual cash withdrawals for family living expenses are computed based on a linear consumption function shown below:

CONSUMPTION = MINIMUM LIVING EXPENSES + 0.75 (DISPOSABLE INCOME - MINIMUM LIVING EXPENSES).

The minimum annual expenses were estimated as 90 percent of the average family living expenses reported during the interviews. The maximum expenses, on the other hand, were estimated at 110 percent of the average reported because farmers often tend to overestimate family consumption. The value of 0.75 is the marginal propensity to consume (MPC) assumed for rural households in Kenya. This value appears reasonable because rural households in developing countries consume a greater proportion of their disposable income on household consumption (Mellor 1988). In TIES simulation analyses, the minimum or maximum value is used if the annual family living expense estimated by the consumption function is less or greater, respectively.

The minimum food nutrients required by the household were estimated from FAO recommended levels for an adult male in Africa as shown in Table 4.7. Consequently, members of the household were converted into male adult equivalents using the conversion ratios given in Appendix II so that food nutrients for the household could be estimated using a common factor. The food nutrient contents in various foods consumed by households were estimated based on the values for the most commonly eaten food items in East Africa (Pepping and Temaliwa 1988).

Macro-level Assumptions

The macro-level assumptions in this study relate to inflation, interest, and discount rates used in the simulation model over the 10-year planning horizon. Inflation rates for costs

Table 4.7. Recommended Intake of Important Food Nutrients for a 65 Kilogram Weight Adult Male Equivalent

Food Item	Units	Daily Requirement	Annual Requirement
Energy	kilocalories	3,000	1,095,000
Proteins	grams	56	20,440
Calcium	milligrams	500	182,500
Iron	milligrams	15	5,475
Vitamin A	micrograms	600	219,000

Source: World Health Organization Technical Report Series 724. Geneva, 1985; Reported in FAO (1988). Tropical Food Plants.

Table 4.8. Nominal Interest rates for Commercial Banks and Government Agricultural Lending Institutions in Kenya, 1988-1991.

	Commercial Banks		Government Institutions		
Year	Savings Deposits	Loans and Advances	Land Loans	Intermediate Loans	Operating Loans
			(percent)		
1988	10.0	18.0	12.0	13.0	14.0
1989	12.5	18.0	12.0	13.0	14.0
1990	13.5	19.0	12.0	13.0	14.0
1991	14.5	20.5	12.0	13.0	14.0
Aver.	12.6	18.9	12.0	13.0	14.0

Source: Kenya Republic (1991), Economic Survey.

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In this study, mortality rates for calves and mature cattle for the base farms were derived from available literature. Mortality rates for calves in Uasin Gishu were derived from estimates by Stotz (1983) for cattle dairy production systems in the highlands. The estimates were 15 and 10 percent for Grade and Zebu calves, respectively. Mortality rates for calves in Kaloleni were derived from Mukhebi et al (1992a). The estimates were assumed to be 20 and 10 percent for Grade and Zebu cattle, respectively. Mortality rates for mature cattle were derived from Mukhebi et al (1992a) and assumed to be 10 and 5 percent for Grade and Zebu cattle, respectively, for both Kaloleni and Uasin Gishu. The mortality rates used in the model include all the causes of mortality in cattle. However, because ECF is a major cause of mortality in cattle in Kenya (Kenya 1981 and 1986), the disease was assumed to account for 80 percent of the mortality rates. Due to lack of precise estimates on mortality rates for cattle, a sensitivity analysis was done on this variable to determine its effects over a wide range.

A major advantage of introducing immunization by ITM as a control measure against ECF is that it reduces mortality rates in cattle. Most studies which have evaluated the technical feasibility of the method indicate that the mortality rate for cattle exposed to ECF challenge is zero (Morzalia et al 1986, Young et al 1990, and de Castro 1985). However, the overall reduction in mortality rate ranges between 80 to 90 percent. The main reason is that mortality in cattle can also occur due to other causes such as tick-borne disease other than ECF, and other diseases and malnutrition in calves.

(3) Live weight gains and losses in milk production

Studies on the reduction in cattle productivity from tick infestation and ECF in Kenya are scarce and the few that are available relate mostly to the effects of immunization on live weight gains of Grade animals. Furthermore, the effects on productivity vary according to the type of tick control method used. Morzalia et al (1988) estimated the live weight gains of immunized and unimmunized Grade cattle at different levels of tick control and indicate that the gains range from 29 to 68 percent. Other researchers (de Castro et al 1985) indicate that when Zebu cattle are immunized, weight gains between dipped and undipped animals are not significantly different. They estimated weights gains to be between 20 and 26 percent for undipped and dipped cattle, respectively. Mukhebi et al (1992a) estimated loss in beef production to be 10 and 5 percent for surviving ECF infected immature cattle and calves, respectively, for all types of cattle. This study used the same values as reported by Mukhebi et al for live weights associated with ITM. However, the live weights were varied for different scenarios of tick control regimes with immunization.

There are no studies that have been done in Kenya on the reduction of milk production from ECF although most researchers acknowledged that the reduction is substantial. Studies done in Zambia (Pegram et al 1990) indicated that the increase in milk production in a tick-free area is about 21 percent. Mukhebi et al (1992a) estimate the loss in milk production in Kenya for surviving ECF affected cattle to be 25 percent. This study assumed ECF control increases milk production by 25 percent for both Zebu and Grade cattle.

Generating Probability Distributions and Random Values

A major advantage in using simulation to analyze the economic impacts of new technologies is that simulation allows for risk analysis to be easily undertaken. The first step in risk analysis is to assign to each stochastic variable a probability distribution. The difficulty, however, lies in selecting a probability distribution which accurately describes the stochastic process. Generally a theoretical distribution can be found that accurately describes the stochastic process, but at times obtaining a distribution which provides an adequate fit is usually difficult. This problem is more serious in developing countries where time series data are limited to only a few years and, therefore, are not adequate for use in determining the actual distribution for most stochastic processes. VanTassel, Richardson and Conner (1989) indicate that researchers can utilize the available actual data themselves to define an empirical distribution. However, where historical data are not available Reutlinger (1970) indicates that the data required for estimating probability distributions can be generated using experience of experts and others. This study used the available historical data and data generated from the experience of extension officers and farmers to define probability distributions that were used to generate random values of the stochastic variables.

Empirical Distributions

Empirical distributions can be defined when the actual values of the individual observations are available or when only intervals are specified along with the number of observations falling within each interval (Law and Kelton 1991, pp. 350). Given discrete data, a continuous piece-wise linear distribution function F can be specified by sorting the data set into increasing order. For example, by specifying the values of a variable as X_i's, the data are then sorted from X_1 to X_n where, X_1 is the smallest of the X_i's and X_n is the largest such that

$$X_1 \leq X_2 \leq ... \leq X_n.$$

The probability distribution of the data set can be estimated using the frequencies of occurrence from historical data or subjectively estimated. The disadvantage of specifying an empirical distribution in this way is that random values generated from it during the simulation process can never be less than X_1 or greater than X_n.

If the data are grouped, then a different approach is used because the values of individual X_i's are not known. For example, if n X_i's are grouped into k adjacent intervals $[a_0, a_1]$, $[a_1, a_2]$,...,$[a_{k-1}, a_k]$, so that the j^{th} interval contains n_j observations and $n_1 + n_2 + ... + n_k = n$, the a_j's can be equally spaced. But this is not necessary (Kelton and Law). Using the grouped data, a piecewise-linear empirical distribution function can be specified using the frequencies of occurrence from historical data or subjective estimation. The random values generated from this distribution will also be bounded both below by a_0 and above by a_k.

In this study grouped data were used to define the probability distribution. By using grouped data, one of the most limiting factors (data availability) for conducting economic analyses in a developing country is at least partially overcome. The observed occurrence of the minimum, mean and maximum of stochastic variables were determined using historical data and the experience of extension specialists. The frequency of occurrence of values within any group is used to estimate the probability p(x) for the group. The frequency was determined from historical data where they existed. However, where historical data did not exist, the frequencies of occurrence in each class interval were assumed to be equal, but the lower and upper bound were each assigned a frequency of occurrence of 0.05. The probability distributions were then used to generate random numbers by TIES during the simulation process.

Random Values

The process of generating crop and livestock yields and output prices for the outputs consists of generating independent random normal deviates using a random number generator. The normal deviates represent a number from which the deviation from the mean is obtained. The stochastic yield or price is calculated by adding the deviation value to the specified mean of that variable. The use of the yield and price distributions in combination with the random number generator allows the resulting yields and prices to occur much as they would in the real world. When repeated samplings are made (100 iterations in this study), the random variables occur at approximately the same frequency defined in their respective probability density functions.

Alternative Scenarios Analyzed

In this study alternative ECF control strategies were analyzed. Specifically, immunization against ECF by ITM was analyzed in relationship to the current control method based on acaricide application and chemotherapy. Because ITM controls only ECF while ticks cause productivity losses in cattle directly or through transmission of other tick-borne diseases, different combinations of acaricide use and ITM adoption were analyzed as alternative scenarios. The objective was to analyze the effects of reduction in acaricide use following immunization: Detailed data on the outlined scenarios are given in Appendix III.

Scenario A.

Scenario A is the base scenario which considers the current tick control method used on each farm. The actual acaricide and treatment costs on the farm derived from farm surveys were used. The mortality rates of cattle used were those that were derived from available literature. Cattle productivity (live weights and milk production) levels used were those derived for each region from the Ministry of Livestock reports and the base farms surveys.

Scenario B

Scenario B includes no change in acaricide use from the base scenario with adoption of immunization by ITM. The cost of immunization was assumed to be Kshs. 544 per animal for the whole planning horizon as estimated by Mukhebi et al (1991) or Kshs. 54.40 per cow per year. The rationale for not reducing acaricide use was to assess a situation whereby farmers might hedge against the risk of losses from ticks and other tick-borne diseases. However, treatment costs associated with ECF were assumed to be reduced drastically. But because some breakthrough can occur in ECF resistance when infestation by ticks is high or when new cattle are introduced on the farm, treatment costs were assumed to be reduced by 95% from those in Scenario A. The Mortality rates in calves and mature cattle were assumed to decrease by 80 percent from the base scenario. Live weights were assumed to increase by 10 and 5 percent for calves and mature cattle, respectively, while milk production increases by 25 percent.

Scenario C

Scenario C included a 50-percent reduction in acaricide use from Scenario A with adoption of ITM. All other assumptions remained the same as in Scenario B. Available empirical results suggest that such reduction in acaricide application would not lead to significant productivity loss from any increase in tick burdens *per se* (Tatchell et al 1986, Norval et al 1988, and Morzalia et al 1988).

Scenario D

Scenario D includes a 75-percent reduction in acaricide use from Scenario A with the adoption of ITM. The treatment costs for ECF were reduced by 90% from those in Scenario A. All other assumptions remained the same as in Scenario C. Most studies (Morzalia et al, Norval et al, Young et al and de Castro et al) indicate that the use of acaricides can be greatly relaxed because ticks and tick-borne diseases except ECF cause very low mortality in cattle and they can be effectively and cheaply treated at very low costs. The losses in productivity from ticks and tick- borne diseases except ECF are not substantially different from high intensity levels of acaricide use. However, eliminating acaricide use as a means of tick control is not recommended because of the risks associated with high tick infestation levels and other tick-borne diseases.

Scenario E

Scenario E included a 75-percent reduction in acaricide use from Scenario A with ITM adoption. Changes in mortality rates, reduction in treatment costs and productivity changes were similar to Scenario D, except that live weight was increased by 5 percent for calves and milk production was increased by 20 percent. This scenario was used to compare the effects of a large reduction in acaricide use with low but substantial productivity change in the live weights of calves and milk yields from in the presence of high tick infestation levels as opposed to scenario D.

Sensitivity Analysis Assumptions

Sensitivity analyses were undertaken to explore the effects of some of the major assumptions in the model. The major assumptions relate to the estimates of the effects of ECF and tick infestation on cattle mortality and productivity. As indicated in previous sections of this chapter, the mortality rates of cattle on base farms (Scenario A) were estimates derived from various assumptions. Furthermore, no precise estimates were available from research results on the estimates. The problem was the same for the improved ECF control method (ITM). Besides estimates of mortality rates, productivity parameters associated with different tick control methods were also not precisely known. Consequently, sensitivity analysis was done on the mortality and cattle productivity parameter estimates on the dominant scenario to determine the level at which the ranking changed. The costs of acaricide use and immunization were also varied accordingly to determine the sensitivity of the dominant ECF control method.

The results from sensitivity analyses were used to test the initial rankings of the alternative scenarios. Sensitivity analyses were important in indicating the range of changes in parameters that allowed the selected choice set to remain the same. The analyses also helped to answer the "what if" questions regarding the estimates of the tick and tick-borne disease epidemiology parameters and the alternative control methods that might be recommended.

CHAPTER V

ANALYSIS AND DISCUSSION OF RESULTS

The primary objective of this study was to evaluate and predict farm-level financial and economic impacts of alternative ECF control methods. In this Chapter, the results of the survey and the simulation analysis are presented. First, the survey results are presented. The survey results include cattle production systems that were practiced in Uasin Gishu District and Kaloleni Division. The cattle production systems are described and discussed to indicate the intensity of use of inputs during the production process and to show the role cattle play in household economies. Second, simulation results are presented and analyzed to indicate the financial and economic impacts of alternative ECF control methods. Finally, the alternative ECF control methods are analyzed using stochastic dominance to indicate the most preferred strategy. Sensitivity analysis was also undertaken to determine the stability of the most preferred ECF control method with respect to cattle mortality rates, milk yields, ITM costs, and acaricide costs. Some specific conclusions and implications of the analysis for each section are also given.

Survey Results

Selected features of the 12 case farms that were used in the analysis are presented in Appendix IV as well as in textural and tabular form in this section. The summarized information in Appendix IV indicates the land size available for cropping and pasturing, the initial balance sheet, and the numbers of each livestock type produced on each case farm. Due to the diversity of crops grown on the case farms and because the emphasis of this study was on cattle, a breakdown of the crops grown on each case farm is not given in Appendix IV. The cattle production systems, production and management practices, and the importance of cattle on the farm households in Uasin Gishu District and in Kaloleni Division are presented in the following sub-sections.

Cattle Production Systems

Economic analysis of alternative cattle disease control methods relies heavily on the production system which is also part of the total farm system. The cattle production system indicates the various activities undertaken during the production process and the interactions that occur with other parts of the whole farm system. There are four main classes of cattle production systems in Kenya as discussed in Chapter II. These are: 1) Zebu cattle grazing on natural pastures 2) Grade cattle grazing natural pastures 3) Grade cattle under semi-zero grazing and 4) Grade cattle under zero grazing.

In Kaloleni Division, three cattle production systems were identified. On all of the Zebu cattle farms, whether they were small, medium or large, free range grazing systems on natural pastures were practiced. The Grade cattle farms practiced free range grazing on natural pastures and semi-zero grazing. Small farmers practiced semi-zero grazing, while the medium and large farmers practiced free range grazing. In Uasin Gishu District, two cattle production systems were identified. All of the Zebu cattle farms practiced free range grazing system on natural pastures, while all of the Grade cattle farms practiced some level of semi-zero grazing. Grade cattle were grazed on natural or improved pastures but they were also fed on fodder crops and crop residues.

Production and Management Practices

The importance of the cattle production systems in economic analysis is shown by the intensity of use of production inputs and management practices. The intensity of use of inputs during the production process for cattle in Kaloleni Division and Uasin Gishu District is indicated by the variable costs incurred as shown in Table 5.1 and Table 5.2, respectively.

The highest variable expenses for both types of cattle for farms in the two areas except for the large Zebu farm in Kaloleni, was purchased feed (Tables 5.1 and 5.2). The second highest expense in all cases was acaricide costs. The highest acaricide costs estimated at

Table 5.1. Annual Variable Expenses Per Cow for Cattle Production for Kaloleni Division, Kilifi District, 1991.

		Type of Farm		
Item	Unit	Small	Medium	Large
A. Zebu Cattle				
Breeding Costs	(Kshs.)	0.00	0.00	0.00
Purchased Forage	(Kshs.)	0.00	0.00	0.00
Purchased Feed	(Kshs.)	1632.00	600.00	0.00
Disease Treatment (TBD*)	(Kshs.)	90.00	55.00	45.00
Acaricide Costs	(Kshs.)	282.00	144.00	172.00
Helminth Costs	(Kshs.)	177.50	60.00	7.70
Other Health Costs	(Kshs.)	50.00	60.00	4.00
Other Costs	(Kshs.)	195.00	10.00	0.00
Total Variable Expenses	(Kshs.)	2426.50	929.00	228.70
B. Grade Cattle				
Breeding Costs	(Kshs.)	0.00	0.00	40.00
Purchased Forage	(Kshs.)	0.00	0.00	0.00
Purchased Feed	(Kshs.)	2304.00	2160.00	645.00
Disease Treatment (TBD*)	(Kshs.)	0.00	167.00	342.00
Acaricide Costs	(Kshs.)	684.00	500.00	800.00
Helminth Costs	(Kshs.)	120.00	154.00	87.20
Other Health Costs	(Kshs.)	90.00	320.00	212.00
Other Costs	(Kshs.)	250.00	132.00	150.00
Total Variable Expenses	(Kshs.)	3448.00	3433.00	2276.20

* Tick-borne diseases

Table 5.2. Annual Variable Expenses Per Cow for Cattle Production for Uasin Gishu District, Kenya, 1991.

Item	Unit	Type of Farm		
		Small	Medium	Large
A Zebu Cattle				
Breeding Costs	(Kshs.)	20.00	0.00	0.00
Purchased Forage	(Kshs.)	0.00	0.00	0.00
Purchased Feed	(Kshs.)	343.00	48.00	118.00
Disease Treatment (TBD[a])	(Kshs.)	0.00	32.00	318.00
Acaricide Costs	(Kshs.)	150.00	228.00	82.50
Helminth Costs	(Kshs.)	0.00	8.00	68.00
Other Health Costs	(Kshs.)	18.00	28.50	8.10
Other Costs	(Kshs.)	41.60	28.40	36.90
Total Variable Expenses	(Kshs.)	572.00	372.90	631.50
B Grade Cattle				
Breeding Costs	(Kshs.)	40.00	0.00	40.00
Purchased Forage	(Kshs.)	0.00	0.00	0.00
Purchased Feed	(Kshs.)	1475.00	855.00	250.00
Disease Treatment (TBD[a])	(Kshs.)	4.00	850.00	113.00
Acaricide Costs	(Kshs.)	800.00	468.00	440.00
Helminth Costs	(Kshs.)	124.00	460.00	260.00
Other Health Costs	(Kshs.)	100.00	74.80	66.00
Other Costs	(Kshs.)	143.00	175.00	56.00
Total Variable Expenses	(Kshs.)	2686.00	2882.00	1225.00

[a] Tick-borne diseases

Kshs. 800 per cow was for the small Grade cattle farm in Uasin Gishu District and the large Grade cattle farm in Kaloleni Division. The second highest acaricide costs were for the small Grade cattle farm in Kaloleni Division estimated at Kshs. 684 per cow. These were the farms where cattle were sprayed acaricides on the farm rather than having them dipped. The lowest acaricide expenses were for Zebu cattle on large farms both in Kaloleni Division and Uasin Gishu District. The costs were estimated at Kshs. 172 and 82.50 per cow for Kaloleni and Uasin Gishu, respectively.

Acaricide costs vary with the frequency of application. The higher the frequency of acaricide dipping or spraying cattle, the higher the costs. In all regions, the acaricide costs for Grade cattle were higher than for Zebu cattle. The costs indicate a higher frequency of acaricide use on Grade cattle than on Zebu cattle. However, the costs of acaricides were higher for farms where cattle were sprayed compared to farms where cattle were dipped. The acaricide costs per head for sprayed cattle were generally lower for large farms than for small farms. The reason may be due to the economies of size enjoyed by large farms with larger numbers of cattle. The costs for dipping cattle also varied according to ownership of the dip. Reported charges for dipping cattle in private dips ranged between Kshs. 3.50 to 10.00 per head. These charges were higher than the Kshs. 2.50 per head charged for public dips where the government subsidized the cost. The costs of dipping cattle, however, did not vary with the numbers kept because the charge was constant per head of cattle dipped regardless of the dip used, public or private.

Overall, Grade cattle farms in each region incurred higher annual expenses in production than Zebu cattle farms. The expenses were higher because the intensity of use of inputs was higher on Grade farms. The highest cost per cow for purchased feeds was for small Grade cattle farms. The cost was estimated at Kshs. 2,304 and 1,475 per cow for Kaloleni and Uasin Gishu, respectively. Purchased feeds were used to supplement farm produced feeds. Therefore, the expenses of purchased feed can reflect the scarcity of farm produced feeds for cattle. Farm produced feeds were more scarce for small Grade farms and more severe in Kaloleni Division.

The general low costs of production for Zebu cattle compared to Grade cattle in the two regions reflect the low management practices accorded to Zebu cattle. In all regions, purchased feed, acaricide, tick-borne disease treatment, and other health costs were lower for Zebu cattle compared to those incurred for Grade cattle. The level of management practices was an important factor that affected the productivity of cattle. The levels of cattle productivity for selected indicators on farms in the two regions are shown in Table 5.3.

Milk yield was highest for Grade cattle when compared to Zebu cattle in the two regions as shown in Table 5.3. Genetically, Grade cattle are more productive than Zebu cattle; however, the level of production also varied with management levels, particularly the feeding regime. Milk production for Grade cattle was highest for Uasin Gishu District partly because the

Table 5.3. Selected Indicators of Cattle Productivity in Kaloleni Division and Uasin Gishu District, 1991.

Productivity Indicator	Unit	Zebu Cattle			Grade Cattle		
		Small	Med[a]	Large	Small	Med.[a]	Large
A. Kaloleni							
Calving rate	%/yr	60.0	75.0	60.0	90.0	70.0	67.0
Milk Yield	Kgs/yr	675.0	720.0	360.0	1260.0	1060.0	960.0
B. Uasin Gishu							
Calving rate	%/yr	60.0	60.0	60.0	86.0	80.0	75.0
Milk Yield	Kgs/yr	900.0	810.0	1080.0	1680.0	1920.0	2400.0

[a] Med. for Medium

Grade cattle were high producing taurine breeds and highly selected crosses. However, in Kaloleni Division the Grade cattle were first generation crosses between taurine and Zebu cattle; hence, milk yields were not as high as for highly selected crosses. Feeds, particularly natural improved pastures, were also plentiful in Uasin Gishu compared to Kaloleni. The effect of feeding is also shown by the small Grade farm in Kaloleni Division. The higher milk yields for the small Grade cattle farm compared to medium and large farms in the area may be attributed to the intensive semi-zero grazing that was practiced on the small farm.

Calving percentage is the frequency of annual calving of cows in the herd. Calving percentage is affected by both feeding and disease control practices. A high calving percentage indicates that feeding and disease control practices are of high standards. The calving percentage for Zebu cattle at 60 percent was the lowest in both areas (Table 5.3). The lowest calving percentage for Grade cattle was 67 percent for the large farm in Kaloleni Division. The highest calving percentages were for the small Grade farms estimated at 90 and 86 percent for Kaloleni and Uasin Gishu, respectively. Grade cattle farms also had the highest feed purchase, acaricide and disease control costs in each of the two areas. Hence, calving interval was closely related to the intensity of feeding and disease control practices.

Importance of Cattle in Farm Households

The importance of cattle in farm households is indicated by their contribution to farm income, the use of cattle products as food for the family and in other farm production processes. The contribution of cattle to farm incomes in the two areas is shown by income statements in Tables 5.4 and 5.5 which were prepared from deterministic simulation results for the initial year.

Cattle contribution to cash farm income receipts in Uasin Gishu District ranged between Kshs. 12,600 for small Zebu farms to about Kshs. 235, 000 for the large Grade cattle farm as shown in Table 5.4. Cattle cash contribution was 64 and 72 percent of the total

Table 5.4. Farm Income Statements, Off-farm Income and Household Living Expenses for Farms in Uasin Gishu District, 1992.

	Zebu Cattle Farms			Grade Cattle Farms		
Item	Small	Med[a].	Large	Small	Med[a].	Large
	(Thousand Kenya Shillings)					
Cash Income						
Crop Receipts	5.95	8.11	58.99	32.75	13.87	81.69
Cattle Receipts	12.60	12.48	76.34	18.60	45.25	235.58
Other Livestock	0.49	0.00	4.05	1.23	4.75	6.85
Total Cash	19.04	20.59	139.38	52.58	63.87	324.12
Cash Farm Expenses						
Crop Costs	15.79	7.29	71.06	17.21	12.17	82.56
Cattle Costs	2.33	1.86	10.01	8.06	14.41	28.18
Other Livestock	0.00	0.00	0.00	0.00	1.15	2.16
Hired Labor	0.00	4.10	23.10	8.75	0.35	18.24
Other Costs	0.00	2.00	0.00	0.00	0.00	28.45
Total Costs	18.12	15.25	104.17	34.02	28.08	159.90
Net Cash Farm Income	0.84	5.34	35.21	18.56	35.79	164.22
Depreciation	0.32	11.37	0.46	0.97	6.54	91.87
Value of Household Consumption	26.92	10.96	18.85	17.76	19.89	23.69
Net Farm Income	27.44	4.93	53.60	35.35	49.14	96.04
Off-Farm Income	48.00	36.00	36.00	78.00	24.00	40.00
Household Living Expenses	35.97	31.50	40.70	48.40	34.10	60.50

[a] Med. for Medium

Table 5.5. Farm Income Statements, Off-farm Income and Household Living Expenses for Farms in Kaloleni, 1992.

Item	Zebu Cattle Farms			Grade Cattle Farms		
	Small	Med[a].	Large	Small	Med[a].	Large
	(Thousand Kenya Shillings)					
Cash Income						
Crop Receipts	11.73	6.77	6.16	9.01	20.15	33.01
Cattle Receipts	11.36	23.67	18.38	18.67	26.99	30.46
Other Livestock	5.48	4.79	3.82	0.63	3.85	2.64
Total Cash	28.57	35.23	28.36	28.31	55.99	66.11
Cash Farm Expenses						
Crop Costs	5.05	6.39	6.53	3.13	13.50	22.21
Cattle Costs	4.85	4.65	1.60	6.90	10.30	6.83
Hired Labor	0.00	0.00	5.05	1.50	24.00	3.60
Other Costs	0.00	0.00	0.00	1.00	0.00	0.00
Total Costs	9.90	11.04	13.18	12.53	47.80	32.64
Net Cash Income	18.67	24.19	15.18	15.78	8.10	33.47
Depreciation	0.43	0.23	0.13	0.43	0.18	0.38
Value of Household Consumption	5.42	7.89	9.63	4.92	14.56	14.34
Net Farm Income	23.66	31.85	24.68	20.27	22.48	47.51
Off-Farm Income	12.00	15.00	14.40	12.00	36.00	20.40
Household Living Expenses	29.16	37.66	31.14	28.50	28.05	49.50

[a] Med. for Medium

farm receipts, respectively. In Kaloleni, the contribution by cattle to cash farm income ranged between Kshs. 9,800 for the small Zebu cattle farm to about Kshs. 30,500 for the large Grade cattle farm as shown in Table 5.5. This was 34 and 44 percent of the total farm receipts on small Zebu and large Grade cattle farms, respectively. Thus, cattle contributed more to farm income in Uasin Gishu than in Kaloleni. The main sources of cattle receipts were milk sales and the sale of cull cows, bull calves, steers, cull bulls, and oxen. None of the farms reported the sale of manure but farmers reported the sale of hides from cattle that were slaughtered or died on the farm. The medium and large Zebu cattle farms in Uasin Gishu District were the only ones that reported generation of income from oxen traction.

Net cash income is the amount of cash available to the farmer to use for household living and farm expenses, and savings. In Uasin Gishu District, the proportion of net cash farm income to household living expenses for small, medium, and large Zebu cattle farms calculated from Table 5.4 were 3, 12 and 83 percent, respectively. For small, medium, and large Grade cattle farms, the proportions were 39, 110 and 202 percent, respectively.
The proportional contribution of net cash farm income to household living expenses for Grade cattle farms in Kaloleni Division calculated from Table 5.5 were 64, 60 and 58 percent for the small, medium and large Zebu cattle farms, respectively. The calculated proportions for the small, medium and large Grade cattle farms were 58, 25 and 66 percent, respectively. The results indicate that only the medium and large Grade cattle farms in Uasin Gishu District were able to generate net cash farm income that could cover household living expenses.
The remaining farms had to rely on off-farm cash income to offset the shortfalls in cash income required for household living expenses. Generally, Zebu cattle farms in the two regions, except for the large Zebu cattle farm in Uasin Gishu, depended more on off-farm income to cover household living expenses. The large Zebu cattle farm in Uasin Gishu District generated a high proportion of its net cash farm income from crops.

The value of household consumption indicates the contribution of farm produced output to net farm income. The proportional contribution of the value in kind of farm products to net farm income were highest for small farms in Uasin Gishu District. The proportional contributions were about 98 and 50 percent for the small Zebu and Grade cattle farms in Uasin Gishu District, respectively (Table 5.4). The respective contributions of the value in kind to net farm income for large Zebu and Grade cattle farms in Uasin Gishu District were about 33 and 24 percent, respectively. In Kaloleni Division, unlike in Uasin Gishu District, the proportional contribution of the value in kind for household consumption to net farm income was highest for large farms. The respective contributions were about 40 and 30 for the large Zebu and Grade cattle farms compared to about 23 and 25 percent for the small Zebu and Grade cattle farms, respectively (Table 5.5).

Simulation Results

The simulation results for five alternative methods of controlling ECF on the twelve farms that were studied are presented in this section. The alternative methods that were analyzed are discussed in detail in Chapter IV. The alternative methods were: (1) Base farm (Scenario A) in which the farm was simulated based on the current ECF control methods; (2) Scenario B in which ITM was introduced with no change in acaricide use; (3) Scenario C in which ITM was introduced with a 50-percent reduction in acaricide use; (4) Scenario D in which ITM was introduced with a 75-percent reduction in acaricide use, but no change in cattle mortality and productivity from B and C; and (5) Scenario E in which ITM was introduced with a 75-percent reduction in acaricide use and changes in cattle productivity from B and C. The simulated results from each alternative ECF control method for each farm are analyzed to assess the impacts on the farm and to determine the most preferred alternative for farmers. The results are presented and analyzed in the following three phases:

First, the economic and financial performance of new alternative ECF control methods are analyzed and compared to the base scenario. The economic output variables used for the analysis were net present value (NPV), present value of ending net worth (PVENW), internal rate of return (IRR), and benefit cost ratio (BCR). The financial output variables used were average annual cash receipts, average annual cash expenses, and average annual net cash and net farm income. The mean, minimum, maximum and standard deviation values, and the coefficient of variation are presented for each variable. The values are used in the analysis to indicate the performance of each alternative ECF control method on farms.

Second, the economic impacts of the alternative ECF control methods were analyzed using the probability of survival and the probability of economic success of the farm. The probability of survival was defined as the probability that the farm maintains an equity to asset ratio greater or equal to 19.0 percent annually for the whole 10-year planning horizon. In other words, the farm remains solvent over the simulation period. The probability of economic success was defined as the probability that the farm will generate at least a rate of return of 12.6 percent (discount rate used to calculate present values) on the owner's initial equity. Other criteria used to evaluate economic success of farms were probability of IRR exceeding 12.6 percent, probability of BCR exceeding 1.0, and probability of lower real equity.

Third, the alternative ECF control methods were ranked according to the simulated net present value probability distributions using the stochastic dominance criterion, SDWRF. The farmers were assumed to be risk averse. Although the upper bound risk aversion coefficient was estimated for each farm using the method by McCarl and Bressler (1989), a value of -0.00001 was used for all the farms. The estimated risk aversion values for each farm were all close to this value. Besides, use of the same value for all farms offered an opportunity to rank alternative ECF control methods using a similar risk aversion coefficient and attitude for all farmers. Stochastic dominance was also used to estimate the premium convictions for alternative ECF control methods. The premiums were used to indicate the additional value of adopting a given ECF control method compared to the dominated one.

Economic and Financial Performance

Uasin Gishu Farms

The economic and financial performance of alternative ECF control methods on each farm for Uasin Gishu District are presented in Tables 5.6 to 5.11. The pattern of the impacts of the economic and financial variables were discussed for farms of different sizes but having similar cattle types. These were used to determine the superior alternative ECF control method according to the performance of the variables. The performance of the alternative ECF control methods on the basis of the economic and financial variables were then discussed across farms of similar size but different cattle types.

Grade Cattle Farms

The simulated results for the small Grade cattle farm presented in Table 5.6 indicate that all new ECF control methods Scenario B, C, D and E generated higher mean NPV, PVENW, IRR, BCR, annual cash receipts, and annual cash and net farm income than the Base scenario. Scenario D also generated the highest values for these variables except for annual cash receipts which were the same as for B and C. Scenarios C, E and B followed D accordingly in descending order, in generating high values for mean NPV, PVENW and IRR. The order of ranking using BCR in terms of the highest to the lowest mean values generated were D, E, C, B and the Base scenario. In this case, E ranked higher than C when ranking was based on average NPV and IRR. This result was consistent with the findings in the literature that BCR tends to discriminate against investments with relatively high costs and returns, even though they may be shown to have a greater wealth generating capacity than that of alternatives with a higher BCR (Gittinger 1982, pp. 346). In this case, Scenario C had higher average annual cash expenses (Kshs. 34,560) and annual net cash farm income (Kshs. 51,070) compared to Scenario E which had lower average annual net cash farm expenses (Kshs. 33,960) and net cash farm income (Kshs. 23,160).

Table 5.6. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Small Grade Cattle Farm, Uasin Gishu District

	SCENARIO				
VARIABLE*	A	B	C	D	E
Probability IROR> 12.6(%)	100.0	100.0	100.0	100.0	100.0
Probability B/C > 1.0(%)	100.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	100.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	0.0	0.0	0.0	0.0	0.0
Net Present Value, 1000 Kshs					
Mean	320.93	390.62	401.91	407.55	398.61
Std. dev.	23.27	25.53	25.53	25.53	25.07
Coef var(%)	7.25	6.54	6.35	6.26	6.29
Minimum	249.60	315.37	326.66	332.30	324.10
Maximum	384.14	458.80	470.09	475.73	465.79
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	1347.59	1520.94	1550.58	1565.40	1541.82
Std. dev.	63.27	69.48	69.48	69.48	68.21
Coef var(%)	4.70	4.57	4.48	4.44	4.42
Minimum	1153.07	1315.13	1344.77	1359.59	338.16
Maximum	1505.90	1692.36	1722.00	1736.82	710.02
Internal Rate of Return (%)					
Mean	18.92	22.05	22.52	22.76	22.39
Std. dev.	1.13	1.19	1.19	1.19	1.17
Coef var(%)	5.98	5.41	5.28	5.21	5.21
Minimum	15.29	18.36	18.85	19.10	18.75
Maximum	21.78	25.00	25.45	25.69	25.30
Benefit Cost Ratio					
Mean	3.99	4.88	5.13	5.26	5.17
Std. dev.	0.21	0.24	0.25	0.25	0.25
Coef var(%)	5.23	4.97	4.88	4.83	4.83
Minimum	3.35	4.17	4.40	4.52	4.43
Maximum	4.54	5.51	5.78	5.92	5.81

Table 5.6. Continued

VARIABLE[a]	SCENARIO A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	45.08	51.07	51.07	51.07	50.12
Std. dev.	2.30	2.52	2.52	2.52	2.47
Coef var(%)	5.10	4.93	4.93	4.93	4.93
Minimum	38.08	43.58	43.58	43.58	42.74
Maximum	52.05	58.64	58.64	58.64	57.57
Average Annual Cash Expenses, 1000 Kshs					
Mean	36.56	35.76	34.56	33.96	33.96
Std. dev.	0.18	0.18	0.18	0.18	0.18
Coef var(%)	0.48	0.49	0.51	0.52	0.52
Minimum	36.04	35.24	34.04	33.44	33.44
Maximum	37.02	36.22	35.02	34.42	34.42
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	8.51	15.31	16.51	17.11	16.16
Std. dev.	2.17	2.40	2.40	2.40	2.35
Coef var(%)	25.53	15.67	14.53	14.02	14.55
Minimum	2.05	8.35	9.55	10.15	9.30
Maximum	15.03	22.43	23.63	24.23	23.16
Average Annual Net Farm Income, 1000 Kshs					
Mean	25.87	33.07	34.27	34.87	33.91
Std. dev.	2.49	2.71	2.71	2.71	2.67
Coef var(%)	9.64	8.21	7.92	7.78	7.87
Minimum	18.51	25.20	26.40	27.00	26.14
Maximum	33.25	41.03	42.23	42.83	41.75

[a] Legend of definitions

Probability of IROR > 12.6 - Chance that the farm will generate an internal rate of return greater than the discount rate, 12.6%.

Probability of B/C > 1.0 - Chance that the farm will generate a Benefit Cost ratio greater than or equal to one.

Probability of Survival - Chance that the farm will not be declared insolvent, i.e., equity to asset ratio greater than the minimum of 0.19.

[a] Legend of definitions continued

Probability of Economic Success - Chance that the farm will earn a return on initial equity greater than 0.126.
Probability of Lower Real Equity - Chance that the farm will experience a decrease in net worth after adjusting for inflation.
Net Present Value - After-tax net return to initial equity, assuming an after-tax discount rate of 0.126
Present Value Ending Net Worth - Discounted value of farm's net worth in the last year simulated
Internal Rate of Return - Calculated rate of return to capital invested in the farm operation.
Benefit Cost Ratio - The ratio of present value for annual returns divided by the present value of annual costs.
Cash Receipts - Total cash receipts from crops, cattle and other farm related activities.
Cash Expenses - Total cash costs for crop and livestock production, including interest costs and fixed cash costs; excludes depreciation.
Annual Net Cash Income - Total cash receipts minus total cash expenses; excludes family living expenses, principal payments, and costs to replace capital assets.
Net Farm Income - Net cash farm income minus consumptive use depreciation for machinery and minus family consumption.

Table 5.7. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Medium Grade Cattle Farm, Uasin Gishu District

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability IROR> 12.6 (%)	0.0	100.0	100.0	100.0	100.0
Probability B/C > 1.0 (%)	100.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	100.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	0.0	0.0	0.0	0.0	0.0
Net Present Value, 1000 Kshs					
Mean	94.95	271.42	280.60	283.52	269.37
Std. dev.	14.07	24.45	24.45	24.45	23.59
Coef var(%)	14.82	9.01	8.71	8.62	8.76
Minimum	55.49	209.35	218.52	221.44	208.98
Maximum	142.88	346.19	355.37	358.29	342.48
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	648.37	1103.89	1128.14	1135.86	1098.24
Std. dev.	29.62	64.36	64.36	64.36	62.05
Coef var(%)	4.57	5.83	5.70	5.67	5.65
Minimum	564.50	948.73	972.97	980.69	947.37
Maximum	745.32	1290.39	1314.63	1322.35	1280.50
Internal Rate of Return (%)					
Mean	7.49	16.95	17.37	17.51	16.86
Std. dev.	1.01	1.23	1.21	1.21	1.19
Coef var(%)	13.47	7.23	6.99	6.92	7.04
Minimum	4.69	14.05	14.52	14.67	14.04
Maximum	10.75	20.48	20.87	20.99	20.33
Benefit Cost Ratio					
Mean	1.80	3.85	4.02	4.08	3.93
Std. dev.	0.12	0.26	0.26	0.26	0.26
Coef var(%)	6.55	6.64	6.52	6.48	6.50
Minimum	1.46	3.19	3.35	3.40	3.27
Maximum	2.19	4.61	4.81	4.87	4.70

Table 5.7. Continued

VARIABLE*	SCENARIO A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	47.74	58.90	58.90	58.90	57.42
Std. dev.	1.92	2.32	2.32	2.32	2.24
Coef var(%)	4.03	3.94	3.94	3.94	3.90
Minimum	42.30	52.25	52.25	52.25	50.96
Maximum	54.18	66.29	66.29	66.29	64.62
Average Annual Cash Expenses, 1000 Kshs					
Mean	32.32	28.16	27.20	26.89	26.89
Std. dev.	0.12	0.12	0.12	0.12	0.12
Coef var(%)	0.38	0.44	0.46	0.46	0.46
Minimum	32.01	27.85	26.89	26.58	26.58
Maximum	32.59	28.43	27.48	27.17	27.17
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	15.42	30.75	31.71	32.01	30.53
Std. dev.	1.88	2.28	2.28	2.28	2.20
Coef var(%)	12.16	7.42	7.20	7.13	7.21
Minimum	10.00	24.11	25.07	25.37	24.08
Maximum	21.59	37.86	38.82	39.12	37.45
Average Annual Net Farm Income, 1000 Kshs					
Mean	22.69	38.28	39.24	39.55	38.07
Std. dev.	2.41	2.85	2.85	2.85	2.76
Coef var(%)	10.64	7.45	7.27	7.21	7.26
Minimum	15.78	30.10	31.06	31.36	30.08
Maximum	30.27	46.77	47.73	48.03	46.37

* See definitions, pages 135-36

Table 5.8. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Large Grade Cattle Farm, Uasin Gishu District

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability IROR> 12.6(%)	0.0	9.0	10.0	10.0	6.0
Probability B/C > 1.0(%)	2.0	98.0	100.0	100.0	98.0
Probability Survival (%)	88.0	100.0	100.0	100.0	100.0
Probability Success (%)	2.0	98.0	100.0	100.0	98.0
Probability of Lower Real Equity (%)	100.0	4.0	1.0	1.0	4.0
Net Present Value, 1000 Kshs					
Mean	-543.88	566.34	643.40	679.39	547.31
Std. dev.	249.50	247.10	243.09	240.09	238.15
Coef var(%)	-45.87	43.63	37.78	35.34	43.51
Minimum	-1196.79	-54.20	27.04	71.68	-55.92
Maximum	36.03	1083.37	1156.68	1189.61	1048.99
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	1152.73	3400.41	3556.88	3629.76	3361.30
Std. dev.	543.19	495.47	490.49	485.79	476.55
Coef var(%)	47.12	14.57	13.79	13.38	14.18
Minimum	-400.17	2155.58	2312.83	2400.49	2151.21
Maximum	2308.01	4435.04	4587.44	4654.79	4363.38
Internal Rate of Return (%)					
Mean	-13.26	8.07	9.02	9.45	7.85
Std. dev.	7.08	3.18	3.00	2.91	3.09
Coef var(%)	-53.38	39.39	33.27	30.80	39.41
Minimum	-31.19	-0.98	0.48	1.24	-1.01
Maximum	0.64	13.76	14.47	14.78	13.42
Benefit Cost Ratio					
Mean	0.54	1.70	1.83	1.89	1.69
Std. dev.	0.19	0.35	0.36	0.37	0.34
Coef var(%)	34.77	20.36	19.92	19.61	20.15
Minimum	0.09	0.95	1.03	1.08	0.94
Maximum	1.04	2.48	2.65	2.74	2.47

Table 5.8. Continued

VARIABLE*	SCENARIO A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	324.82	396.33	396.33	396.33	385.96
Std. dev.	13.12	17.66	17.66	17.66	16.99
Coef var(%)	4.04	4.46	4.46	4.46	4.40
Minimum	289.26	355.35	355.35	355.35	346.46
Maximum	365.14	441.39	441.39	441.39	429.71
Average Annual Cash Expenses, 1000 Kshs					
Mean	404.81	292.88	280.03	274.04	285.65
Std. dev.	26.30	26.03	24.96	24.33	25.21
Coef var(%)	6.50	8.89	8.91	8.88	8.83
Minimum	347.77	244.67	235.74	230.99	238.51
Maximum	464.30	355.20	339.99	332.29	346.31
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	-79.99	103.45	116.30	122.29	100.31
Std. dev.	36.61	41.04	40.05	39.41	39.63
Coef var(%)	-45.77	39.67	34.44	32.23	39.51
Minimum	-164.90	1.05	15.36	23.06	0.82
Maximum	15.91	188.88	200.75	206.17	183.33
Average Annual Net Farm Income, 1000 Kshs					
Mean	-153.71	33.07	45.97	51.93	30.01
Std. dev.	37.28	41.63	40.63	39.97	40.22
Coef var(%)	-24.26	125.87	88.38	76.95	134.05
Minimum	-241.82	-75.16	-60.79	-53.09	-75.34
Maximum	-56.76	118.60	130.56	135.97	113.14

* See definitions, pages 135-36

Table 5.9. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Small Zebu Cattle Farm, Uasin Gishu District

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability IROR> 12.6(%)	94.0	100.0	100.0	100.0	100.0
Probability B/C > 1.0(%)	100.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	100.0	100 0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	0.0	0.0	0.0	0.0	0.0
Net Present Value, 1000 Kshs					
Mean	126.70	170.83	173.66	175.07	168.08
Std. dev.	17.56	19.30	19.30	19.30	18.92
Coef var(%)	13.86	11.30	11.11	11.02	11.26
Minimum	87.24	125.81	128.63	130.04	124.09
Maximum	194.95	243.86	246.68	248.09	240.15
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	514.23	626.64	634.05	637.76	619.34
Std. dev.	43.70	48.55	48.55	48.55	47.52
Coef var(%)	8.50	7.75	7.66	7.61	7.67
Minimum	411.45	508.22	515.64	519.34	503.94
Maximum	675.53	799.89	807.30	811.01	790.22
Internal Rate of Return (%)					
Mean	15.71	19.56	19.80	19.91	19.34
Std. dev.	1.82	1.84	1.83	1.83	1.81
Coef var(%)	11.56	9.39	9.25	9.18	9.38
Minimum	11.46	15.12	15.38	15.50	14.97
Maximum	22.59	26.43	26.68	26.78	26.18
Benefit Cost Ratio					
Mean	3.27	4.16	4.26	4.31	4.18
Std. dev.	0.31	0.35	0.35	0.36	0.35
Coef var(%)	9.45	8.39	8.31	8.27	8.37
Minimum	2.58	3.36	3.45	3.49	3.38
Maximum	4.44	5.45	5.57	5.63	5.48

Table 5.9. Continued.

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	16.74	21.21	21.21	21.21	20.47
Std. dev.	1.68	1.86	1.86	1.86	1.82
Coef var(%)	10.03	8.75	8.75	8.75	8.88
Minimum	12.46	16.31	16.31	16.31	15.69
Maximum	22.83	27.86	27.86	27.86	27.00
Average Annual Cash Expenses, 1000 Kshs					
Mean	18.51	18.48	18.18	18.03	18.03
Std. dev.	0.13	0.12	0.12	0.12	0.12
Coef var(%)	0.69	0.67	0.68	0.69	0.69
Minimum	18.24	18.21	17.91	17.76	17.76
Maximum	18.92	18.87	18.57	18.42	18.42
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	-1.77	2.73	3.03	3.18	2.44
Std. dev.	1.59	1.77	1.77	1.77	1.73
Coef var(%)	-89.37	65.01	58.57	55.80	71.14
Minimum	-5.89	-1.99	-1.69	-1.54	-2.16
Maximum	3.91	8.99	9.29	9.44	8.58
Average Annual Net Farm Income, 1000 Kshs					
Mean	22.62	27.24	27.54	27.69	26.94
Std. dev.	2.32	2.49	2.49	2.49	2.45
Coef var(%)	10.24	9.13	9.03	8.99	9.10
Minimum	17.35	21.27	21.57	21.72	21.11
Maximum	31.44	36.62	36.92	37.07	36.21

[a] See definitions, pages 135-36

Table 5.10. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Medium Zebu Cattle Farm, Uasin Gishu District

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability IROR> 12.6(%)	0.0	0.0	0.0	0.0	0.0
Probability B/C > 1.0(%)	100.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	100.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	0.0	0.0	0.0	0.0	0.0
Net Present Value, 1000 Kshs					
Mean	88.97	129.53	133.71	136.20	128.90
Std. dev.	10.17	15.08	15.32	15.42	14.53
Coef var(%)	11.43	11.64	11.46	11.32	11.28
Minimum	62.57	94.86	98.56	100.89	95.34
Maximum	126.20	176.95	182.01	184.92	175.11
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	833.35	927.98	938.36	944.11	926.33
Std. dev.	20.26	35.00	35.90	36.30	33.68
Coef var(%)	2.43	3.77	3.83	3.85	3.64
Minimum	774.56	844.91	853.49	858.81	846.16
Maximum	909.88	1034.79	1048.38	1055.72	1030.11
Internal Rate of Return (%)					
Mean	4.99	6.95	7.14	7.26	6.92
Std. dev.	0.53	0.71	0.72	0.72	0.69
Coef var(%)	10.54	10.26	10.04	9.90	9.93
Minimum	3.58	5.24	5.43	5.54	5.27
Maximum	6.87	9.13	9.34	9.46	9.06
Benefit Cost Ratio					
Mean	3.04	4.02	4.22	4.35	4.17
Std. dev.	0.23	0.35	0.37	0.38	0.36
Coef var(%)	7.63	8.69	8.69	8.67	8.52
Minimum	2.44	3.21	3.37	3.48	3.35
Maximum	3.86	5.09	5.35	5.52	5.28

Table 5.10. Continued.

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	20.76	26.13	26.13	26.13	25.21
Std. dev.	1.47	1.77	1.77	1.77	1.71
Coef var(%)	7.10	6.78	6.78	6.78	6.79
Minimum	17.07	21.65	21.65	21.65	20.89
Maximum	25.74	31.81	31.81	31.81	30.76
Average Annual Cash Expenses, 1000 Kshs					
Mean	15.54	15.44	14.89	14.59	14.59
Std. dev.	0.07	0.06	0.06	0.06	0.06
Coef var(%)	0.46	0.41	0.42	0.43	0.43
Minimum	15.39	15.30	14.75	14.45	14.45
Maximum	15.76	15.64	15.09	14.79	14.79
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	5.22	10.69	11.24	11.53	10.62
Std. dev.	1.44	1.74	1.74	1.74	1.68
Coef var(%)	27.53	16.30	15.50	15.10	15.82
Minimum	1.60	6.30	6.85	7.15	6.38
Maximum	9.98	16.17	16.73	17.02	15.96
Average Annual Net Farm Income, 1000 Kshs					
Mean	6.29	11.96	12.51	12.81	11.89
Std. dev.	1.83	2.16	2.16	2.16	2.09
Coef var(%)	29.07	18.07	17.28	16.88	17.61
Minimum	1.54	6.38	6.93	7.22	6.47
Maximum	12.04	18.42	18.97	19.27	18.21

[a] See definitions, pages 135-36

Table 5.11. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Large Zebu Cattle Farm, Uasin Gishu District

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability IROR> 12.6(%)	0.0	0.0	0.0	0.0	0.0
Probability B/C > 1.0(%)	85.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	85.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	24.0	0.0	0.0	0.0	0.0
Net Present Value, 1000 Kshs					
Mean	52.35	217.37	223.35	224.00	200.69
Std. dev.	51.48	59.99	60.12	60.12	58.08
Coef var(%)	98.32	27.60	26.92	26.84	28.94
Minimum	-122.54	77.26	84.54	85.36	62.13
Maximum	194.86	380.59	386.80	387.50	360.17
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	2496.23	2905.20	2920.60	2922.25	2861.80
Std. dev.	115.93	159.67	160.28	160.31	153.91
Coef var(%)	4.64	5.50	5.49	5.49	5.38
Minimum	2131.64	2548.68	2566.21	2568.20	2512.93
Maximum	2811.95	3319.38	3335.68	3337.53	3265.45
Internal Rate of Return (%)					
Mean	0.87	3.40	3.49	3.50	3.16
Std. dev.	0.85	0.87	0.87	0.87	0.85
Coef var(%)	98.23	25.63	24.96	24.87	27.01
Minimum	-2.19	1.28	1.39	1.40	1.03
Maximum	3.08	5.62	5.71	5.72	5.36
Benefit Cost Ratio					
Mean	1.17	1.72	1.74	1.75	1.67
Std. dev.	0.16	0.20	0.20	0.20	0.19
Coef var(%)	13.70	11.57	11.50	11.49	11.61
Minimum	0.67	1.25	1.27	1.27	1.20
Maximum	1.61	2.25	2.28	2.29	2.19

The highest average NPV was generated by Scenario D and was estimated at kshs. 407,550 with a maximum of Kshs. 475,730 and a minimum of Kshs. 332,300 (Table 5.6). The lowest NPV was generated by the Base scenario and was estimated at Kshs. 320,930 with a maximum of Kshs. 384,140 and a minimum of Kshs. 249,600. The Base scenario had the highest coefficient of variation for NPV estimated at about 7 percent. The high coefficient of variation for the Base scenario compared to the other alternatives indicated that it is a relatively more risky ECF control method.

Among the new ECF control methods, Scenario B generated the lowest average NPV with a value estimated at Kshs. 390,620 (Table 5.6). The average PVENW ranged from Kshs. 1,347,590 for the Base scenario to Kshs. 1,565,400 for Scenario D. The highest IRR was 22.76 percent for Scenario D while, the lowest was 18.92 percent generated by the Base scenario. The IRR for all the ECF control methods was higher than the discount rate used (12.6 percent). This result indicates that the rate of return from investing in ECF control for all the alternatives was higher than the opportunity cost of investing elsewhere. The highest BCR generated by Scenario D was 5.26, while the lowest was 3.99 generated by the Base scenario. The values for these economic variables generated by the new ECF control methods indicate that it is economically feasible to invest in either of the methods when compared to the current practice.

Scenarios B, C and D generated the same amount of cash receipts which were estimated at Kshs. 51,070 as shown in Table 5.6. The lowest mean annual cash receipts for the new ECF control method was estimated at Kshs. 50,120 and was generated by Scenario E. The highest reduction in cash expenses were for scenarios D and E which was estimated at about 7 percent from the Base scenario. These were mainly due to the reduction in acaricide use by 75 percent from the Base scenario. The value of the expenses for these control methods was estimated at Kshs. 33,960. The highest expenses for the new improved ECF control methods was generated by Scenario B and was estimated at Kshs. 35,760. However, Scenario B had lower cash expenses than the Base scenario even though it had no reduction

Table 5.11. Continued.

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	113.38	126.96	126 96	126.96	124.42
Std. dev.	5.52	6.28	6.28	6.28	6.12
Coef var(%)	4.87	4.95	4.95	4.95	4.92
Minimum	102.65	114.26	114.26	114.26	12.11
Maximum	132.26	147.75	147.75	147.75	144.81
Average Annual Cash Expenses, 1000 Kshs					
Mean	110.50	104.44	103.78	103.70	103.71
Std. dev.	2.98	0.68	0.66	0.65	0.72
Coef var(%)	2.70	0.65	0.63	0.63	0.69
Minimum	107.83	103.34	102.68	102.61	102.61
Maximum	128.44	109.39	108.46	108.35	109.06
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	2.88	22.52	23.19	23.26	20.70
Std. dev.	7.33	6.31	6.30	6.30	6.16
Coef var(%)	254.32	28.00	27.15	27.06	29.78
Minimum	-25.77	5.83	6.77	6.87	3.82
Maximum	22.47	42.61	43.27	43.34	40.40
Average Annual Net Farm Income, 1000 Kshs					
Mean	20.11	40.67	41.33	41.41	38.82
Std. dev.	7.64	6.64	6.63	6.63	6.50
Coef var(%)	38.01	16.33	16.04	16.01	16.74
Minimum	-7.94	24.65	25.58	25.68	22.60
Maximum	40.48	61.50	62.16	62.23	59.27

[a] See definitions, pages 135-36

less than the discount rate of 12.6 percent used in discounting future benefits and costs, even though the maximum attained was 14.78 percent. The low mean IRR estimate below the discount rate implies that the rate of return from investing in new ECF control methods for the large farm was less than the opportunity cost of investing elsewhere. However, the rate of return may be less when the opportunity cost of capital is overestimated because of the difficulties of estimating the accurate discount rate in developing countries (Gittinger 1982 and Brown 1979).

When the magnitude of the economic and financial variables are compared among the Grade cattle farms, the large farm tends to have a higher mean NPV, PVENW, and annual cash and net farm income for the new ECF control methods than for the small farm. The highest NPV generated by the new ECF control alternative (Scenario D) was Kshs. 679,390 (Table 5.8) compared to Kshs. 283,520 and 401,550 for the medium (Table 5.7) and small (Table 5.6) farms, respectively. The IRR and BCR values tended to be higher for the small and medium farms. The highest generated mean IRR for the small farm was estimated at 22.76 percent for Scenario D, while the highest for the large farm was 9.45 percent. The highest generated mean IRR for the medium farm was 17.51 percent. The highest mean BCR estimated at 5.26 was generated by the small farm while the highest estimated mean BCR for the medium and large farms were 4.08 and 1.89, respectively.

Using the simulated mean IRR or BCR results to recommend the type of farms that would use the alternative ECF control methods could discriminate against the large farm. On the other hand, selecting or recommending the farms that should or should not use a particular improved ECF control method on the basis of highest mean NPV would discriminate against smaller ones. These results were consistent with the findings in the literature which indicate that selection of independent investments using either NPV, IRR or BCR can be misleading (Gittinger 1982 and Brown 1979). The three criteria are only useful in showing the investments that meet the selection criteria for economic acceptability rather than ranking them directly.

Consequently, the alternative ECF control methods analyzed in this study were also ranked using stochastic dominance criteria.

Zebu Cattle Farms

The results of the economic and financial output values for the small, medium and large Zebu cattle farms in Uasin Gishu district for all the alternative ECF control methods are presented in Tables 5.9, 5.10 and 5.11, respectively. The results indicate that all the new ECF control methods outperformed the Base scenario. Scenario D had the highest mean NPV, PVENW, IRR, BCR, annual cash receipts, and annual cash and net farm income. D was followed by C, B and E in terms of the highest simulated mean values for these variables except for BCR. For BCR, Scenario E was ranked higher than Scenario B for the small and medium farms but it ranked Scenario B higher than Scenario E for the large farm. However, the results generally showed a similar pattern to the one shown by Grade cattle farms.

The highest mean NPV estimated at Kshs. 224,000 was generated by Scenario D for the large farm (Table 5.11). The highest mean NPV estimates for the medium and small farm were generated by Scenario D (Kshs. 136,200 and 175,070, respectively) as shown in Tables 5.9 and 5.10. The highest mean IRR estimated at 19.91 percent was generated by the small farm, while the mean estimates for the medium and large farms were 7.26 and 3 50, respectively. These results for IRR indicate that on the average the new ECF control methods would not be economically acceptable for the medium and large farms because they generated a rate of return less than the opportunity cost of capital (12.6 percent). However, the high discount rate may be attributed to overestimation of the opportunity cost of capital as indicated before. The simulated highest mean BCR was also for the medium farm and was estimated at 4.35. The estimates for the small and large farms were 4.31 and 1.67, respectively. Just as for the case of Grade cattle farms, mean NPV was high for the large farm, while mean IRR and BCR were high for the medium and small farms. These results could also lead to erroneous recommendations if they were used to recommend farms which should use or should not use the alternative new ECF control methods. However, the results are useful for identifying the economically acceptable ECF control methods that could be used on each farm

In general, the results for all farms in Uasin Gishu district show that large farms regardless of the type of cattle kept, tend to generate higher average annual net cash and farm income than the smaller farms. However, on a per cow basis there seems to be no substantial differences among farms in the simulated average annual net cash incomes (Kshs. 5700 and 5300 for small and large Grade farms, respectively and Kshs. 795 and 894 per cow for the small and large Zebu cattle farms, respectively). The higher aggregate average net cash and farm incomes on large farms may be due to the relatively higher reduction in acaricide and treatment costs compared to the savings made on cash expenses from adoption of ITM. In relative terms, the acaricide costs were higher for large farms than for smaller ones. Furthermore, the reduction in cattle mortality rates may result in a large number of animals (male and surplus females culls) that are sold by large farms when compared to smaller farms The increase in milk yields per cow from adopting ITM and the large number of cows kept also adds to the higher receipts that are realized on large farms than for the smaller farms.

The higher mean IRR for small farms which is also much higher than the discount rate, indicates that small farms could generate higher rates of return from investing funds in ECF control methods compared to the rates of return for medium and large farms. However, regardless of the proportional sizes generated for the values of the economic and financial variables, the new alternative ECF control methods appear to perform better both economically and financially than the Base scenario or the currently practiced methods for all farms.

Among farms of similar size but different types of cattle, Grade cattle farms tended to generate higher mean values for NPV, PVENW, average annual cash receipts, and average annual cash and net farm income than Zebu cattle farms. The highest average annual receipts for the small Grade farm shown in Table 5.6 was about two and a half times greater than that for the Zebu cattle farm shown in Table 5.9 (Kshs. 51,1070 compared to Kshs. 21,210). The corresponding average annual expenses were higher for the large farm than for the small farm, Kshs. 33,960 compared to Kshs. 18,030. The trend was similar for the medium and large farms, with Grade cattle farms generating higher receipts than Zebu cattle farms. The results appears to indicate that Grade cattle farms generated proportionately higher returns than Zebu cattle from improved ECF control methods. These results are plausible considering that Grade cattle have a higher potential of increasing productivity than Zebu cattle and the Grade cattle are also more susceptible to ECF.

Kaloleni Farms

The economic and financial performance of alternative ECF control methods on each farm for Kaloleni Division are presented in Tables 5.12 to 5.17. Just as for the case of Uasin Gishu District, the impacts of the economic and financial variables are discussed for the farms to determine the superior alternative ECF control method according to the performance of the variables. The results were also compared across farms of different sizes and cattle types.

Grade Cattle Farms

The simulated results for the small Grade cattle farm in Kaloleni Division are presented in Table 5.12. The results indicate that all new ECF control methods Scenario B, C, D and E, generated higher mean NPV, PVENW, IRR, BCR, average annual cash receipts, and average annual cash and net farm income than the Base scenario. Scenario D generated the highest mean NPV, PVENW, IRR, BCR, average annual cash receipts, and average annual cash and net farm incomes. Scenario D was followed by Scenarios C. However, the results do not appear to show substantial differences between the simulated mean values of these variables for Scenarios B and E.

The highest mean NPV generated by Scenario D shown in Table 5.12 was estimated at Kshs. 155,130. The lowest mean NPV was generated by the Base scenario and was estimated at Kshs. 87,120. Thus, Scenario D generated a 78 percent larger mean NPV than the Base scenario. The average PVENW ranged between Kshs. 263,460 for the Base scenario to

Table 5.12. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Small Grade Cattle Farm, Kaloleni Division

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability ROR> 12.6(%)	100.0	100.0	100.0	100.0	100 0
Probability B/C > 1.0(%)	100.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	100.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	0.0	0.0	0.0	0.0	0.0
Net Present Value, 1000 Kshs					
Mean	87.12	146.48	151.91	155.13	146.63
Std. dev.	9.25	11.61	11.61	11.61	11.16
Coef var(%)	10.62	7.93	7.65	7.49	7.61
Minimum	61.97	115.43	120.80	124.02	116.58
Maximum	107.80	173.31	178.81	182.03	172.28
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	263.46	419.60	433.34	441.79	419.44
Std. dev.	24.13	30.56	30.56	30.56	29.35
Coef var(%)	9.16	7.28	7.05	6.92	7.00
Minimum	196.00	335.26	348.87	357.32	337.96
Maximum	318.32	492.44	506.39	514.84	488.81
Internal Rate of Return (%)					
Mean	23 46	32.90	33.87	34.37	33.06
Std. dev.	1.93	2.17	2.18	2.19	2.11
Coef var(%)	8.21	6.59		6.38	6.39
Minimum	17.96	26.97	27.96	28.45	27.27
Maximum	27.91	38.19	39.18	39.77	38.19
Benefit Cost Ratio					
Mean	3.20	4.68	5.00	5.18	4.96
Std. dev.	0.24	0.29	0.31	0.32	0.30
Coef var(%)	7.36	6.30	6.18	6.12	6.15
Minimum	2.55	3.87	4.14	4.31	4.11
Maximum	3.71	5.33	5.68	5.88	5.62

Table 5.12. Continued

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	27.80	34.30	34.20	34.20	33.29
Std. dev.	0.87	1.11	1.11	1.11	1.06
Coef var(%)	3.14	3.24	3.24	3.24	3.19
Minimum	25.82	31.83	31.71	31.71	30.90
Maximum	29.58	36.61	36.51	36.51	35.51
Average Annual Cash Expenses, 1000 Kshs					
Mean	13.34	13.45	12.76	12.42	12.42
Std. dev.	0.04	0.04	0.04	0.04	0.04
Coef var(%)	0.28	0.28	0.29	0.30	0.30
Minimum	13.27	13.38	12.70	12.35	12.35
Maximum	13.41	13.52	12.84	12.50	12.50
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	14.46	20.85	21.43	21.77	20.87
Std. dev.	0.87	1.11	1.11	1.11	1.06
Coef var(%)	6.04	5.32	5.18	5.10	5.09
Minimum	12.46	18.36	18.93	19.27	18.46
Maximum	16.24	23.17	23.76	24.10	23.10
Average Annual Net Farm Income, 1000 Kshs					
Mean	18.59	25.27	25.85	26.19	25.29
Std. dev.	1.08	1.32	1.32	1.32	1.28
Coef var(%)	5.82	5.24	5.12	5.05	5.05
Minimum	16.10	22.26	22.82	23.16	22.35
Maximum	20.89	28.10	28.69	29.03	28.04

[a] See definitions, pages 135-36

Table 5.13. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Medium Grade Cattle Farm, Kaloleni Division

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability IROR> 12.6(%)	0.0	98.0	100.0	100.0	98.0
Probability B/C > 1.0(%)	100.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	100.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	0.0	0.0	0.0	0.0	0.0
Net Present Value, 1000 Kshs					
Mean	66.46	235.19	245.82	250.79	231.59
Std. dev.	20.66	26.31	26.31	26.31	25.32
Coef var(%)	31.08	11.19	10.70	10.49	10.93
Minimum	23.45	176.02	186.66	191.62	174.61
Maximum	121.28	304.87	315.50	320.47	298.74
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	600.33	1004.16	1031.65	1044.48	994.81
Std. dev.	49.59	66.12	66.12	66.12	63.51
Coef var(%)	8.26	6.58	6.41	6.33	6.38
Minimum	494.27	846.87	874.35	887.18	843.57
Maximum	741.20	1190.40	1217.89	1230.72	1173.69
Internal Rate of Return (%)					
Mean	5.41	15.48	16.00	16.25	15.30
Std. dev.	1.53	1.37	1.35	1.34	1.33
Coef var(%)	28.21	8.86	8.46	8.28	8.68
Minimum	2.04	12.22	12.78	13.04	12.16
Maximum	9.30	19.17	19.66	19.88	18.88
Benefit Cost Ratio					
Mean	1.33	2.29	2.37	2.41	2.30
Std. dev.	0.10	0.15	0.15	0.15	0.15
Coef var(%)	7.84	6.56	6.46	6.42	6.46
Minimum	1.12	1.95	2.03	2.06	1.97
Maximum	1.62	2.71	2.80	2.84	2.72

Table 5.13. Continued

VARIABLE*	SCENARIO A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	63.66	78.88	78.88	78.88	76.76
Std. dev.	2.15	2.71	2.71	2.71	2.60
Coef var(%)	3.38	3.44	3.44	3.44	3.39
Minimum	59.11	73.23	73.23	73.23	71.34
Maximum	69.23	85.65	85.65	85.65	83.25
Average Annual Cash Expenses, 1000 Kshs					
Mean	61.75	60.00	58.83	58.28	58.28
Std. dev.	0.54	0.50	0.50	0.50	0.50
Coef var(%)	0.88	0.83	0.85	0.86	0.86
Minimum	60.69	58.99	57.82	57.27	57.27
Maximum	63.20	61.29	60.11	59.56	59.56
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	1.91	18.88	20.06	20.61	18.49
Std. dev.	2.24	2.78	2.78	2.78	2.66
Coef var(%)	116.95	14.70	13.84	13.47	14.41
Minimum	-2.70	13.17	14.35	14.90	13.00
Maximum	7.31	25.68	26.86	27.40	24.99
Average Annual Net Farm Income, 1000 Kshs					
Mean	17.57	35.45	36.63	37.17	35.05
Std. dev.	2.65	3.20	3.20	3.20	3.08
Coef var(%)	15.06	9.02	8.73	8.60	8.80
Minimum	11.15	27.81	28.98	29.53	27.64
Maximum	23.68	42.85	44.02	44.57	42.16

* See definitions, pages 135-36

Table 5.14. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Large Grade Cattle Farm, Kaloleni Division

VARIABLE[a]	SCENARIO A	B	C	D	E
Probability IROR> 12.6(%)	0.0	97.0	100.0	100.0	98.0
Probability B/C > 1.0(%)	92.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	92.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	100.0	3.0	0.0	0.0	0.0
Net Present Value, 1000 Kshs					
Mean	28.73	124.60	134.21	138.76	127.54
Std. dev.	21.16	15.56	16.39	16.69	15.41
Coef var(%)	73.65	12.49	12.21	12.03	12.09
Minimum	-28.83	91.35	97.30	100.66	93.67
Maximum	77.35	178.73	190.02	195.18	181.10
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	226.50	395.38	418.81	430.10	402.22
Std. dev.	39.97	36.03	39.07	40.16	36.16
Coef var(%)	17.65	9.11	9.33	9.34	8.99
Minimum	119.22	322.24	333.86	338.63	328.32
Maximum	311.77	522.25	551.90	565.46	528.57
Internal Rate of Return (%)					
Mean	4.28	15.63	16.51	16.92	15.91
Std. dev.	3.20	1.56	1.59	1.60	1.53
Coef var(%)	74.91	10.00	9.65	9.47	9.64
Minimum	-6.34	12.19	12.83	13.14	12.48
Maximum	10.59	20.44	21.31	21.71	20.62
Benefit Cost Ratio					
Mean	1.20	1.98	2.08	2.13	2.04
Std. dev.	0.15	0.12	0.13	0.14	0.13
Coef var(%)	12.28	6.26	6.44	6.48	6.25
Minimum	0.83	1.71	1.78	1.81	1.76
Maximum	1.54	2.39	2.52	2.58	2.46

Table 5.14. Continued

VARIABLE[a]	SCENARIO A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	58.78	69.24	69.24	69.24	67.88
Std. dev.	1.58	1.85	1.85	1.85	1.79
Coef var(%)	2.68	2.67	2.67	2.67	2.64
Minimum	54.92	64.82	64.82	64.82	63.57
Maximum	64.50	75.70	75.70	75.70	74.19
Average Annual Cash Expenses, 1000 Kshs					
Mean	42.43	37.71	36.51	35.96	35.96
Std. dev.	2.19	0.34	0.34	0.34	0.34
Coef var(%)	5.15	0.90	0.93	0.94	0.94
Minimum	38.98	37.07	35.87	35.32	35.32
Maximum	47.82	38.46	37.26	36.72	36.72
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	16.35	31.52	32.72	33.27	31.92
Std. dev.	3.38	1.79	1.79	1.79	1.73
Coef var(%)	20.69	5.69	5.48	5.39	5.43
Minimum	7.36	26.94	28.14	28.69	27.47
Maximum	24.47	37.53	38.73	39.27	37.76
Average Annual Net Farm Income, 1000 Kshs					
Mean	31.43	47.00	48.20	48.75	47.39
Std. dev.	3.78	2.33	2.33	2.33	2.27
Coef var(%)	12.04	4.96	4.83	4.78	4.78
Minimum	21.44	41.34	42.54	43.09	41.89
Maximum	40.84	54.28	55.48	56.03	54.52

[a] See definitions, page 135-36

Table 5.15. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Small Zebu Cattle Farm, Kaloleni Division

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability IROR> 12.6(%)	100.0	100.0	100.0	100.0	100.0
Probability B/C > 1.0(%)	100.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	100.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	40.0	8.0	6.0	5.0	7.0
Net Present Value, 1000 Kshs					
Mean	54.17	77.60	80.79	87.29	78.34
Std. dev.	10.42	17.28	17.89	19.28	16.79
Coef var(%)	19.24	22.26	22.14	22.09	21.44
Minimum	30.09	43.13	44.82	48.39	44.96
Maximum	79.94	121.88	126.17	135.93	120.90
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	122.40	171.77	178.94	182.41	172.97
Std. dev.	19.22	39.83	41.89	42.88	38.91
Coef var(%)	15.70	23.19	23.41	23.51	22.49
Minimum	83.00	102.88	105.18	106.36	104.85
Maximum	181.45	279.63	290.19	295.12	277.22
Internal Rate of Return (%)					
Mean	20.83	26.78	27.53	27.88	26.97
Std. dev.	3.13	4.17	4.21	4.24	4.02
Coef var(%)	15.04	15.55	15.31	15.21	14.91
Minimum	12.81	16.99	17.58	17.86	17.57
Maximum	28.31	36.52	37.21	37.69	36.23
Benefit Cost Ratio					
Mean	2.30	2.94	3.08	3.16	3.05
Std. dev.	0.25	0.42	0.46	0.47	0.43
Coef var(%)	10.89	14.41	14.75	14.92	14.25
Minimum	1.67	2.08	2.15	2.19	2.17
Maximum	2.94	4.01	4.23	4.34	4.15

Table 5.15. Continued

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	29.75	32.93	32.93	32.93	32.41
Std. dev.	1.96	2.49	2.49	2.49	2.37
Coef var(%)	6.60	7.56	7.56	7.56	7.33
Minimum	25.39	27.18	27.18	27.18	26.93
Maximum	34.27	39.07	39.07	39.07	38.19
Average Annual Cash Expenses, 1000 Kshs					
Mean	13.88	13.52	13.06	12.85	12.85
Std. dev.	0.56	0.50	0.47	0.46	0.46
Coef var(%)	4.02	3.73	3.63	3.58	3.58
Minimum	12.15	12.13	11.69	11.52	11.53
Maximum	15.60	14.74	14.17	13.90	13.94
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	15.88	19.41	19.87	20.08	19.56
Std. dev.	1.73	2.15	2.17	2.18	2.07
Coef var(%)	10.92	11.08	10.90	10.84	10.57
Minimum	11.38	14.27	14.71	14.90	14.65
Maximum	19.39	24.52	25.05	25.29	24.41
Average Annual Net Farm Income, 1000 Kshs					
Mean	19.45	23.09	23.55	23.76	23.24
Std. dev.	2.03	2.46	2.47	2.48	2.37
Coef var(%)	10.45	10.64	10.49	10.43	10.20
Minimum	13.84	17.03	17.47	17.66	17.41
Maximum	23.87	29.50	30.02	30.27	29.38

[a] See definitions, pages 135-36

Table 5.16. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Medium Zebu Cattle Farm, Kaloleni Division

	SCENARIO				
VARIABLE[a]	A	B	C	D	E
Probability IROR> 12.6(%)	0.0	0.0	0.0	0.0	0.0
Probability B/C > 1.0(%)	48.0	100.0	100.0	100.0	100.0
Probability Survival (%)	100.0	100.0	100.0	100.0	100.0
Probability Success (%)	48.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	100.0	75.0	70.0	65.0	78.0
Net Present Value, 1000 Kshs					
Mean	-1.07	65.44		68.73	63.17
Std. dev.	24.56	14.75	13.72	13.41	15.35
Coef var(%)	-2296.75	22.54	20.25	19.51	24.30
Minimum	-66.78	6.42	11.71	14.16	3.51
Maximum	51.01	91.74	93.42	94.19	88.61
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	659.19	788.29	792.05	793.54	784.93
Std. dev.	47.99	24.58	22.25	21.55	26.32
Coef var(%)	7.28	3.12	2.81	2.72	3.35
Minimum	530.62	679.28	689.96	694.89	673.35
Maximum	763.93	823.07	826.30	827.79	816.60
Internal Rate of Return (%)					
Mean	-0.11	3.43	3.55	3.59	3.31
Std. dev.	1.44	0.75	0.70	0.68	0.78
Coef var(%)	-1347.29	21.90	19.65	18.91	23.60
Minimum	-4.31	0.37	0.66	0.79	0.21
Maximum	2.74	4.73	4.80	4.84	4.58
Benefit Cost Ratio					
Mean	1.06	3.11	3.27	3.34	3.10
Std. dev.	0.52	0.60	0.59	0.59	0.64
Coef var(%)	49.06	19.23	18.03	17.67	20.77
Minimum	0.03	1.14	1.26	1.32	1.07
Maximum	2.55	4.19	4.34	4.41	4.21

Table 5.16. Continued

VARIABLE[a]	SCENARIO A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	25.75	30.94	30.94	30.94	30.14
Std. dev.	1.22	1.58	1.58	1.58	1.51
Coef var(%)	4.76	5.11	5.11	5.11	5.01
Minimum	22.29	26.62	26.62	26.62	25.99
Maximum	29.08	35.06	35.06	35.06	34.11
Average Annual Cash Expenses, 1000 Kshs					
Mean	18.03	11.56	11.07	10.87	11.27
Std. dev.	2.96	1.48	1.35	1.30	1.58
Coef var(%)	16.43	12.81	12.18	11.96	14.03
Minimum	11.73	10.28	9.98	9.83	9.83
Maximum	25.19	17.17	16.29	15.88	17.03
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	7.72	19.38	19.86	20.07	18.87
Std. dev.	3.99	2.76	2.62	2.57	2.81
Coef var(%)	51.68	14.26	13.19	12.82	14.87
Minimum	-2.72	9.45	10.33	10.74	8.96
Maximum	16.23	24.69	24.98	25.12	24.17
Average Annual Net Farm Income, 1000 Kshs					
Mean	13.72	25.55	26.04	26.24	25.04
Std. dev.	4.29	3.11	2.97	2.92	3.15
Coef var(%)	31.27	12.18	11.41	11.14	12.58
Minimum	1.99	14.28	15.16	15.57	13.79
Maximum	22.50	31.64	31.94	32.08	31.13

[a] See definitions, page 135-36

Table 5.17. Summary of Selected Output Variables From Simulated Alternative ECF Control Methods for Large Zebu Cattle Farm, Kaloleni Division

	SCENARIO				
VARIABLE*	A	B	C	D	E
Probability IROR> 12.6(%)	0.0	41.0	56.0	62.0	43.0
Probability B/C > 1.0(%)	35.0	100.0	100.0	100.0	100.0
Probability Survival (%)	80.0	100.0	100.0	100.0	100.0
Probability Success (%)	35.0	100.0	100.0	100.0	100.0
Probability of Lower Real Equity (%)	100.0	99.0	99.0	97.0	99.0
Net Present Value, 1000 Kshs					
Mean	-10.12	59.33	64.31	66.50	59.80
Std. dev.	22.57	15.56	14.28	13.50	14.62
Coef var(%)	-222.91	26.23	22.20	20.30	24.46
Minimum	-62.51	11.14	21.41	26.29	14.54
Maximum	35.83	84.78	88.32	90.31	83.86
Present Value Ending Net Worth (PVENW), 1000 Kshs					
Mean	66.57	207.03	215.65	219.37	208.11
Std. dev.	47.61	25.83	22.94	21.27	24.15
Coef var(%)	71.51	12.48	10.64	9.69	11.60
Minimum	-51.33	120.71	141.56	151.48	127.58
Maximum	153.60	253.11	257.54	259.54	250.96
Internal Rate of Return (%)					
Mean	-1.75	11.57	12.36	12.71	11.65
Std. dev.	6.14	2.64	2.38	2.25	2.47
Coef var(%)	-351.11	22.82	19.29	17.69	21.20
Minimum	-27.22	2.73	4.87	5.81	3.47
Maximum	8.31	16.16	16.61	16.83	15.98
Benefit Cost Ratio					
Mean	0.86	2.53	2.77	2.88	2.65
Std. dev.	0.38	0.48	0.47	0.46	0.48
Coef var(%)	44.32	18.79	16.99	15.95	18.27
Minimum	0.10	1.22	1.47	1.61	1.31
Maximum	1.81	3.32	3.52	3.64	3.46

Table 5.17. Continued

VARIABLE[a]	SCENARIO A	B	C	D	E
Average Annual Cash Receipts, 1000 Kshs					
Mean	25.23	30.82	30.82	30.82	29.91
Std. dev.	1.06	1.61	1.61	1.61	1.52
Coef var(%)	4.18	5.21	5.21	5.21	5.10
Minimum	22.67	26.76	26.76	26.76	26.03
Maximum	27.45	34.70	34.70	34.70	33.63
Average Annual Cash Expenses, 1000 Kshs					
Mean	20.96	14.67	13.70	13.26	13.71
Std. dev.	2.23	1.22	1.05	0.94	1.13
Coef var(%)	10.63	8.34	7.63	7.07	8.26
Minimum	16.29	13.46	12.84	12.55	12.56
Maximum	26.16	18.41	17.14	16.51	17.28
Average Annual Net Cash Farm Income, 1000 Kshs					
Mean	4.27	16.14	17.12	17.55	16.20
Std. dev.	3.09	2.68	2.50	2.39	2.50
Coef var(%)	72.33	16.57	14.59	13.59	15.46
Minimum	-2.38	8.39	10.09	10.90	8.95
Maximum	11.04	21.14	21.77	22.05	20.91
Average Annual Net Farm Income, 1000 Kshs					
Mean	11.79	23.77	24.74	25.18	23.83
Std. dev.	3.58	3.30	3.13	3.02	3.13
Coef var(%)	30.36	13.88	12.63	12.00	13.12
Minimum	3.87	13.92	15.62	16.43	14.48
Maximum	20.15	29.91	30.64	30.95	29.67

[a] See definitions, pages 135-36

Kshs. 441,790 for Scenario D. The highest average IRR was 34.37 percent for Scenario D while, the lowest was 23.46 percent for the Base scenario. The average BCR ranged from 3.20 for the Base scenario to 5.18 for Scenario D. These results indicate that the new ECF control methods were economically superior to the current method.

Scenarios B, C and D generated about the same amount of average annual cash receipts estimated at Kshs. 43,200 (Table 5.12). This estimate was about 23 percent higher than the Base scenario. The highest reduction in average annual cash expenses were for scenarios D and E which were estimated at about 7 percent less than the Base scenario (Kshs 12,420 for Scenario D and E, compared to Kshs. 13,340 for the Base scenario). The highest average annual cash and net farm income were estimated at Kshs. 21,770 and 26,190 for D, respectively. These values were about 50 and 40 percent greater than the mean generated by the Base scenario for the two respective variables. The results indicate that the new ECF control methods reduced the average annual farm expenses and also increased both the average annual net cash and farm incomes for the small Grade farm in Kaloleni Division.

The results of simulated economic and financial output variables for the medium and large Grade cattle farms for Kaloleni Division shown in Tables 5.13 and 5.14 indicated a similar trend to the results for the small Grade cattle farm. The results show that the new alternative ECF control methods generated higher values for mean NPV, PVENW, IRR, BCR, average annual cash receipts, and average annual cash and net farm incomes than the Base scenario. Scenario D generated the highest mean values of NPV, PVENW, IRR, average annual cash receipts, and average annual cash and net farm incomes. Scenarios C generated the second highest results for the variables except for the average annual expenses. However, the pattern of ranking of the results for B and E were not uniform for all the variables. Scenario B was ranked higher than E based on mean annual cash receipts for the small farm while, Scenario E was ranked higher than B for mean NPV, PVENW, IRR and BCR in the two farms (Table 5.12 and 5.14).

The unclear pattern of ranking Scenarios B and E indicated that the trade-offs between the reduction in acaricide use and the benefits are not distinct at very low levels of acaricide use (Scenario E) and high levels of acaricide use (Scenario B). The high levels for acaricide use for Scenario B generated high costs while, the higher productivity in milk production and live weight gains led to higher benefits. On the other hand, in E the low use of acaricides led to low costs, while the relatively high losses in productivity resulted in lower benefits.

The magnitude of the values for the variables across farms indicated that the differences in the results for mean NPV and PVENW were not clearly distinguished according to farm sizes as was the case for Uasin Gishu. The highest mean NPV was for the medium farm and was estimated at Kshs. 250,790 (Table 5.13). The mean NPV for the large farm (Table 5.14) was Kshs. 140,360, while the mean NPV for the small farm was Kshs. 164,520 (Table 5.12). Thus, the mean NPV was not necessarily greater for large farms than small farms. The lack of a distinct trend in NPV according to farm size implied that no generalizations could be made about the impacts of new ECF control methods for farms of different land size using NPV in Kaloleni Division. These results may be attributed to lack of homogeneity in the Grade cattle kept in terms of the purity of the breeds. The Grade cattle kept in Kaloleni Division were of different degrees of crosses between taurine and Zebu breeds, and consequently, their productivity varied greatly. For example, the milk yield for the small cattle farm was estimated at 1,260 kilograms per cow per year compared to 960 kilograms for the large cattle farm (Table 5.3).

The mean IRR and BCR, unlike NPV, were distinctly different between small and large farms. The highest mean IRR was generated by the small farm and was estimated at 34.37 percent (Table 5.12). The estimates for the medium and large farms were 16.25 and 15.20 percent (Tables 5.13 and 5.14), respectively. The mean BCR was highest for the small farm and was estimated at 5.18. The estimates for the medium and large farms were 2.41 and 2.52, respectively. Thus, the same relationship in IRR and BCR was shown by Grade cattle farms in Kaloleni Division as for Uasin Gishu District.

Zebu Cattle Farms

The results of the Zebu cattle farms for the alternative ECF control methods for Kaloleni Division are shown in Tables 5.15 to 5.17. All of the new ECF control methods generated higher mean values for the economic and financial variables similar to the trends shown for Grade cattle farms. Scenario D generated the highest mean NPV, PVENW, IRR, BCR, average annual cash receipts, and average annual net cash and farm income. Scenario C generated the second highest values for the variables for all of the alternative ECF control methods. However, ranking of the variables for Scenarios B and E was not clearly defined for all variables and farms just as was for the Grade cattle farms. For some farms, Scenario B was ranked higher than Scenario E, while for others Scenario E was ranked higher than Scenario B.

The highest mean NPV for Zebu cattle farms was estimated at Kshs.87,290 and was generated by Scenario D for the small farm (Table 5.15). The highest mean NPV for the medium and large farms were also generated by Scenario D and were Kshs. 68,730 and 66,500, respectively (Tables 5.16 and 5.17). These results were different from those observed in Uasin Gishu District in which large farms tended to generate higher mean NPV than small farms. A possible explanation was the differences in productivity of cattle kept by each farm. The productivity of cattle on small farms, particularly milk production, was higher than for the large farms (Table 5.3). Thus, although large farms keep more cattle than small farms, the returns for the small farms were higher than for the large farms because milk production was proportionately higher for the former. The small farm also generated the highest mean IRR estimated at 27.88 percent for Scenario D (Table 5.15) compared to 3.59 and 12.71 percent for the medium and large farms, respectively (Table 5.16 and 5.17). However, the mean BCR was highest for the medium farm estimated at 3.34 compared to 3.16 for the small farm and 2.88 for the large farm. The BCR indicated that the medium farm generated proportionately higher returns than costs when compared to the small and large farms.

The highest mean cash receipts were generated by the small farm and were estimated at Kshs. 32,930 for Scenarios B, C, and D. The estimates for the medium and large farms were Kshs. 30,940 and 30,820, respectively. Average annual expenses generated by the same Scenario D for all farms were highest for the small farm and were estimated at Kshs. 12,850, while the estimates for the medium and large farms were Kshs. 11,270 and 13,260, respectively. However, the highest mean annual expenses for all Zebu cattle farms were generated by the Base scenario. These were Kshs. 13,880, 18,030, and 20,960 for the small, medium, and large farms, respectively (Tables 5.15, 5.16 and 5.17). These results indicated that the new ECF control methods generated higher receipts and reduced annual cash expenses more than the current methods. Thus, the new methods were financially and economically superior to the current methods just as for Grade cattle farms.

When the performance of the economic and financial results are compared between farms of the same size but with different cattle types, Grade cattle farms generated higher values in absolute terms than Zebu cattle farms for the new ECF control methods. The mean NPV for the highest ranked ECF control alternative method, Scenario D for all cases, were Kshs. 164,520, 250,790, and 140,360 for small, medium, and large Grade cattle farms (Tables 5.12, 5.13 and 5.14), respectively, compared to Kshs. 87,290, 68,730 and 66,500 (Tables 5.15, 5.16 and 5.17) for the small, medium, and large Zebu cattle farms, respectively. The highest mean IRR for Grade cattle farms were 34.87, 16.25, and 15.2 percent for the small, medium, and large farms, respectively, compared to 27.88, 3.59, and 12.71 percent for the small, medium, and large Zebu cattle farms, respectively. The average annual cash receipts were also higher for the Grade cattle farms when compared to Zebu cattle farms. Although the expenses were also high for the Grade cattle farms, the average annual cash and net cash incomes were higher than for the Zebu cattle farms of similar farm size. These results indicated that although both Grade and Zebu cattle farmers benefitted from adopting new ECF control methods, the Grade cattle farmers benefitted proportionately more. These results were similar to those for Uasin Gishu District.

The Survivability of Farms

Farm survival, was evaluated using the probability that the farm annually maintains an equity to asset ratio greater than 19 percent, the minimum equity required by commercial banks. The probability of survival indicates whether or not the farm remains solvent throughout the planning horizon. The estimated probabilities of survival for farms in both Uasin Gishu District and Kaloleni Division are shown in Table 5.6 to 5.17. The results indicated that all farms had a 100-percent probability of survival for the new ECF control methods. For the Base scenario, the results indicate that all farms, except for the large Grade cattle farm in Uasin Gishu District and the large Zebu cattle farm in Kaloleni Division, had a 100-percent chance of survival for the Base scenario. The probability of survival for the large Grade farm in Uasin Gishu was estimated at 88 percent (Table 5.8), while the probability of survival for the large Zebu farm in Kaloleni was estimated at 80 percent (Table 5.17).

The 100-percent probability of survival indicated that the farms were able to generate an equity to asset ratio greater than the minimum of 19 percent for the whole planning horizon of 10 years. The 88-percent probability of success for the Grade cattle farm indicated the chance that the farm would generate an equity to asset ratio greater than the minimum. The lower probability of survival for this farm under the Base scenario is due to initial high debts that reduced the equity to asset ratio. The large Grade cattle farm had the highest invested capital and was the only one where commercial loans were borrowed to invest in the farm. However, the 100-percent probability of survival shown for the new ECF control methods implied that the new methods enabled the farm to generate an equity to asset ratio greater or equal to the minimum. A similar situation existed for the large Zebu cattle farm in Kaloleni Division.

Probability of Economic Success

The probability of economic success indicated the probability of the farm generating a rate of return on initial equity greater than 12.6 percent, the discount rate used to calculate net present value. The probabilities of economic success were also estimated using the probabilities of IRR, BCR and lower real equity to indicate the conviction that the estimated values could be within the acceptable range required for investing in the new ECF control methods. The probability of economic success using IRR was the probability that the simulated IRR would be equal or greater than the discount rate of 12.6 percent. The probability of economic success using BCR was the probability that the estimated BCR could be equal or greater than 1. The probability of lower real equity was the probability that the farm would generate a ratio of ending net worth to beginning net worth less or equal to 1; that is, the chance that the farm would experience a decrease in real net worth.

The probabilities that the rate of return on initial equity was greater than 12.6 percent shown in Tables 5.6 to 5.17 were 100-percent for all new ECF control methods. However, even most of the Base scenarios in which ECF was controlled using conventional methods of tick control and chemotherapy, had a 100 percent probability of earning a return on equity greater than 12.6 percent. The exceptions were the large Grade and Zebu cattle farms in Uasin Gishu District where the probabilities were estimated at 98 and 85 percent, respectively (Tables 5.8 and 5.9). In Kaloleni Division, the farms that generated a probability for earning a return on equity less than 12.6 percent were the large Grade (93 percent), medium Zebu (48 percent) and large Zebu (35 percent) cattle farms (Tables 5.9, 5.16 and 5.17), respectively.

The probability that the farm would generate an internal rate of return greater than 12.6 percent varied greatly for different farms and alternative ECF control methods. All of the Base scenarios for all of the farms except the small Grade cattle farm in Uasin Gishu District and the small Grade and Zebu cattle farms in Kaloleni Division generated probabilities lower than 100 percent. Most farms generated an IRR greater or equal to 12.6 for Scenario D 100 percent of the time. This scenario had the highest absolute IRR values for all farms. However, some farms generated probabilities which were less than 100 percent. These farms were the medium and large Zebu cattle farms in Kaloleni Division which generated probabilities estimated at zero and 62 percent, respectively. The small Grade, and the medium and large Zebu cattle farms in Uasin Gishu District also generated a probability of zero. The probability for the large Grade cattle farm was 10 percent. When these results are compared to the mean IRR values used to accept or reject alternative ECF control methods, the mean IRR values criterion would reject all of the alternatives with a mean IRR less than the 12.6 percent cut-off rate. This result however, does not indicate the probability that there would be a chance of the alternative being acceptable. Therefore, the use of probabilities in addition to the absolute values would assist decision makers in determining the chances of an investment being economically acceptable.

The probability that the BCR for alternative ECF control methods would be greater than 1 was 100 percent for most farms. The exceptions in Uasin Gishu District were all scenarios for the large Grade Cattle farm and the Base scenario for the large Zebu cattle farm (Tables 5.9 and 5.11). In Kaloleni Division the exceptions were the Base scenarios for the large Grade (85 percent), medium Zebu (48 percent) and large Zebu (80 percent) cattle farms (Tables 5.14, 5.16 and 5.17). These probabilities indicated the chance that the ratio of benefits to costs was greater than 1.

The probabilities that farms would experience lower real equity were greater than zero for all farms in Kaloleni Division except for the small and medium Grade cattle farms (Tables 5.12 to 5.17). The probabilities for the Base scenarios for all the Zebu farms in this region were 100 percent. However, the adoption of new ECF control methods reduced the probabilities of lower real equity. Scenario D which generated the highest mean PVNEW for all farms had the highest reduction in the probabilities of lower real equity. These probabilities were estimated at 5, 65 and 99 percent for the small, medium and large Zebu cattle farms, respectively (Tables 5.15, 5.16 and 5.17). The large Grade cattle farm in Kaloleni also generated probabilities of lower real equity that were greater than zero for all scenarios. The Base scenario generated a 100-percent probability but this was reduced to 8 percent by Scenario D (Table 5.13). In Uasin Gishu District, the probabilities of lower real equity were greater than zero for the large Grade and Zebu cattle farms (Tables 5.9 and 5.11). All scenarios for the large Grade farm generated probabilities greater than zero ranging from 100 to 1 percent for the Base scenario and Scenario D, respectively. The probability for lower real equity was 24 percent for the Base scenario but was reduced to zero for all new ECF control methods (Table 5.11). These results indicated that although the new ECF control methods increased net worth of farms, there was a chance that the net worth would be decreased. The risk of reducing net worth was highest for Zebu cattle farms in Kaloleni Division.

Stochastic Dominance Ranking

The performance of the new ECF control methods were shown to be economically and financially superior to the current control methods using absolute mean values of NPV, IRR and BCR. However, these criteria are not robust enough to rank unequivocally the most preferred alternative while taking into consideration the risk attitude of the decision maker. Such ranking is necessary to aid decision makers in selecting among the alternative ECF control methods based on risk preference. Because NPV's were stochastically generated for each alternative ECF control method, SDWRF or GSD was used to rank the generated NPV probability density functions under the assumption that the farmers were risk averse. The risk aversion coefficient bounds used in the ranking were -0.00001 to 0.00000

The results of SDWRF rankings for the alternative ECF control methods for each farm for Uasin Gishu District and Kaloleni Division are shown in Tables 5.18 and 5.19, respectively. The results indicate that Scenario D was the most preferred alternative ECF control method (most efficient set) for all farms. Scenario C was also the second most preferred alternative for

Table 5.18. SDWRF Rankings of NPV Probability Density Functions and Confidence Premiums for Alternative ECF Control Methods in Uasin Gishu District, Kenya.

		Alternative ECF Control Method Preferred for Cattle Type and Farm Size					
		Grade Cattle			Zebu Cattle		
Rankings		Small	Med.[a]	Large	Small	Med.[a]	Large
Most Preferred Scenario		D	D	D	D	D	D
2nd Most Preferred Scenario		C	C	C	C	C	C
3rd Most Preferred Scenario		E	B	B	B	B	B
4th Most Preferred Scenario		B	E	E	E	E	E
5th Most Preferred Scenario		BASE	BASE	BASE	BASE	BASE	BASE
Mean Annual Confidence Premiums in Kshs. Per Cow							
Dominant	Challenger						
D	C	189	584	141	35	50	40
D	B	1055	300	621	141	184	45
D	E	489	586	1229	317	332	195
D	BASE	3952	4379	N/A[b]	1531	1285	1289
C	B	490	1836	323	70	84	376
C	E	112	410	773	211	181	183
C	BASE	3199	4145	N/A	1390	1084	1272
B	E	264[c]	43	113	70	27	107
B	BASE	2332	3594	N/A	1178	831	1159
E	BASE	2861	3506	N/A	1037	803	940

[a] Med. for Medium
[b] The value was reduced to 0 because the probability distribution of the NPV for the Base scenario had large negative values which made it lie outside the admissible functions used in the analysis.
[c] E is ranked higher than B, the premium refers to change from B to E

Table 5.19. SDWRF Rankings of NPV Probability Density Functions and Confidence Premiums for Alternative ECF Control Methods in Kaloleni Division, Kenya.

	Alternative ECF Control Method Preferred for Cattle Type and Farm Size						
	Grade Cattle			Zebu Cattle			
Rankings		Small	Med.[a]	Large	Small	Med.[a]	Large
Most Preferred Scenario		D	D	D	D	D	D
2nd Most Preferred Scenario		C	C	C	C	C	C
3rd Most Preferred Scenario		E	B	E	E	B	E
4th Most Preferred Scenario		B	E	B	B	E	B
5th Most Preferred Scenario		BASE	BASE	BASE	BASE	BASE	BASE
Mean Annual Confidence Premiums in Kshs. per Cow							
Dominant	Challenger						
D	C	161	99	91	166	18	30
D	B	1021	413	605	651	83	227
D	E	587	792	318	399	193	126
D	BASE	4428	4500	2800	1501	1571	1312
C	B	538	117	330	147	45	134
C	E	265	500	135	64	135	64
C	BASE	3785	4103	2433	827	1495	1188
B	E	6[b]	75	58[b]	175[b]	44	50[b]
B	BASE	2824	3465	1908	598	1356	983
E	BASE	2988	3312	2025	634	1266	995

[a] Med. for Medium

[b] E is ranked higher than B, the premium refers to change from B to E

all farms. The Base scenario was the least preferred ECF control method for all farms. These results implied that risk averse producers ranked D and C in a similar manner. However, preference of B and E varied among farms. Scenario B was ranked as the third most preferred ECF control alternative for some farms, while E was also ranked as the third most preferred alternative for others.

Tables 5.18 and 5.19 also indicate the confidence premiums for the specified probability density functions for the NPV associated with each scenario. As discussed in Chapter IV, the lower and upper premium bounds reflect the minimum and maximum amounts of money an individual is willing to spend to move from the dominated alternative to the dominant one. That is, the bounds constitute a measure of conviction or attractiveness held by the decision maker for a preferred ECF control method over the dominated one, assuming all other things equal. The arithmetic means of the lower and upper bounds are used in this analysis for comparative purposes to show differences, if any, among farms of different land size and cattle types.

The highest confidence premiums from the Base scenario were generated by Scenario D, which was also the most preferred ECF control alternative method for both Uasin Gishu and Kaloleni farms. In Uasin Gishu District, the highest confidence premium were Kshs. 4,379 per year per cow for the medium Grade cattle farm (Table 5.18). This premium was higher than the value for the small farm that was estimated at Kshs. 3,952. There was no estimate for the most preferred Scenario D and the Base scenario for the large Grade cattle farm. The probability density function for the Base scenario was outside the admissible range of values considered for stochastic dominance. The admissible probability density functions for stochastic dominance were those that had positive NPV distributions. The confidence premiums for Zebu cattle farms estimated for Scenario D over the Base scenario were higher for the small farm than for the larger farms. The estimated values were Kshs. 1,531, 1,285, and 1,289 per cow for the small, medium, and large Zebu cattle farms, respectively. The confidence premiums were higher for Grade cattle farms than for Zebu cattle farms because of the higher productivity of Grade cattle than Zebu cattle.

In Kaloleni Division, the highest confidence premium for Grade cattle farms from the Base scenario was for the medium farm and was estimated at Kshs. 4,500 (Table 5.19). The confidence premiums for the small and large Grade cattle farms were Kshs. 4,428 and 2,800, respectively. For Zebu cattle farms, the highest confidence premium was Kshs. 1,571 for the medium farm. The estimates for the small and large farms were Kshs. 1,501 and 1,312, respectively.

The estimated confidence premiums did not seem to show substantial differences among farms of different land sizes but with similar cattle types in each region. However, the confidence premiums seemed to show substantial differences among farms of similar land size but with different cattle types. Grade cattle farms had higher confidence premium estimates than Zebu cattle farms in each of the two regions. The results implied that Grade cattle producers held higher convictions for new improved ECF control methods when compared to Zebu cattle producers. These higher convictions were likely held because the gains from ECF control for Grade cattle were more than the gains from Zebu cattle.

Sensitivity Analyses

Sensitivity analyses were undertaken to test the stability of the most preferred ECF control method. As pointed out in Chapter IV, the values of most parameters, mortality rates and milk productivity, among other variables associated with alternative ECF control methods, were not precisely known. The estimates used in the analysis were derived from secondary data based on the assumptions outlined in Chapter IV. In addition, some variables, such as the costs of ITM and the acaricides used, were also likely to change. Consequently, sensitivity analyses were done on these variables for the most dominant control method to test the robustness or validity of the estimates used in the analyses and to answer the "what if" questions which arise from lack of precise estimates. The sensitivity analyses were done using three farms from each region: small and large Grade cattle farms, and a medium Zebu cattle farm. The variables on which sensitivity analyses were done were mortality rates, milk production, ITM cost, and acaricide costs.

Cattle Mortality Rates

The mortality rates of both calves and mature cattle in the initial analysis before sensitivity analysis was done were assumed to decrease by 80 percent from the Base scenario with the introduction of ITM. The mortality rates were then applied for all new ECF control methods including Scenario D in which acaricide costs were reduced by 75 percent. The estimates for mortality rates used in the analysis for Grade cattle in Uasin Gishu District were 0.03 for calves and 0.02 for mature cattle. The estimates for Zebu cattle were; 0.02 for calves and 0.01 for mature cattle. In Kaloleni Division, the mortality rates used were 0.04 for Grade calves and 0.02 for mature Grade cattle and 0.02 and 0.01 for Zebu calves and mature Zebu cattle, respectively.

Sensitivity analysis on mortality rates was done by increasing the mortality rate for Scenario D to determine the level at which the scenario would no longer dominate all of the alternative ECF control methods. The results of the analyses for the farms analyzed for Uasin Gishu District are presented in Table 5.20. Results in the table show that a 125 percent change in the mortality rate of cattle in the small and large Grade cattle farms was required before Scenario D was dominated by Scenario C. However, at this mortality rate change, the new Scenario D_1 still dominated B, E and the Base scenario. The mortality rates for the new Scenario D_1 were 6.8 and 4.5 percent for calves and mature cattle, respectively. The mean NPV for the new Scenario D_1 control method compared to the original Scenario D for the small Grade cattle farm were Kshs. 401,239 and 407,553, respectively. The mean NPV values for the changes from the original scenario D to the new Scenario D_1 for the large Grade cattle farm were Kshs. 679,391 to 345,391.

Table 5.20. Stochastic Dominance Results for Sensitivity Analysis on Mortality Rates for Uasin Gishu District Farms

	Level of Mortality Rates					
	Small Grade Farm		Large Grade Farm		Medium Zebu Farm	
Ranking	Scenario D	125% increase	Scenario D	125% increase	Scenario D	150% increase
Most Preferred Scenario	D	C	D	C	D	C
2nd Most Preferred Scenario	C	E	C	D_1	C	D_1
3rd Most preferred Scenario	E	D_1	B	B	B	B
4rd Most Preferred Scenario	B	B	E	E	E	E
5th Most Preferred Scenario	BASE	BASE	BASE	BASE	BASE	BASE

Confidence Premiums Generated for Sensitivity Analysis Kshs. per Year per Cow

Dominant	Challenger	Small Grade Farm	Large Grade Farm	Medium Zebu Farm
D	D_1	400	392	148
C	D_1	23	95	15
D_1	E	214	518	84
D_1	B	698	875	181
D_1	BASE	3384	N/A	1084

Results in Table 5.20 also indicate that the mortality rate change in Scenario D that was required for the scenario to be dominated by Scenario C for the medium Zebu cattle farm was 150 percent. This was a mortality rate of 7.5 and 5 percent for calves and mature cattle, respectively. The mean NPV values for Scenario D compared to the new Scenario D_1 were Kshs. 136,200 and 118,200, respectively. These sensitivity analysis results for mortality rates indicate that a 75 percent change in acaricide use with the adoption of immunization by ITM, will be preferred by farmers over a wide range of mortality rates for cattle in Uasin Gishu District. The mortality rate range was widest for the medium Zebu cattle farm.

The results of sensitivity analyses for mortality rates of cattle in Kaloleni Division are presented in Table 5.21. The results indicated that mortality rates were required to change by 90 percent for the small Grade cattle farm and 80 percent for the large Grade and the medium Zebu cattle farms before Scenario D was dominated by Scenario C. In all cases, however, the new scenario D_1 still dominated B, E and the Base scenario at the respective mortality rate changes from the levels originally used for D. The mortality rates for the new Scenario D_1 were 5.7 and 3.8 percent for calves and mature cattle, respectively, for the small Grade farm.

The mortality rates for the new Scenario D_1 for the large Grade cattle farm were 5 4 and 3.6 percent for calves and mature cattle, respectively. On the other hand, the mortality rates for the calves and mature cattle for the medium Zebu cattle farm were 3.6 and 1.8 percent, respectively. The mean NPV values for the new Scenario D_1 compared to the original Scenario D were Kshs. 151,289 and Kshs. 155,131, respectively, for the small Grade cattle farm; Kshs. 133,115 and 138,758, respectively, for the large Grade cattle farm; and Kshs. 67,315 and 68,733, respectively for the medium Zebu cattle farm.

The mortality rate sensitivity results for cattle farms in Kaloleni Division were similar to the results for Uasin Gishu District cattle farms. Acaricide reduction by 75 percent with immunization was the most preferred ECF control method over a wide range of mortality rates for all farms. Thus, Scenario D was relatively stable with regard to changes in mortality rates.

Table 5.21. Stochastic Dominance Results for Sensitivity Analysis on Mortality Rates for Kaloleni Division Farms.

	Level of Mortality Rates					
	Small Grade Farm		Large Grade Farm		Medium Zebu Farm	
Ranking	Scenario D	90% increase	Scenario D	80% increase	Scenario D	80% increase
Most Preferred Scenario	D	C	D	C	D	C
2^{nd} Most Preferred Scenario	C	D_1	C	D_1	C	D_1
3^{rd} Most preferred Scenario	E	E	E	E	B	B
4^{rd} Most Preferred Scenario	B	B	B	B	E	E
5^{th} Most Preferred Scenario	BASE	BASE	BASE	BASE	BASE	BASE

Confidence Premiums Generated for Sensitivity Analysis Kshs. per Year per Cow

Dominant	Challenger	Small Grade Farm	Large Grade Farm	Medium Zebu Farm
D	D_1	161	205	47
C	D_1	50	22	9
D_1	B	721	416	47
D_1	E	480	243	171
D_1	BASE	3936	2497	1520

Milk Yields

Milk production was an important cattle productivity indicator which affected the performance of new ECF control methods. Milk production from cows was not only affected by ECF but also by the intensity of tick infestation as well as other diseases. The effects of cattle immunization by ITM on milk production were not precisely known. However, researchers generally conclude that milk production will increase because the effects of ECF disease on cattle will be minimized or eradicated with immunization. One of the major advantages of ITM as advanced by researchers and as outlined in Chapter I is that it will lead to a reduction in the levels of use of acaricides. However, reduction in acaricide use is likely to result in higher intensities of tick infestation which might lead to a reduction in milk yields. The extent to which the levels of milk production will be reduced without changing the most preferred ECF control method was tested by reducing milk yields to the level where Scenario D was no longer the dominant one. The initial Scenario D assumed that milk yields would increase by 25 percent from the Base scenario. The levels of milk production for each of the base farms is summarized in Table 5.3.

The results on sensitivity analysis for farms in Uasin Gishu District and Kaloleni Division are summarized in Tables 5.22 and 5.23, respectively. The results indicated that a 10 percent reduction in milk production from the original levels used for Scenario D for each farm led to a change in the ranking of the most preferred ECF control method. Scenario C became the most preferred ECF control method and the new Scenario D_1 was also dominated by Scenarios B and E. The new Scenario D_1 dominated the Base scenario only. The estimated mean NPV values for the new Scenario D_1 compared to the original Scenario D in Uasin Gishu District were Kshs. 362,257 and 407,553, respectively for the small Grade farm, Kshs. 345,974 and 679,391 for the large Grade cattle farm, and Kshs. 118,200 and 136,200, respectively for the medium Zebu cattle farm. The respective mean NPV values for D_1 and D for Kaloleni farms were Kshs. 133,827 and 155,131 for the small Grade cattle farm, Kshs. 112,077 and 138,758 for

Table 5.22. Stochastic Dominance Results for Sensitivity Analysis on Milk Yields for Uasin Gishu District Farms.

	Level of Milk Yield					
	Small Grade Farm		Large Grade Farm		Medium Zebu Farm	
Ranking	Scenario D	10% decrease	Scenario D	10% decrease	Scenario D	10% decrease
Most Preferred Scenario	D	C	D	C	D	C
2nd Most Preferred Scenario	C	E	C	B	C	B
3rd Most preferred Scenario	E	B	B	E	B	E
4rd Most Preferred Scenario	B	D_1	E	D_1	E	D_1
5th Most Preferred Scenario	BASE	BASE	BASE	BASE	BASE	BASE

Confidence Premiums Generated for Sensitivity Analysis Kshs. per Year per Cow

Dominant	**Challenger**			
D	D_1	1803	2712	697
C	D_1	2362	2125	496
B	D_1	184	1154	244
E	D_1	713	893	216
D_1	BASE	6648	N/A	2523

Table 5.23. Stochastic Dominance Results for Sensitivity Analysis on Milk Yield for Kaloleni Division Farms.

Level of Milk Yield

Ranking	Small Grade Farm: Scenario D	Small Grade Farm: 10% decrease	Large Grade Farm: Scenario D	Large Grade Farm: 10% decrease	Medium Zebu Farm: Scenario D	Medium Zebu Farm: 10% decrease
Most Preferred Scenario	D	C	D	C	D	C
2nd Most Preferred Scenario	C	E	C	E	C	B
3rd Most preferred Scenario	E	B	E	B	B	E
4rd Most Preferred Scenario	B	D_1	B	D_1	E	D_1
5th Most Preferred Scenario	BASE	BASE	BASE	BASE	BASE	BASE

Confidence Premiums Generated for Sensitivity Analysis, Kshs. per Year per Cow

Dominant	Challenger	Small Grade Farm	Large Grade Farm	Medium Zebu Farm
D	D_1	2090	1146	523
C	D_1	1446	779	447
B	D_1	633	254	308
E	D_1	649	371	218
D_1	BASE	5533	4150	1586

the large Grade cattle farm, and Kshs. 51,977 and 68,733 for the medium Zebu cattle farm.

The change in ranking for Scenario D within a very narrow range of change in milk production for all farms implied that the economical and financial soundness of the new ECF control methods were very sensitive to milk production. If the reduction in acaricide use leads to reduced milk production as a result of high tick infestation or other tick-borne disease incidence, the feasibility of Scenario D declines rapidly.

Infection and Treatment Method Costs

The cost of immunizing cattle by the ITM method used in the analysis was estimated at a total cost of Kshs. 544.00 per animal over the planning horizon or Kshs. 54.40 per animal per year. This cost was estimated by Mukhebi et al (1991) and was based on the initial trials of immunizing cattle in Kaloleni Division. However, the cost is likely to vary from region to region and from time to time. Due to the importance of the cost of ITM in influencing the farmer's decision to use the improved ECF control methods, sensitivity analysis was done to determine the stability of the most preferred ECF control method (Scenario D).

The results of sensitivity analysis on the cost of ITM for Uasin Gishu District farms are shown in Table 5.24. The results indicated that the cost of ITM had to be changed upwards by 350 percent for the small Grade farm, and 200 percent for the large Grade and medium Zebu cattle farms from the cost used for the original Scenario D before the strategy was dominated by Scenario C. However, the new Scenario D_1 still dominated B, E, and the Base scenario. The respective mean NPV values for the original D compared to the new D_1 were Kshs. 407,553 and 401,412 for the small Grade farm, Kshs. 679,391 and 636,927 for the large Grade cattle farm, and Kshs. 136,200 and 131,913 for the medium Zebu cattle farm. The ITM cost which led to changes in the most preferred ECF control method from Scenario D to Scenario C were kshs. 244.80 per animal per year for the small Grade cattle farms, and Kshs. 217.60 per animal per year for the large Grade and medium Zebu cattle farms.

The results for sensitivity analyses for Kaloleni farms presented in Table 5.25 indicate

Table 5.24. Stochastic Dominance Results for Sensitivity Analysis on the Cost of ITM for Uasin Gishu District Farms

	Level of ITM Cost					
	Small Grade Farm		Large Grade Farm		Medium Zebu Farm	
Ranking	Scenario D	350% increase	Scenario D	200% increase	Scenario D	200% increase
Most Preferred Scenario	D	C	D	C	D	C
2nd Most Preferred Scenario	C	D_1	C	D_1	C	D_1
3rd Most preferred Scenario	E	E	B	B	B	B
4rd Most Preferred Scenario	B	B	E	E	E	E
5th Most Preferred Scenario	BASE	BASE	BASE	BASE	BASE	BASE

Confidence Premiums Generated for Sensitivity Analysis, Kshs. per Year per Cow

Dominant	**Challenger**	Small Grade Farm	Large Grade Farm	Medium Zebu Farm
D	D_1	896	304	136
C	D_1	17	7	36
D_1	B	274	445	102
D_1	E	95	888	163
D_1	BASE	1889	N/A	1776

Table 5.25. Stochastic Dominance Results for Sensitivity Analysis on ITM Cost for Kaloleni Division Farms

	Level of ITM Cost					
	Small Grade Farm		Large Grade Farm		Medium Zebu Farm	
Ranking	Scenario D	350% Increase	Scenario D	350% increase	Scenario D	350% increase
Most Preferred Scenario	D	C	D	C	D	C
2nd Most Preferred Scenario	C	D_1	C	D_1	C	B
3rd Most preferred Scenario	E	E	E	E	E	D_1
4rd Most Preferred Scenario	B	B	B	B	B	E
5th Most Preferred Scenario	BASE	BASE	BASE	BASE	BASE	BASE

Confidence Premiums Generated for Sensitivity Analysis, Kshs. per Year per Cow

Dominant	**Challenger**	Small Grade Farm	Large Grade Farm	Medium Zebu Farm
D	D_1	481	874	184
C	D_1	5	141	127
D_1	B	580	840	35[a]
D_1	E	313	362	10
D_1	BASE	3821	6088	1360

[a] B is dominant over D_1

that ITM cost was needed to be changed upwards by 325, 350, and 300 percent for the small Grade, the large Grade, and the medium Zebu cattle farms, respectively, from the initial cost before Scenario D could be dominated by Scenario C. At this level the new Scenario D_1 still dominated Scenarios E, B, and the Base farm. The estimated respective mean NPV's for the original Scenario D and the new Scenario D_1 were Kshs. 155,131 and 151,808 for the small Grade farm, Kshs. 138,875 and 134,024 for the large Grade cattle farm, and Kshs. 68,733 and 63,635 for the medium Zebu cattle farm. The new ITM costs per animal per year which caused the changes were Kshs. 244.80, 231.00 and 217.00 for the small and large Grade, and medium Zebu cattle farms, respectively.

The sensitivity analysis results on ITM costs for Uasin District and Kaloleni Division indicated that a reduction of acaricide use by 75 percent (Scenario D) was stable over a wide range of ITM costs for farms of different land sizes and cattle types. The widest range was obtained by the small Grade Cattle farm in Uasin Gishu and the large Grade cattle farms in Kaloleni Division. These were the farms that incurred the highest costs in acaricide use as shown in Table 5.1.

Acaricide Costs

The reduction of the use of acaricides in controlling ECF is one of the most important advantages to be realized from immunizing cattle using the ITM because acaricides are the second largest cattle production expense after feeds on farms (Tables 5.1 and 5.2 for Kaloleni Division and Uasin Gishu District, respectively. The use of acaricides varied from farm to farm and depended mostly on the frequency of dipping or spraying cattle. Thus, the costs of acaricides use varied greatly among farms. In addition, the costs of acaricides were also likely to change due to changes in the general level of prices in the country. Consequently, sensitivity analysis was done on acaricide costs for the most preferred ECF control method (Scenario D) to determine the range under which the method remained the most preferred ECF control method.

Table 5.26. Stochastic Dominance Results for Sensitivity Analysis on Acaricide Cost for Uasin Gishu District Farms

	Level of Acaricide Cost					
	Small Grade Farm		Large Grade Farm		Medium Zebu Farm	
Ranking	Scenario D	100% increase	Scenario D	100% increase	Scenario D	100% increase
Most Preferred Scenario	D	C	D	C	D	C
2nd Most Preferred Scenario	C	D_1	C	D_1	C	D_1
3rd Most preferred Scenario	E	E	B	B	B	B
4th Most Preferred Scenario	B	B	E	E	E	E
5th Most Preferred Scenario	BASE	BASE	BASE	BASE	BASE	BASE

Confidence Premiums Generated for Sensitivity Analysis, Kshs. per Year per Cow

Dominant	**Challenger**	Small Grade Farm	Large Grade Farm	Medium Zebu Farm
D	D_1	378	307	152
C	D_1	1	8	7
D_1	B	775	565	111
D_1	E	255	1007	202
D_1	BASE	3478	N/A	1098

Table 5.27. Stochastic Dominance Results for Sensitivity Analysis on Acaricide Costs for Kaloleni Division Farms.

Level of Acaricide Costs

Ranking	Small Grade Farm: Scenario D	Small Grade Farm: 100% increase	Large Grade Farm: Scenario D	Large Grade Farm: 125% increase	Medium Zebu Farm: Scenario D	Medium Zebu Farm: 100% Increase
Most Preferred Scenario	D	C	D	C	D	C
2nd Most Preferred Scenario	C	D_1	C	D_1	C	D_1
3rd Most preferred Scenario	E	E	E	E	B	B
4rd Most Preferred Scenario	B	B	B	B	E	E
5th Most Preferred Scenario	BASE	BASE	BASE	BASE	BASE	BASE

Confidence Premiums Generated for Sensitivity Analysis, Kshs. per Year per Cow

Dominant	**Challenger**	Small Grade Farm	Large Grade Farm	Medium Zebu Farm
D	D_1	6335	308	44
C	D_1	6	33	6
D_1	B	322	337	36
D_1	E	508	175	736
D_1	BASE	3755	2407	1510

The sensitivity analysis results for Uasin Gishu farms are presented in Table 5.25. The results suggest that acaricide costs would have to change upwards from the initial Scenario D by 100 percent for the small and large Grade farms, and 125 percent for the medium Zebu cattle farm before the control method would be dominated by Scenario C. However, the new Scenario D_1 still dominated B, E, and the Base scenario. The respective mean NPV for the new Scenario D_1 compared to the original Scenario D were Kshs. 401,908 and 407,553 for the small Grade cattle farm, Kshs. 641,383 and 679,391 for the large Grade cattle farm, and Kshs.151,914 and 235,187 for the medium Zebu cattle farm. The acaricide costs over which Scenario D was stable were Kshs. 200 to 400 for the small Grade farm, Kshs. 110 to 220 for the large Grade cattle farm, and Kshs. 57 to 128 for the medium Zebu cattle farm.

The sensitivity results for acaricide costs on the Kaloleni farms are presented in Table 5.26. As shown in the table, the percentage changes required in acaricide costs for Scenario D to be dominated by Scenario C were 100 for the small Grade and medium Zebu cattle farms, and 125 for the large Grade cattle farm. The respective mean NPV values for the original D and D_1 were Kshs. 235,187 and 151,914 for the small Grade cattle farm, Kshs. 138,758 and 132,559 for the large Grade cattle farm, and Kshs. 68,733 and 67,483 for the medium Zebu cattle farm. The levels of acaricides costs for which acaricide costs remained stable were Kshs. 171 to 342 for the small Grade cattle farm, Kshs. 200 to 450 for the large Grade cattle farm, and Kshs. 38.90 to 77.80 for the medium Zebu cattle farm.

The sensitivity results on acaricide costs for Uasin Gishu District and Kaloleni Division suggest that acaricide use and, therefore, costs could be reduced over a wide range before the most preferred ECF control method (reduction of acaricide costs by 75 percent) was dominated by a reduction of acaricide costs by 50 percent. The widest range occurred for the Zebu cattle farm in Uasin Gishu District and the large Grade cattle farm in Kaloleni Division

CHAPTER VI

SUMMARY, CONCLUSIONS, IMPLICATIONS AND LIMITATIONS

The Problem and Objectives of The Study

Economic analysis is an important prerequisite in the development of new technologies before they are transferred to farmers for adoption. However, economic evaluation and assessment, particularly for *ex-ante* analyses is usually complicated. Generally the benefits, costs, and impacts of the technology in *ex-ante* analysis are evaluated before the technology is actually introduced on the farm or ranch. Consequently, the actual results on the farm or ranch are not known but are instead based on experimental research trials. The evaluation of a new technology based on research trial results does not always reflect the economic viability of the technology on an actual farm because the conditions on the farm, particularly resource endowments, may be quite different from those on research stations. Another problem with economic analysis for new technologies is the measurement of benefits and costs. Most of the traditional benefit and cost analyses do not adequately take into account the risks which are involved in the use of the technology.

Although the development of improved East Coast Fever (ECF) control methods are emphasized in Africa, available economic analyses on the new and existing control methods are limited to costs, financial, and other economic estimates using budgeting techniques. However, budgeting techniques usually include assumptions that stochastic variables such as price and yields are known with certainty. Consequently, price and production risks among other risks are not usually adequately accounted for in the benefit cost analyses. Furthermore, the traditional techniques usually do not determine the economic viability or survival of farms as a result of adopting new technologies.

To bridge the gap that exists between development and economic evaluation of livestock disease control methods in Africa, the socioeconomic program at the International Laboratory Research for Animal Diseases (ILRAD) is developing methodologies for economic analysis. One such technology is a firm level simulation model known as the Technology Impact Evaluation Simulator (TIES). The TIES is a computerized simulation model which quantifies the economic impacts of both livestock and crop technologies on farms in developing countries. The model is used to assess and predict the financial and economic impacts of alternative technologies on farms.

In this study, the TIES model was used to evaluate the financial and economic impacts of alternative ECF control methods in Uasin Gishu District and Kaloleni Division in Kenya. The main purpose was to evaluate the impacts of a newly developed technique for controlling ECF. The new ECF control method, known as "Infection and Treatment Method" (ITM), is an immunization procedure which has proven to be technically and economically feasible on research stations. Consequently, most governments in East, Central, and Southern Africa intend to introduce the method for use by farmers. However, the economic impacts of the new technology have not been assessed. Hence, the overall objective of this study was to evaluate and predict farm-level financial and economic impacts of alternative ECF control methods under different cattle production systems in Kenya. The specific objectives were the following:

1) To describe the cattle production systems and identify current farm level ECF control methods.
2) To evaluate the financial and economic impacts of alternative ECF control methods on farm level.
3) To determine the most preferred ECF control method that would be used on farms.

Procedures and Analytical Methods

Whole farm simulation was used for the analyses in this study. The simulation used the TIES model. TIES is a Monte Carlo simulation model that simulates annual production, marketing, financial management and family consumption activities of a farm over a 10-year planning horizon. The model uses one year as its time step and simulates 10 years recursively, by starting each year with the ending debt and asset information for the previous year. It is a Monte Carlo simulator in that exogenous variables influenced by weather (such as crop yields and milk production per cow) and market forces (crop and livestock prices) are drawn at random to simulate the uncertainty and risk faced by farmers. The model incorporates farm production activities, such as crop mix, yield, production, family consumption, livestock feeding, and marketing. The annual economic activities included in the model are the calculation of variable and fixed costs, debt repayment, machinery depreciation and replacement, family consumption, off-farm income, marketings and total receipts, income taxes, government payments, and balance sheet values (assets and liabilities). Risks associated with crop yields, livestock production, and crop and livestock prices are estimated within the model from empirical probability distributions. The computation components of the model include accounting equations, identities, and table look-up functions. However, no econometric relationships with fixed parameters are included in the model.

Primary and secondary data were used in this study. The primary data were collected from selected farms in Uasin Gishu and Kilifi Districts in Kenya. The farms were selected using a stratified sampling framework on the basis of agro-ecological zones, land size of the farms and the cattle types kept or produced. The cattle types were broadly classified into Grade cattle (taurine breeds and crosses between taurine and indigenous breeds) and Zebu cattle (indigenous breeds). In total, data were collected from 30 farms, fifteen farms from each region. However, in the final analysis, six farms were analyzed in detail for each region. These were three Grade cattle farms classified according to land size as small, medium and large, and three Zebu cattle farms also classified similarly as for the Grade farms. During the survey, data were collected using a structured questionnaire. The collected data included all the farm resources and enterprises, yields, inputs, input and output prices, and production and management practices on the farms. Data on farm assets, liabilities, off-farm investments and income, crop and livestock sales, and consumption along with food requirements by the household were also collected from the case farms. Secondary data were collected from existing records, particularly those from the Ministries of Agriculture and Livestock Development reports. The emphasis on secondary data collection was on ticks and tick-borne disease control methods. These data included the costs of tick and tick-borne disease control technologies and the technical coefficients on cattle productivity associated with alternative control methods.

The TIES model was used to simulate the case farms over a 10-year planning horizon using random values for crop and livestock yields and output prices. One hundred replications of each of the alternative ECF disease control methods were simulated with the model. The output variables from the model included net present values, ending net worth, beginning net worth, benefit-cost ratio, internal rate of return, average annual cash receipts, average annual cash expenses, and average annual cash and net farm income. The simulation results indicated the minimum, mean, maximum, standard deviation values and the coefficient of variation in percentage terms. The simulation also indicated the probability of farm survival and success. In addition, the model developed a cumulative probability density function for the net present value of the farms for each alternative ECF control method.

Alternative ECF control methods were evaluated by defining and specifying how epidemiological cattle disease parameters, physical inputs and yields, and costs change from the currently practiced method. Five alternative ECF control methods were specified for evaluation. These scenarios were: (A) the currently practiced ECF control methods on the farm, (B) adoption of immunization with no change in acaricide use, (C) adoption of immunization with a 50-percent reduction in acaricide use, (D) adoption of immunization with a 75- percent reduction in acaricide use but with similar cattle productivity and mortality effects to alternative B and C, and (E) adoption of immunization with a 75-percent reduction in acaricide use with changes in cattle productivity from alternative D.

The alternative ECF control methods were compared for financial and economical performance using the generated simulated key output variables in TIES. The compared parameters were the means, standard deviations, minimum and maximum values of the simulated annual cash receipts, annual cash expenses, annual cash and farm incomes, net present value, ending net worth, internal rate of return, and benefit-cost ratio. The financial and economic impacts of the methods were evaluated using three criteria. These criteria were; 1) the probability of farm survival, 2) probability of economic success, and 3) stochastic dominance with respect to a function.

Results

Survey Results

This study analyzed five alternative ECF control methods in two regions in Kenya, Uasin Gishu District and Kaloleni Division. Different cattle production systems were identified in these regions. In Uasin Gishu District, two cattle production systems were identified. All the Zebu cattle farms were grazed on natural pastures. Grade cattle farms practiced some level of semi-zero grazing in which cattle were grazed on natural or improved pastures, but they were also fed on fodder crops and crop residues in enclosures. In Kaloleni Division, three cattle production systems were identified. All Zebu cattle were kept on free range grazing on natural pastures. The small Grade cattle farms practiced semi-zero grazing, while the medium and large Grade cattle farms kept cattle on free range grazing but the cattle were also fed on improved fodder and purchased feed in enclosures.

The importance of the cattle production systems in economic analysis is to indicate the intensity of use of production inputs and management practices. The cattle production systems in Uasin Gishu and Kaloleni indicated that the highest expense on farms for all cases was the purchased feed costs followed by acaricide costs. The highest acaricide expenses were estimated at Kshs. 800 per cow for the small Grade cattle farm in Uasin Gishu District and the large Grade cattle farm in Kaloleni Division. Acaricide costs varied with the frequency of application. The greater the frequency of dipping or spraying, the higher the costs of the acaricides. The acaricide costs were also higher for Grade cattle farms than for Zebu cattle farms in the two regions. The higher cost indicated a higher frequency of acaricide use on Grade cattle than on Zebu cattle. However, the acaricide costs were also higher for farms where cattle were sprayed compared to farms where cattle were dipped. The cost of dipping cattle was lower partly because the government subsidized the cost.

The importance of cattle in the household economies of the two regions was the use of cattle products as food for the family and in other production processes and the contribution of cattle and cattle products to farm income. Cattle contributed more to farm income in Uasin Gishu District than in Kaloleni Division (Tables 5.4 and 5.5). The main sources of cattle receipts were milk sales and the sale of cull cows, bull calves, steers, cull bulls, and oxen. The sale of manure on farms was uncommon, while a few farmers sold hides from the slaughtered cattle or from those which died on the farm. In general, the medium and large Grade cattle farms were able to generate adequate net cash farm income to meet household living expenses. Most of the other farms had to rely on off-farm income to offset shortfalls in cash income required for household living and farm expenses.

Simulation Results

The simulation results from the five alternative ECF control methods were used to analyze the financial and economic performance of the farms, the probability of survival and the probability of economic success of the farms. The economic output variables that were compared among farms were net present value (NPV), present value of ending net worth (PVENW), internal rate of return (IRR), and benefit cost ratio (BCR). The financial output variables that were considered in the analysis were average annual cash receipts, average annual cash expenses, and average annual cash and net farm income. The probability of survival was analyzed using the probability that the farm would annually maintain an equity to asset ratio greater or equal to 19.0 percent (the interest rate charged by commercial banks on borrowed funds) for the whole 10-year planning horizon. The probability of economic success was analyzed using the probability that the farm would generate at least a rate of return of 12.6 (discount rate used to calculate net present value) or more to the initial equity of the owner. The other criteria used to evaluate the economic success of farms were the probability of IRR being equal or greater than 12.6 percent, the probability of BCR being equal or greater than 1.0 and the probability of lower real equity. Finally, the alternative ECF methods were evaluated using the criterion, stochastic dominance with respect to a function to rank them according to the most preferred generated highest NPV. Stochastic dominance was also used to calculate the confidence premiums of the dominant alternative ECF control methods over the dominated ones.

Financial and Economic Performance

The simulation results indicated that all the new ECF control methods generated higher mean values for NPV, PVENW, IRR, BCR, annual receipts, and annual cash and net farm income than the currently used control methods for all farms in the two regions. The currently practiced method, however, generated higher annual mean expenses than most of the new ECF control methods. In all cases the highest values for mean NPV, PVENW, IRR, average annual receipts, and average annual cash and net farm income were generated by the ECF control method with a 75-percent reduction in acaricide costs (Scenario D) and was followed by the control method with a 50-percent reduction in acaricide use (Scenario C). The Base farm scenario was ranked last for all farms.

Rankings of Scenario B (adoption of ITM with no change in acaricide use) and Scenario E (adoption of ITM with a 75-percent reduction in acaricide use with a decline in cattle productivity) was not uniform for all farms in the regions. Some farmers ranked Scenario B higher than Scenario E using mean NPV and PVENW, while others ranked Scenario E higher than Scenario B. The differences in ranking were explained by the relative low reduction in expenses for Scenario B from introducing ITM with no change in acaricide use and the relatively higher reduction in productivity in Scenario E that also included large reductions in acaricide use. If the reduction in annual cash expenses in B were relatively higher than the reduction in economic productivity in E, then B was ranked higher than E. However, if the reduction in expenses for B were relatively lower than the economic productivity reduction in E, then E was ranked higher than B. Zebu cattle farms in Uasin Gishu District tended to rank Scenario E higher than Scenario B, while Grade cattle farms tended to rank B higher than E. Rankings of alternatives for all farms using BCR were also not uniform. In all cases the highest BCR was generated by Scenario D; however, ranking of the subsequent alternatives varied from farm to farm. In general, BCR ranked alternative ECF control methods with relatively low returns and costs higher than the alternatives with relatively higher receipts and expenses.

In general, the results on the financial and economic performance of farms in Uasin Gishu District indicated that large farms, regardless of the cattle types, generated relatively higher NPV, PVENW and average annual net cash and farm income than the smaller ones (Tables 5.6 to 5.11). The results were attributed to the relatively higher reduction in acaricide and ECF treatment costs for the large farm compared to the small ones. Furthermore, the reduction in cattle mortality rates resulted in a larger number of animals (male and surplus female culls) to be sold from large farms than for the small farms. The increase in milk yields per cow from adopting ITM and the larger number of cows kept by large farms also added to the higher receipts that were realized when compared to the small farms. The small farms however, generated relatively higher IRR and BCR than the larger farms. Regardless of the proportional sizes of the financial and economic variables, the new ECF control methods appeared to perform better than the currently practiced ECF control methods for farms of all land sizes.

Among farms of same land size but different cattle types in Uasin Gishu District, Grade cattle farms tended to generate higher values for NPV, PVENW, average annual cash receipts, and average annual cash and net farm income than the Zebu farms. The highest average annual receipts for the Grade cattle farms were about two times as high as those of Zebu cattle for small farms (Table 5.6 and 5.9). All the other farm sizes indicated a similar trend. Hence, Grade cattle appeared to generate proportionately higher returns from improved ECF control methods than Zebu cattle.

The results generated for NPV and PVENW for farms of different land sizes for both Grade and Zebu cattle in Kaloleni Division were not distinctly and clearly ranked as in Uasin Gishu District. The estimated NPV for Grade cattle was about Kshs. 164,520 for the small farm, Kshs. 250,790 for the medium farm and Kshs.140,360 for the large farm (Table 5.12, 5.13 and 5.14). On the other hand, the NPV estimates for the Zebu cattle farms were Kshs. 87,290 for the small farm, Kshs. 68,730 for the medium farm, and Kshs. 66,500 for the large farm. The possible explanation was attributed to lack of homogeneity in the types of cattle produced. In Kaloleni Division, the Grade cattle were of different degrees of crosses between taurine and indigenous breeds; consequently, their productivity, particularly milk production, varied greatly. A further explanation could be the feeding standards which affected the productivity of the cattle. Large farms seemed to use low levels of purchased feeds as indicated in Table 5.1. Consequently, milk productivity was relatively low, particularly for the large Zebu cattle scale farm.

The performance of the economic and financial results for farms of similar size but different cattle types in Kaloleni Division indicated a trend similar to that observed in Uasin Gishu District. Grade cattle farms generated higher values in absolute terms than Zebu cattle farms for the new ECF control methods. The generated NPV ranged from about two times higher for the large farms to about three times higher for the small farms (Tables 5.12 to 5.17). The highest generated IRR was 34.87 percent for the small Grade cattle farm compared to 27.87 percent for the small Zebu cattle farm. Although the average annual expenses were fairly high for the Grade cattle farms, the average annual cash and net farm income were also fairly high. These results indicated that although both Grade and Zebu cattle farms will benefit from the improved ECF control methods, Grade cattle farms are likely to benefit proportionately more. These results were similar to those generated for Uasin Gishu District.

Probability of Survival

The simulated results indicated that all farms had a 100-percent probability of survival for all the new ECF control methods. Some of the farms also indicated a probability of survival of 100 percent for the currently used ECF control methods. The exceptions were the large Grade cattle farm in Uasin Gishu District and the large Zebu cattle farm in Kaloleni Division. The low probability of survival estimated for the large Grade cattle farm in Uasin Gishu District was attributed to large loan debts on the farm. This was the only farm that had borrowed funds from commercial banks for investment on the farm. After the adoption of the new ECF control methods, the farm had a probability of survival of 100 percent for all alternative new ECF control methods.

Probability of Economic success

All farms indicated a probability of economic success of 100 percent for the new improved ECF control methods on the basis of the internal rate of return for the initial equity of the owner being greater or equal to 12.6 percent. This result was in contrast to the probabilities shown for some farms for the currently practiced ECF control methods. The results on large Grade and Zebu cattle farms in Uasin Gishu and the medium and large Zebu cattle farms in Kaloleni indicated a probability of economic success of less than 100 percent.

The probabilities of economic success using the probability of IRR being greater or equal to 12.6 percent varied among farms. Results on all farms in both Uasin Gishu and Kaloleni indicated a probability less than 100 percent for the currently practiced ECF control methods. Most farms, however, generated a probability of 100 percent for Scenario D (the scenario that generated the highest absolute IRR for all farms) except for the large Grade and Zebu cattle farms in Uasin Gishu District, the small Grade and the medium and large Zebu cattle farms in Kaloleni Division. When these results were compared to the absolute IRR values as a criterion for rejecting or accepting new ECF control methods, the absolute IRR values could reject all the alternatives with a value less than the cut-off rate. This rejection, however, does not indicate the probability that there would be some chance that the alternative would be accepted. Therefore, the use of probabilities in addition to the absolute values in selecting among alternative ECF control methods or any other investments can assist decision makers in determining the chances of an investment being financially and economically acceptable.

The probability that the BCR would be greater than 1.0 was 100 percent for most farms for the new ECF control methods. The exception was for the large Grade cattle farm in Uasin Gishu District for all alternatives. The large Grade and Zebu cattle farms and the medium Zebu cattle farm in Kaloleni Division also had probabilities less than 100 percent that the BCR would be greater or equal to 1.0. The probabilities below 100 percent for the BCR being less than 1.0 indicated the chance that the ratio of benefits to costs would be equal or greater than 1.0.

The probability that farms would generate lower real equity were greater than zero for most farms in Kaloleni Division except for the small and medium Grade cattle farms. The probabilities that farms would generate lower real equity for Zebu cattle farms were 100 percent for all farms in this region. However, the adoption of new ECF control methods reduced the probabilities to less than 100 percent. In Uasin Gishu District, the probability of lower real equity were greater than zero and higher for the large Grade and Zebu cattle farms for the Base scenario. However, these probabilities were also reduced with the adoption of new ECF control methods. The results indicated that although the new ECF control methods increased the net worth of farms, there was a chance that the net worth would be decreased. The risk of reducing net worth was highest for Zebu cattle farms in Kaloleni.

Stochastic Dominance Analysis

The results of stochastic dominance ranking indicated that the most preferred alternative ECF control method for all farms was the reduction in acaricide expenses by 75 percent with the adoption of ITM (Scenario D). This was followed by Scenario C for all farms. The currently practiced methods (the Base scenario) was the least preferred ECF control method for all farms. The results imply that all risk averse farmers chose Scenario D as the most efficient ECF control method.

The highest confidence premiums from the Base scenario were generated by Scenario D for all farms. This scenario was also the most preferred alternative ECF control method in all cases. In Uasin Gishu District, the highest confidence premium was Kshs. 4,379 per cow for the medium Grade cattle farm, while the lowest was Kshs. 1,285 per cow for the medium Zebu cattle farm. In Kaloleni Division, the highest confidence premium was Kshs. 4,500 per cow for the medium Grade cattle farm and the lowest was Kshs. 1,312 per cow for the large Zebu cattle farm. The confidence premiums indicated how much the farmers were willing to pay to adopt the new ECF control methods. However, because the values were calculated for the whole cow herd, care should be taken if they are to be used to determine the appropriate cost for the new ECF control method.

Sensitivity Analysis Results

The sensitivity analysis results indicated that the most preferred new ECF control method (reduction of acaricide costs by 75 percent with the adoption of ITM) was stable over a wide range of cattle mortality rates, ITM costs and acaricide costs. However, the most preferred method was sensitive to changes in milk productivity. The ranges at which the method was stable for cattle mortality rates are shown in Tables 5.20 and 5.21 for Uasin Gishu District and Kaloleni Division, respectively. The estimated ranges in Uasin Gishu District were between 3.0 to 6.8 percent for Grade cattle calves and 2.0 to 4.5 percent for mature Grade cattle, while the estimates for the Zebu cattle were 2.0 to 5.0 percent for calves and 1.0 to 2.5 percent for mature cattle. The estimated cattle mortality ranges for cattle in Kaloleni Division for Grade cattle were between 4.0 to 7.2 percent for calves and 2.0 to 3.6 percent for mature cattle. The ranges for Zebu cattle were between 2.0 and 3.6 for calves and 1.0 to 1.8

percent for mature cattle.

The most preferred new ECF control method was sensitive to narrow ranges of change in milk production. The range within which the most preferred ECF control method was stable was 10 percent from the production level for cattle at the currently practiced ECF control methods. At this percentage change in milk production (over 10 percent), the most preferred alternative ECF control method was the reduction in acaricide use by 50-percent with the adoption of ITM. In addition, at this percentage changes for milk production, Scenario B (adoption of ITM with no change in acaricide use) and Scenario E (ITM adoption with 75-percent reduction in acaricide use but with changes in cattle productivity) also dominated the most preferred Scenario D. These results indicated that a 75-percent reduction in acaricide use as a result of adopting ITM could lead to a reduction in the economical soundness of this ECF control method if this technology was accompanied by a reduction in milk production from tick infestation or other diseases.

The costs of ITM at which Scenario D was stable for Uasin Gishu farms ranged from Kshs. 54.40 to Kshs. 217.60 per animal per year, an increase of ITM costs of up to 300 percent. The range of ITM costs within which the most preferred Scenario D was stable for Kaloleni farms was Kshs. 54.40 up to Kshs. 244.80, an increase of ITM costs of up to 350 percent. The cost changes in acaricides within which Scenario D remained stable were between Kshs. 200 to 400 for Grade cattle and Kshs. 110 to 225 for Zebu cattle farms in Uasin Gishu, an increase in acaricide costs of up to 100 and 125 percent, respectively. In Kaloleni the range for the acaricide costs were Kshs. 171 to 384.75 for Grade cattle farms and Kshs. 38.90 to 77.90 for Zebu cattle farms, an increase of acaricide costs of up to 125 and 100 percent, respectively. These results indicated that ITM and acaricide costs could be varied greatly with a high reduction in acaricide use without changing the most preferred ECF control method.

Conclusions and Implications

Simulation modelling

The present study has demonstrated that whole farm simulation offers a flexible method for assessing and predicting the financial and economic impacts of new technologies on farms. Assessment and prediction were accomplished using the TIES model which accounts for the stochastic nature of yield and prices. Using the model, risk associated with these parameters are easily incorporated using probability distributions. The model can use either objective probability distributions from available data or subjective estimates from the experience of producers, researchers or extension agents. The TIES model appears to be a useful tool that could assist researchers in developing countries to assess new or alternative technologies even in the absence of time series data. Nevertheless, this model like most other farm economic models requires realistic information concerning the farming situation under consideration.

The simulated results for NPV, PVENW, IRR, and BCR among farms of different land size indicate different patterns in magnitudes. The large farms tended to generate high values for NPV and PEVNW, while the small farms tended to generate high values for IRR and BCR. Using the generated mean NPV and PVENW to recommend the farms that should or should not use the improved ECF control method on the basis of highest generated values would discriminate against small farms. On the other hand, using the generated highest mean IRR and BCR to recommend farms that should or should not use the improved ECF control method would also discriminate against large farms. These results were consistent with the findings in the literature that the selection of independent investments using either NPV, IRR or BCR can be misleading (Gittinger 1982 and Brown 1979). The three criteria are only useful in showing the investments that meet the selection criteria for financial or economic acceptability rather than ranking them directly. However, simulation modelling in this case allows for the alternative technologies or investments to be ranked using the stochastic dominance criterion.

Simulation modelling offers an opportunity to estimate the probabilities associated with the output variables such as NPV, PVENW, IRR, and BCR. The generated probabilities of the output variables were used in this study to estimate the probability distributions of survival and economic success of the alternative technologies or investments on farms. These estimates were important in indicating the economic viability of farms from the use of new technologies. The probability distributions of NPV were also used to rank the alternative ECF control methods using the generalized stochastic dominance criterion.

The simulation results from this study demonstrate that the traditional criteria of selecting new technologies or investments (using absolute values of mean NPV, IRR, and BCR) can indicate whether a new investment is acceptable at a given level for the chosen variable. However, the absolute measures do not indicate the chance that the investment can attain the required criterion level. The use of stochastic simulation, on the other hand, generates probabilities associated with the estimated selection criteria which indicates the chances of the criteria being attained. Hence, in addition to generating mean values for selecting among alternative investments, simulation analysis with this model also generates probabilities that indicate the chances of attaining the criterion.

The results from this study also demonstrate that the generalized stochastic dominance criterion can be used to rank alternative ECF control methods unequivocally as opposed to using the simulated absolute mean values of NPV, IRR, and BCR. The criterion ranks alternative technologies for decision makers with a given risk attitude by eliminating the inefficient choice sets. This simulation analysis also incorporates the risk attitudes of the decision maker in selecting among alternative technologies or investments. The stochastic dominance criterion allows for the estimation of confidence premiums or convictions associated with the most preferred investment or technology alternative. The calculated confidence premiums for the preferred scenarios and its challengers indicate the shadow prices that might be attached to alternative technologies or practices.

Study Specific

The results from this study have demonstrated that the new improved ECF control scenarios are financially and economically viable for use on farms. The most preferred alternative ECF control scenario was the adoption of ITM with a 75-percent reduction in acaricide use. However, this alternative is sensitive to changes in cattle productivity, particularly milk production, even though it was shown to be stable over a wide range of cattle mortality rates, ITM, and acaricide cost levels. Results have indicated that if milk production is reduced by 10 percent or more, then adopting ITM with a high reduction in acaricide use would not be the most preferred ECF control method. Lower levels of acaricide reduction such as 50-percent, should be used instead.

Results have further shown that there is a trade-off between the levels of acaricide use and cattle productivity. The higher levels of acaricide use generate higher costs but result in higher productivity in milk production and live weight gains which lead to higher benefits. On the other hand, the lower use of acaricide results in lower costs but generates higher losses in milk and live weight gains which lead to lower benefits. To determine the point of optimizing benefits would require an accurate estimation of the losses from productivity in milk and live weight gains associated with different levels of acaricide use with the adoption of ITM. This information is currently lacking and should be the focus of technical research in the future.

Results from this study have also shown that the benefits associated with the use of the improved ECF control method for Grade cattle are higher than those generated from Zebu cattle. This result along with the findings that the new improved methods are financially and economically viable on farms, imply that removal of the ECF risk can increase the incomes of producers if they produce Grade cattle. However, the success of such a program will depend on the availability of initial capital in the form of loans for the farmers to invest in the new improved ECF control methods, in Grade cattle, and for purchasing cattle feed. This problem might be more severe in Kaloleni Division than in Uasin Gishu District because of the current low levels of farm income in the former region when compared to the latter.

Limitations of the Study

A major limitation of the simulation model used in this study is that the method does not indicate the economically optimal alternative. Determining the optimal solution would require use of optimizing techniques such as mathematical programming routines which were not included in the TIES model. Consequently, the most preferred ECF control method by farmers indicated in this study may not necessarily be the optimal solution in terms of resource allocation on the farm. Hence, caution is required when interpreting and recommending the alternative ECF control methods. The inherent assumption in determining the most preferred ECF control method was that farmers allocated resources efficiently; therefore, stochastic dominance was used to identify and select the most efficient choice set from among the inefficient choice sets.

Another limitation of this study was that it does not indicate the most preferred ECF control method from the point of view of the whole society. The economic analysis for this study was only concerned with the impacts of the alternative ECF control methods at the farm level. The analysis did not consider the impacts of the ECF control methods on society as a whole. Whereas, the most preferred ECF control method on the farm may be the most preferred for society as well, the relationship may not always be true. Economic analysis for alternative ECF control methods for the whole society (region or nation) will consider some factors such as subsidies for dipping costs for farmers as a cost to society, while the subsidy is considered as a benefit to the individual producer. Hence, the results of the economic analysis for a region or nation may be quite different from the results from the analysis for individual farms. Therefore, caution is required when interpreting the results of this study from the point of view of the whole society. However, the results from this study provide a bench-mark for an economic analysis of the ECF control methods for a region or the nation at large.

Implications for Future Research

The findings and conclusions from this study indicate that both technical and economic research is required to further improve upon the development of livestock disease control methods in Africa. Technical research is required to provide precise estimates of the various tick and tick-borne disease epidemiological parameters and the effects of the various tick-borne diseases on the productivity of cattle. The areas of emphasis should include:

i. The effects of tick infestation and other tick-borne diseases on the productivity of cattle (fertility rates, milk and beef production)

ii. The mortality rates associated with different tick-borne diseases.

Further economic research is required to provide more information on the sustainability and viability of the alternative ECF control methods on farms and for society at large. The areas of research to be emphasized include:

i. Similar research using the TIES model in other parts of the country and in the region. The research is necessary to provide information about the viability of the improved ECF control methods over a wide area. The findings from this study indicated that different farm circumstances affect the financial and economic viability of alternative ECF control method. Hence, information is required from many areas before generalizing the results from the improved ECF control method

ii. Studies to determine the optimal ECF control method on farms in terms of resource use. Such studies need to be carried out so that improved disease control methods may be evaluated in the context of the limiting resources on farms.

iii. Studies to evaluate the economic impacts of alternative ECF control methods on a a regional (divisional, district or national) basis. Such studies are necessary to indicate the magnitude of benefits and costs from the point of view of the whole society and also to indicate the most preferred and efficient ECF control method for a given region.

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APPENDICES

APPENDIX I

QUESTIONNAIRE USED TO COLLECT DATA FROM FARM SURVEYS

ECONOMIC EVALUATION OF IMPROVED LIVESTOCK DISEASE CONTROL METHODS:

DISTRICT:_____________ DIVISION: _________________

DATE______________ ECOLOGICAL ZONE:________________

SCALE OF FARM:________ CATTLE TYPE __________
GRAZING SYSTEM____________

1. HOUSEHOLD INFORMATION

1.1 HOUSEHOLD HEAD
A1. NAME OF FARMER: _________________
A2. WHO MANAGES DAY-TO-DAY FARM ACTIVITIES IF NOT A1. _______

1.2 HOUSEHOLD MEMBERS

AGE GROUP		NUMBER		
		MALES	FEMALES	ADULT EQUIV.*
i.	0 - 3 YEARS	-------	------------	--------------
ii.	3 - 5 "	-------	----------	---------
iii.	5 - 10 "	--------	----------	---------
iv.	10 - 18 "	-------	--------	---------
v.	MORE THAN 18 "	--------	--------	---------
	TOTAL ADULT EQUIVALENTS			---------

* CALCULATE THE ADULT EQUIVALENTS

1.3 OCCUPATIONS OFF THE FARM AND EARNINGS(*** MEMBERS STAYING ON THE FARM PERMANENTLY OR THOSE STAYING AWAY FOR A MAXIMUM OF 6 MONTHS IN A YEAR**)
INDICATE HOUSEHOLD MEMBER AS(HEAD, ADULT MALE, ADULT FEMALE, CHILD MALE, CHILD FEMALE)

FAMILY MEMBER	JOB NAME	MINOR/MAJOR	SALARY KSHS PER MONTH
1.	------------	-----------	--------------
2.	-------------	------------	--------------
3.	-------------	------------	--------------
4.	--------------	------------	---------------
5.	------------	------------	---------------
6.	-------------	-----------	---------------
7.	-------------	-----------	---------------
TOTAL OFF-FARM INCOME			------------

1.4 FAMILY LIVING EXPENSES (PURCHASED ITEMS)

FOOD ITEMS NORMALLY PURCHASED			QUANTITIES PURCHASED IN
FOOD ITEM	QUANTITIES/MONTH /ANNUAL (KGS)	MONTHLY/ANNUAL EXPENSE KSHS	A BAD (DROUGHT YEAR) KGS/MONTH/YEAR
1. MAIZE FLOUR			
2. RICE			
3. WHEAT			
4. BEANS AND PEAS			
5. ALL GREENS AND VEGETABLES			
6. MEAT			
BEEF			
LAMB/GOAT			
PORK			
7. FISHES			
8. BREAD			
9. SUGAR AND SALT			
10.BEVERAGES E.G TEA,COFFEE ETC			
11.COOKING FATS			
12. OTHERS			
TOTAL			

A2. OTHER PURCHASED ITEMS

ITEM	MONTHLY EXPENSE (KSHS)	OR	ANNUAL EXPENSE (KSHS)
1. CLOTHING			
2. HOUSEHOLD ITEMS			
3. SCHOOLING			
4. HOUSE REPAIRS			
5. TRANSPORTATION			
6. MEDICATION			
7. PARAFFIN AND FIREWOOD			
8. SOAPS(WASHING AND BATH)			
9. SKIN OILS AND POWDERS			
10. OTHERS			
TOTAL			

2. FARM ASSETS AND RESOURCES

2A. LAND

A1. HOW MANY FARMS DO YOU OWN? ____________

A2. SIZE OF THE FARMS

FARM	HECTARES/ACRES
1: FARM1 i.e. THIS FARM	------------------
2. FARM2	------------------
3. FARM3	------------------

A3. LAND UTILIZATION BY FARM

ACTIVITY	HECTARES/ACRES		
	FARM1	FARM2	FARM3
1. LAND UNDER CROPS	---------------	--------------	---------------
2. LAND UNDER PASTURES	---------------	----------------	---------------
3. LAND UNDER HOMESTEAD, ROADS AND FORESTS	---------------	-----------------	-----------------
4. IRRIGATED LAND	--------------	----------------	--------------

A4. FRACTION OF LAND THAT IS TILLABLE ______________

A5. MARKET VALUE OF LAND/HECTARE KSHS. ____________

A6. TOTAL VALUE OF LAND KSHS ____________

A8. OTHER TYPES OF LAND

1. AMOUNT OF LAND RENTED ______________ HA
2. AMOUNT OF LAND LEASED ______________ HA
3. AMOUNT OF PASTURELAND RENTED ______________ HA
4. AMOUNT OF PASTURELAND LEASED ______________ HA

2B. BUILDINGS AND FARM STRUCTURES

WHAT IS THE ESTIMATED CURRENT VALUE OF THE FOLLOWING BUILDINGS?

BUILDING/STRUCTURE	CURRENT VALUE (KSHS)
B1. MAIN FARM HOUSE	-------------------
B2. OTHER FARM HOUSES :	----------------------
1.	-----------------------
2.	------------------------
3.	------------------------
B3. STORES	-----------------------------
B4. WELL	-----------------------------
B5. OTHER	------------------------------

B6. FARM IMPROVEMENTS (DRAINAGE,SOIL CONSERVATION ETC.) VALUE KSHS. ________

TOTAL VALUE OF BUILDINGS AND IMPROVEMENTS ---------------------------

2C. LABOUR

1. SALARY OF A PERMANENT/FULL-TIME LABOURER KSHS. ---------------/MONTH

2. NUMBER OF FULL-TIME LABOURERS ON THE FARM---------------------WORKERS/YEAR

3. WAGE RATE FOR PART-TIME LABOUR KSHS. ---------------------/HOUR/DAY
4. NUMBER OF PART-TIME WORKERS HIRED LAST YEAR ------------------
5. TOTAL AMOUNT OF MONEY PAID TO HIRED LABOUR LAST YEAR KSHS.--------------

2D <u>MACHINERY, EQUIPMENT AND EQUIPMENT</u>
TABLE FOR MACHINERY AND EQUIPMENT INFORMATION

NAME	YEAR OF PURCHASE	PURCHASE PRICE (KSHS)	CURRENT* PRICE (KSHS)	USEFUL LIFE (YEARS)
1.JEMBES AND HOES				
2.PANGAS AND SLASHERS				
3. AXES				
4.FORAGE CHOPPERS				
5.SPADES				
6.WHEELBARROWS				
7.CARTS				
8.OXPLOW AND EQUIPMENT				
9. SPRAY PUMP				
10. SPRAY RACE				
11.MILK CANS AND EQUIPMENT				
12.WATER PUMPS				
13. WATER PIPES				
14.TRACTORS				
15. TRACTOR PLOUGHS				
16. BICYCLE				
17. MOTOR VEHICLE				

* CURRENT PRICE OBTAINED FROM LOCAL SUPPLIERS

2E. VALUE FOR STORED INPUTS AND PRODUCTS
WHAT ARE THE QUANTITIES AND VALUES OF THE FOLLOWING ITEMS AT THE BEGINNING OF 1991?

INPUT/PRODUCT	AMOUNT(KGS)	VALUE (KSHS.)
1. FERTILIZERS	------------	--------------
2. CROP SEEDS	----------------	--------------
3. CROP CHEMICALS	----------------	--------------
4. SPRAY/DIP ACARICIDE	----------------	--------------
5. MOTOR FUEL	----------------	--------------
6. GRAINS A.MAIZE	---------------	--------------
B. WHEAT	----------------	------------------
C. MILLET/SORGHUM	-------------	-----------------
D. OTHERS		
7. PULSES(BEANS AND PEAS)	--------------	--------------
8. NUTS	--------------	--------------
9. OTHERS	--------------	--------------
10. OTHERS		

3. CROP ENTERPRISES

* List all the crop enterprises grown on the farm in 1991 indicating the acreage grown each season using the table below. Any crop mixture is treated as a single crop enterprise. For a crop grown more than once in a year, each production (Long rains season or short rains season) is treated as a separate crop **

CROP ENTERPRISES 1991 TABLE 1

CROP	SEASON 1 ACREAGE (HA/ACRE)	SEASON 2 ACREAGE(HA/ACRE)
FARM 1		
1.-------------------------	----------------	-------------------
2.-------------------------	----------------	-------------------
3 -------------------------	----------------	-------------------
4.-------------------------	----------------	-------------------
5.-------------------------	----------------	-------------------
6. -----------------------	----------------	-------------------
7. -------------------------	----------------	-------------------
8. -------------------------	----------------	-------------------
9. ---------------------	----------------	-------------------
10. GRAZING AREA ON FARM	--------------	-------------------
FARM 2		
1. -------------------	-----------------	-------------------
2. -----------------	-----------------	-------------------
3. -----------------	-----------------	-------------------
4. ------------------	-----------------	-------------------
5. -------------------	-----------------	-------------------
6. GRAZING AREA	----------------	----------------------
FARM3		
1. -------------------	-----------------	-------------------
2. -------------------	-----------------	-------------------
3. -------------------	-----------------	-------------------
4. -------------------	-----------------	-------------------
5. GRAZING AREA ON FARM	----------------	-------------------

** FOR EACH CROP USE THE TABLE GIVEN NEXT PAGE TO GIVE DETAILED INFORMATION ON PRODUCTION, UTILIZATION AND DISPOSAL. THE INFORMATION RELATES TO 1991 CROP SEASONS***

CROP TABLE: NAME ________________ FARM NO.--------------
PURE STAND. ________________ MONTH PLANTED -----------
MIXTURE ________________ MONTH OF HARVEST----------
SEASON ________________
HECTARES PLANTED ________

3.1 PRODUCTION

ACTIVITY	QUANTITY (KGS)		VALUE (KSHS)	
	TOTAL	PER HA	TOTAL	PER HA/BAG
1. AMOUNT OF SEED USED	---------	--------	-----------	------------------
2. FERTILIZERS USED	---------	-------	----------	------------------
3. CHEMICALS USED	---------	--------	-----------	------------------
4. FUEL AND OIL USED	----------	---------	-----------	------------------
5. LAND CLEARING	----------	-----------	-----------	------------------
6. PLOUGHING	----------	--- --------	-----------	------------------
7. HARROWING AND RIDGING	-------	--- ------	-----------	-------------- ---
8. PLANTING CASUAL LABOUR	--------	-----------	------------	------------------
9. WEEDING CASUAL LABOUR	---------	------------	------------	------------------
10.FERTILIZER AND HERBICIDE APPL. CASUAL LABOUR	-----------	---------	------------	------------------
11. IRRIGATION COSTS	-----------	----------	-------------	------------------
12. HARVESTING CASUAL LABOUR	----------	----------	-------------	------------------
13. HARVESTING, GUNNY BAGS AND OTHER MATERIALS	--------	------	--------------	------------
14. TRANSPORTING COSTS FROM FIELD TO STORE	--------	---------	-------------	------------------
15. MARKETING COSTS (CLEANING, GRAD., MARKT. ETC.)	-----	----------	------------	-------------

3.2 CROP UTILIZATION AND DISPOSAL

ITEM/ACTIVITY QUANTITIES(KGS/BAGS)

1. AMOUNT HARVESTED (GREEN) --------- KGS/BAGS/YEAR DRY. -------KGS/BAGS/YEAR
2. AMOUNT USED,KEPT/STORED FOR FAMILY CONSUMPTION----- ---------KG/BAGS/YEAR
3. AMOUNT NORMALLY REQUIRED FOR FAMILY CONSUMPTION -------KGS/BAGS/YEAR
4. AMOUNT SOLD AT HARVEST ---------------KGS/BAGS. PRICE(KSHS)-------------/KG/BAG
5. AMOUNT STORED FOR SALE ----------------KGS/BAG. PRICE(KSHS)-------------/KG/BAG
6. AMOUNT NORMALLY STORED FOR SALE -----------KGS/BAGS
7. AMOUNT GIVEN OUT TO WORKERS AND OTHERS ---------------------KGS/BAGS/YEAR
8. AMOUNT FED TO LIVESTOCK (SPECIFY LIVESTOCK & FEED TYPE i.e. grain,forage etc.

LIVESTOCK TYPE)

Livestock Type	Feed Type Grain/Forage	Quantity KGS/Year	Value Kshs/unit	Total(KSHS)
i. CATTLE	--------------	-------------	-----------	---------
ii. SHEEP	--------------	-------------	------------	----------
Iii.GOATS	--------------	-------------	------------	-----------
iv. PIGS	--------------	-------------	-----------	----------
v. POULTRY	--------------	-------------	------------	-----------

4. LIVESTOCK ENTERPRISES

FOR EACH TYPE OF LIVESTOCK ON THE FARM GET A DETAILED INVENTORY, PRODUCTION REQUIREMENTS AND OUTPUTS.

4.1 CATTLE

A1. INVENTORY AT BEGINNING OF YEAR (1991)

SEX AND AGE GROUP	NUMBER OF CATTLE BELONGING TO		
	OWNER	OTHERS	TOTAL
1. BULLS	---------------	--------------------	-------------------
2. OXEN/STEERS	---------------	-------------------	-------------------
3. COWS, IN MILK	----------------	--------------------	-------------------
4. COWS, DRY	----------------	-------------------	-------------------
5. HEIFERS, OVER 2 YEARS	----------------	--------------------	-------------------
6. HEIFERS, 1 TO 2 YEARS	----------------	-------------------	-------------------
7. HEIFERS, OVER 2 YEARS	----------------	-------------------	-------------------
8. FEMALE CALVES	----------------	-------------------	-------------------
10. MALE CALVES	----------------	-------------------	-------------------
TOTAL NUMBER	----------------	-------------------	-------------------

4.1.B COW INFORMATION

B.1 GENERAL FARM PRACTICES AND REPLACEMENT

1. NUMBER OF MILKING COWS CULLED ANNUALLY ________
2. NUMBER OF MILKING COWS THAT DIE ANNUALLY ________ OVER TIME.-------/---YRS
3. NUMBER OF CALVES BORN ANNUALLY ________
4. NUMBER OF CALVES KEPT ON THE FARM ANNUALLY ________
5. NUMBER OF CALVES THAT DIE ANNUALLY ________ OVER TIME----/------YRS
6. NUMBER OF RAISED YEARLING HEIFERS (OVER 1 TO 2 YEAR) PRESENTLY ON THE FARM ________
7. NUMBER OF RAISED REPLACEMENT HEIFERS (OVER 2 YEARS) THAT ENTER HERD ANNUALLY _______
8. CALVING INTERVAL (MONTHS) _______
9. LACTATION (MILKING) PERIOD (MONTHS/YEAR) _______
10. AVERAGE NUMBER OF YEARS COW IS KEPT IN HERD AFTER FIRST CALF _______
11. NUMBER OF CATTLE CONSUMED ON THE FARM ANNUALLY _______
    A. FEMALE CALVES ------------/YEAR
    B. MALE CALVES ------------/YEAR
    C. HEIFERS ------------/YEAR
    D. BULLS/OXEN ----------/YEAR
12. MAXIMUM NUMBER OF COWS NORMALLY IN HERD PER YEAR ------------
13. MAXIMUM NUMBER OF COWS DESIRED PER YEAR -------------------
14. MAXIMUM NUMBER OF BULLS DESIRED PER YEAR ---------------------
15. MAXIMUM NUMBER OF OXEN DESIRED PER YEAR ----------------------

16. CATTLE SOLD OR GIVEN OUT e.g. FOR DOWRY ETC IN 1991

A. FEMALE CALVES NO.------------- PRICE KSHS/CALF-----------
B. MALE CALVES NO.------------- " " " ------------
C. HEIFERS NO.------------- " " /HEIFER---------
D. BULLS NO. -------------" " /BULL------------
E. OXEN NO. -------------" " /OXEN-------------
F. CULLED COWS NO. -------------- " " /COW------------

B.2 PURCHASED REPLACEMENTS DURING THE YEAR.

** IF NO PURCHASED REPLACEMENTS ARE MADE, INDICATE THE PRICE OF EACH CLASS IF IT WERE TO BE PURCHASED***

PURCHASED CATTLE TYPE	NUMBER BOUGHT 1991	PRICE KSHS/ANIMAL
1. COWS	---------------	--------------------
2. FEMALE CALVES	--------------	--------------------
3. HEIFERS(1 TO 2 YEARS)	-------------	--------------------
4. HEIFERS(2 TO 3YEARS)	--------------	--------------------
5. MALE CALVES	--------------	-------------------
6. MALES (1 TO 2 YEARS)	---------------	--------------------
7. MALES (2 TO 3 YEARS)	---------------	--------------------
8. BULLS	----------------	---------------------
9. OXEN	---------------	---------------------

4.1.C ANNUAL HERD PURCHASED INPUTS

*** Based on whole herd but calculate later on per cow basis****

ITEM	QUANTITY UNIT	TOTAL YEAR QUANTITY KGS/BAG	PRICE/UNIT KSHS	TOTAL COSTS KSHS
1. BREEDING(A.I/BULL)	NO/YEAR	------------	---------	---------------
2. CONCENTRATES	KGS	------------	-----------	--------------
3. SALT/MINERAL	KGS	----------	----------	--------------
4. FORAGES(HAY ETC)	KGS	------------	-----------	-----------------
5. CROP FEEDS	KGS	-------------	------------	----------------
6. WATER	LITRES	------------	-------------	---------------
7. ROPES	NO/YEAR	-----------	--------------	--------------
8. DIPPING	NO/YEAR	-------------	--------------	-----------------
9. SPRAYING ACARICIDE	KGS/LITRES	-------------	--------------	--- ----------
10. VACCINATION	NO/YEAR	-------------	-------------	-------------
11. TREATMENTS TBD*	NO/YEAR	------------	-------------	------------------
12. TREATMENTS,OTHER	NO/YEAR	-------------	-------------	------------------
13. HELMINTHS	NO/YEAR	-------------	--- ----------	---------- --------
14. OTHER MEDICAL AND DRUGS		--------------	--------------	-- --------------
15. OTHER EXPENSES(DEHORN, CASTRATION ETC)	NO/YEAR	--------------	--------------	------------------
16. MILKING SERVE ETC		-------------	--------------	-------------------------
17. TOTAL COSTS				----------------

** TICK-BORNE DISEASES

4.1.D ANNUAL CATTLE HERD OUTPUTS AND UTILIZATION 1991

ITEM	UNIT	QUANTITY PROD.	QUANTITY SOLD	PRICE/UNIT KSHS.	QUANTITY USED BY HOUSEHOLD KGS
1. MILK YIELD AVERAGE (KGS/YEAR/COW)	------------	-------------	------------	--------------	
2. MANURE AVERAGE (KGS/YEAR /HERD)	------------	-----------	----------	-------------	
3. TRACTION/OXEN NO/YEAR	----------------	---------------	--------------	------------	
4. HIDES NO./YEAR	--------------	-------------	---------------	------------	

CATTLE PRODUCT UTILIZATION BY OTHERS (1991)

PRODUCT	UNIT/YEAR	CONSUMED LABOURERS	CONSUMED RELATIVES AND OTHERS
1. MILK	KGS	--------------------	-----------------
2. MANURE	KGS	-------------------	-----------------
3. HIDES	NO.	----------------------	----------------
4. TRACTION FRACTION OF NOS.		------------------	----------------

4.2 SHEEP

4.2.A INVENTORY CHANGES DURING LAST YEAR 1991

FACTOR	ADULT MALES	ADULT FEMALES	IMMAT. MALES	IMMAT. FEMALES	MALE LAMB	FEMALE LAMB
1. NO.BEGINNING	------------	-------------	----------	-----------	-------------	--------------
2. NO.BORN	-------------	-------------	------ -----	------- -------	----------------	-----------------
3.NO. DEAD	--------------	--------------	-----------	---------------	-----------------	----------------
4.NO BOUGHT	--------------	--------------	------------	---------------	--------------	---------------
5.NO. SOLD	--------------	-------------	-----------	--------------	--------------	---------------
6. NO. CONSUMED	------------	--------------	------------	------ -------	----------------	-------------
7. NO GAVE OUT	--------------	-------------	------- ----	---------------	--------------	--------------
8. NO.GIVEN	----- --------	--------------	------------	--------------	---------------	-----------------
9. PRICE PER HEAD(KSHS.)	------------	--------------	------------	-------- -------	--------------	--------------
10. AVERAGE DEATH /YEAR	----------	-------------	-------------	--------------	-------------	-----------

11.AVERAGE LAMBS PER EWE/YEAR --------------

12. AVERAGE NUMBER OF LAMBS KEPT FOR BREEDING --------------

13. AVERAGE ADULT FEMALES SOLD DUE BREEDING FAILURE OR SICKNESS -----------

4.2. B. SHEEP AND SHEEP PRODUCT SALES LAST YEAR(1991)

CLASS	NUMBER SOLD	PRICE kSHS/ANIMAL	TOTAL VALUE KSHS/YEAR
1. FEMALE LAMBS			
2. MALE LAMBS			
3. BREED FAILURE LAMBS			
4. CULLED EWES			
6. CULLED RAMS			
7. WOOL PRODUCTS			

4.2.C LIST QUANTITIES OF INPUTS AND COSTS USED IN SHEEP PRODUCTION

ITEM	QUANTITIES			COSTS(KSHS)	
	UNITS	PER HEAD	TOTAL	PER HEAD	TOTAL
1. PURCHASED FORAGE	KGS				
2. PURCHASED FEED	KGS				
3. CROP FEEDS	KGS				
4. TREATMENT AND DRUGS	KGS/NOS				
5. OTHERS					
TOTAL					

4.3 GOATS

4.3.A INVENTORY CHANGES DURING LAST YEAR

FACTOR	AGE AND SEX GROUP					
	ADULT MALES	ADULT FEMALES	IMMAT. MALES	IMMAT. FEMALES	MALE KIDS	FEMALE KIDS
1. NO. BEGINNING						
2. NO. BORN						
3. NO. DEAD						
4. NO BOUGHT						
5. NO. SOLD						
6. NO. CONSUMED						
7. NO. GAVE OUT						
8. NO. GIVEN						
9. PRICE/VALUE PER HEAD(KSHS)						
10. AVERAGE KIDS/ NANNY/YEAR						
11. AVERAGE ANNUAL DEATH LOSS						

12. AVERAGE NUMBER OF KIDS KEPT FOR BREEDING /YEAR ---------------------------
13. AVERAGE ADULTS SOLD DUE TO SICKNESS OR BREEDING FAILURE ---------------------

4.3.C LIST QUANTITIES OF INPUTS AND COSTS USED IN GOAT PRODUCTION

ITEM	NO. OF GOATS UNITS	QUANTITIES KGS PER HEAD	COSTS KSHS PER HEAD
1. PURCHASED FORAGE			
2. PURCHASED FEED			
3. CROP FEEDS			
4. TREATMENT AND DRUGS			
5.TOTAL COSTS			

4.4. PIGS

4.4.A. INVENTORY CHANGES DURING LAST YEAR

FACTOR	AGE AND SEX GROUP					
	ADULT MALES	ADULT FEMALES	IMMAT. MALES	IMMAT. FEMALES	MALE PIGLETS	FEMALE PIGLETS
1. NO. BEGINNING						
2. NO. BORN						
3. NO. DEAD						
4. NO. BOUGHT						
5. NO. SOLD						
6. NO. CONSUMED						
7. NO. GAVE OUT						
8. NO. GIVEN						
9. PRICE/VALUE PER HEAD(KSHS)						
10. AVERAGE PIGLETS /SOW/YEAR						
11. AVERAGE ANNUAL DEATH LOSS						

12. AVERAGE NUMBER OF WEANERS KEPT FOR BREEDING /YEAR ---------------------------

13. AVERAGE SOWS SOLD DUE TO SICKNESS OR BREEDING FAILURE ------------------------

LIST QUANTITIES OF INPUTS AND COSTS USED IN PIG PRODUCTION

ITEM	NO. OF PIGS UNITS	QUANTITIES KGS PER HEAD	COSTS KSHS PER HEAD
1. PURCHASED FORAGE			
2. PURCHASED FEED			
3. TREATMENT AND DRUGS			
4. OTHER			
5. TOTAL COSTS/PIG			

4.5 OTHER LIVESTOCK

** FOR OTHER LIVESTOCK NOT COVERED, INDICATE THE TOTAL OUTPUTS AND TOTAL INPUTS**

INVENTORY FOR OTHER LIVESTOCK LAST YEAR (1991)

TYPE OF LIVESTOCK	NUMBER	TOTAL VALUE(KSHS)
1. CHICKEN		
2. DUCKS		
3. RABBITS		
4. DONKEYS		
5.OTHERS		

OUTPUTS(SALES) AND INPUTS FOR OTHER LIVESTOCK DURING THE YEAR 1991

LIVESTOCK NAME	TOTAL OUTPUTS		TOTAL INPUTS	
	QUANTITIES (KGS/UNITS)	VALUE KSHS	QUANTITIES (KGS/UNITS)	VALUE KSHS
1. CHICKEN				
2.DUCKS				
3.RABBITS				
4. DONKEYS				
5. OTHERS				
TOTAL OTHER	--------------		----------------------	

5. LOANS AND DEBTS, AND OTHER FINANCIAL INFORMATION

5.1 LOANS AND DEBTS (BEGINNING OF YEAR 1991)

LOAN TYPE	SOURCE OF LOAN	YEAR RECEIVED	AMOUNT KSHS	REPAYMENT YEARS	INTEREST RATE %
1. LAND DEBT					
2. CROPS LOAN					
3. MACHINERY DEBT					
4. LIVESTOCK DEBT					
5. CONSUMPTION LOAN					
6. OTHER LOANS					

SUMMARY OF OUTSTANDING LOANS BEGINNING OF 1991

LOAN TYPE	BALANCE START OF 1991	INTERESTS PAID 1990(END)	INTEREST RATE
1. LAND LOANS	---------------	-------------	-----------
2. MACHINERY LOANS	---------------	---------------	------------
3. CROP INVESTMENT LOANS	---------------	------------	--------------
4. CROP OPERATING LOANS	----------------	--------------	----------------
5. LIVESTOCK INVESTMENT	----------------	---------------	--------------
6. LIVESTOCK OPERATING	------------------	---------------	- --------------

5.2 GENERAL INFORMATION ON NEW LOANS (1991)

1. MINIMUM DOWN PAYMENT FOR LAND LOANS (KSHS) --------------- AMOUNT KSHS.------ LIFE(YEARS)----------- INTEREST RATE % -----------------------
2. MINIMUM DOWN PAYMENT FOR MACHINERY (KSHS)----------------LIFE(YEARS)------------- INTEREST RATE %----------------------------
3. CROPS AMOUNT(KSHS)-------------------LOAN LIFE(YEARS)----------- --INTEREST RATE%
4. LIVESTOCK AMOUNT(KSHS)----------------LOAN LIFE(YEARS)---------------------INTEREST RATE %------------------- ----
5. OPERATING LOANS CROPS AMOUNT(KSHS)---------------------INTEREST RATE %---------
6. OPERATING LOANS LIVESTOCK(KSHS)---------------------------INTEREST RATE %------------

OTHER FIXED EXPENSES (ANNUAL)

FIXED COST	AMOUNT (KSHS)
1.MAINTENANCE AND REPAIR COSTS OF BUILDINGS EQUIPMENT, IMPLEMENTS AND OTHER ASSETS	-------------------------
2. INSURANCE	
CROP INSURANCE	--------------------------
LIVESTOCK INSURANCE	----------------------------
VEHICLES AND MACHINERY INSURANCE	------------------ -----------
TOTAL INSURANCE	---------------------------------
3. LEGAL AND ACCOUNTANT FEES	------------------------------------
4. PROPERTY TAXES(ON LAND OR PERSONAL)	- ----------- -----------------------
5. COSTS OF UTILITIES	--------------------------------------
6. FREIGHT AND OTHER TRACK CONTRACT COSTS	------------------------------------
7. OTHER MISCELLANEOUS FIXED COSTS	--------------- -----------------------

CASH AVAILABLE AT START OF 1991 1. AT HAND KSHS. -------CASH AT BANK KSHS.-----

APPENDIX II

CONVERSION FACTORS FOR ESTIMATING ADULT EQUIVALENTS

Age (Years)	Male	Female
0	0.3	0.3
1	0.4	0.4
2-4	0.5	0.5
5-7	0.6	0.6
8-10	0.7	0.7
11-16	0.8	0.7
17-19	0.9	0.7
20-39	1.0	0.8
40-59	0.9	0.7
60 +	0.7	0.6

Source: Leegwater, P., J. Ngolo, and J. Hoorweg (1990). Nutritional and Dairy Development in Kilifi District. Unpublished Ministry of Economic Planning and National Development, Nairobi, and African Studies Center, Leiden.

APPENDIX III

DATA USED FOR SIMULATING ALTERNATIVE EAST COAST FEVER CONTROL METHODS ON FARMS

Appendix III.1. Alternative ECF Control Methods for Small Grade Cattle Farm, Uasin Gishu District

Item Description	Unit	SCENARIO Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	800	800	400	200	200
ECF Treatment Costs	Kshs/Cow Herd	4.00	0.20	0.20	0.40	0.40
Mortality Calves	Percent	15.0	3.0	3.0	3.0	3.0
Mortality Mature	Percent	10.0	2.0	2.0	2.0	2.0
Liveweight	Kgs					
Calves		80.0	88.0	88.0	88.0	84.0
Heifers 1-2 years		150.0	157.5	157.5	157.5	157.5
Heifers 2-3 years		250.0	262.5	262.5	262.5	262.5
Cows		300.0	315.0	315.0	315.0	315.0
Steers 1-2 years		150.0	157,5	157.5	157.5	157.5
Steers 2-3 years		300.0	315.0	315.0	315.0	315.0
Bulls/Oxen		350.0	367.5	367.5	367.5	367.5
Milk Yield	Kgs/Cow/Year	1680	2100	2100	2100	2016
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.2. Alternative ECF Control Methods for Medium Grade Cattle Farm, Uasin Gishu District

Item Description	Unit	Base	B	C	D	E
		SCENARIO				
Acaricide Costs	Kshs/Cow Herd	468	468	234	117	117
ECF Treatment Costs	Kshs/Cow Herd	850	42.50	42.50	85.00	85.00
Mortality Calves	Percent	15.0	3.0	3.0	3.0	3.0
Mortality Mature	Percent	10.0	2.0	2.0	2.0	2.0
Liveweight	Kgs					
Calves		80.0	88.0	88.0	88.0	84.0
Heifers 1-2 years		150.0	157.5	157.5	157.5	157.5
Heifers 2-3 years		250.0	262.5	262.5	262.5	262.5
Cows		300.0	315.0	315.0	315.0	315.0
Steers 1-2 years		150.0	157.5	157.5	157.5	157.5
Steers 2-3 years		300.0	315.0	315.0	315.0	315.0
Bulls/Oxen		350.0	367.5	367.5	367.5	367.5
Milk Yield	Kgs/Cow/Year	1920	2400	2400	2400	2400
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.3. Alternative ECF Control Methods for Large Grade Cattle Farm, Uasin Gishu District

Item Description	Unit	SCENARIO Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	440	440	220	110	110
ECF Treatment Costs	Kshs/Cow Herd	113	5.65	5.65	11.30	11.30
Mortality Calves	Percent	15.0	3.0	3.0	3.0	3.0
Mortality Mature	Percent	10.0	2.0	2.0	2.0	2.0
Liveweight	Kgs					
Calves		80.0	88.0	88.0	88.0	84.0
Heifers 1-2 years		150.0	157.5	157.5	157.5	157.5
Heifers 2-3 years		250.0	262.5	262.5	262.5	262.5
Cows		300.0	315.0	315.0	315.0	315.0
Steers 1-2 years		150.0	157.5	157.5	157.5	157.5
Steers 2-3 years		300.0	315.0	315.0	315.0	315.0
Bulls/Oxen		350.0	362.5	362.5	362.5	362.5
Milk Yield	Kgs/Cow/Year	2400	3000	3000	3000	2880
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.4. Alternative ECF Control Methods for Small Zebu Cattle Farm, Uasin Gishu District

Item Description	Unit	Base	B	C	D	E
		SCENARIO				
Acaricide Costs	Kshs/Cow Herd	228	228	114	57	57
ECF Treatment Costs	Kshs/Cow Herd	8.0	0.40	0.40	0.80	0.80
Mortality Calves	Percent	10.0	2.0	2.0	2.0	2.0
Mortality Mature	Percent	5.0	1.0	1.0	1.0	1.0
Liveweight	Kgs					
Calves		60.0	66.0	66.0	66.0	63.0
Heifers 1-2 years		100.0	105.0	105.0	105.0	105.0
Heifers 2-3 years		160.0	168.0	168.0	168.0	168.0
Cows		250.0	262.5	262.5	262.5	262.5
Steers 1-2 years		150.0	157.5	157.5	157.5	157.5
Steers 2-3 years		250.0	262.5	262.5	262.5	262.5
Bulls/Oxen		300.0	315.0	315.0	315.0	315.0
Milk Yield	Kgs/Cow/Year	810	1012	1012	1012	972
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.5. Alternative ECF Control Methods for Medium Zebu Cattle Farm, Uasin Gishu District

Item Description	Unit	SCENARIO Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	150	150	75	37.50	37.50
ECF Treatment Costs	Kshs/Cow Herd	0.00	0.00	0.00	0.00	0.00
Mortality Calves	Percent	10.0	2.0	2.0	2.0	2.0
Mortality Mature	Percent	5.0	1.0	1.0	1.0	1.0
Liveweight	Kgs					
Calves		60.0	66.0	66.0	66.0	63.0
Heifers 1-2 years		100.0	105.0	105.0	105.0	105.0
Heifers 2-3 years		160.0	168.0	168.0	168.0	168.0
Cows		250.0	262.5	262.5	262.5	262.5
Steers 1-2 years		150.0	157.5	157.5	157.5	157.5
Steers 2-3 years		250.0	262.5	262.5	262.5	262.5
Bulls/Oxen		300.0	315.0	315.0	315.0	315.0
Milk Yield	Kgs/Cow/Year	900	1125	1125	1125	1080
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.6. Alternative ECF Control Methods for Large Zebu Cattle Farm, Uasin Gishu District

Item Description	Unit	SCENARIO Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	82.50	82.50	41.25	20.62	20.62
ECF Treatment Costs	Kshs/Cow Herd	318.50	15.9	15.9	31.9	31.9
Mortality Calves	Percent	10.0	2.0	2.0	2.0	2.0
Mortality Mature	Percent	5.0	1.0	1.0	1.0	1.0
Liveweight	Kgs					
Calves		60.0	66.0	66.0	66.0	63.0
Heifers 1-2 years		100.0	105.0	105.0	105.0	105.0
Heifers 2-3 years		160.0	168.0	168.0	168.0	168.0
Cows		250.0	262.5	262.5	262.5	262.5
Steers 1-2 years		150.0	157.5	157.5	157.5	157.5
Steers 2-3 years		250.0	262.5	262.5	262.5	262.5
Bulls/Oxen		300.0	315.0	315.0	315.0	315.0
Milk Yield	Kgs/Cow/Year	1080	1350	1350	1350	1296
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.7. Alternative ECF Control Methods for Small Grade Cattle Farm, Kaloleni Division

Item Description	Unit	SCENARIO				
		Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	684	684	342	171	171
ECF Treatment Costs	Kshs/Cow Herd	0.00	0.00	0.00	0.00	0.00
Mortality Calves	Percent	20.0	4.0	4.0	4.0	4.0
Mortality Mature	Percent	10.0	2.0	2.0	2.0	2.0
Liveweight	Kgs					
Calves		65.0	71.5	71.5	71.5	68.25
Heifers 1-2 years		175.0	183.7	183.7	183.7	183.7
Heifers 2-3 years		250.0	262.5	262.5	262.5	262.5
Cows		300.0	315.0	315.0	315.0	315.0
Steers 1-2 years		200.0	210.0	210.0	210.0	210.0
Steers 2-3 years		300.0	315.0	315.0	315.0	315.0
Bulls/Oxen		350.0	367.5	367.5	367.5	367.5
Milk Yield	Kgs/Cow/Year	1260	1575	1575	1575	1512
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.8. Alternative ECF Control Methods for Medium Grade Cattle Farm, Kaloleni Division

Item Description	Unit	SCENARIO Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	500	500	250	125	125
ECF Treatment Costs	Kshs/Cow Herd	167	8.35	8.35	16.70	16.70
Mortality Calves	Percent	20.0	4.0	4.0	4.0	4.0
Mortality Mature	Percent	10.0	2.0	2.0	2.0	2.0
Liveweight	Kgs					
Calves		65.0	71.5	71.5	71.5	68.25
Heifers 1-2 years		175.0	183.7	183.7	183.7	183.7
Heifers 2-3 years		250.0	262.5	262.5	262.5	262.5
Cows		300.0	315.0	315.0	315.0	315.0
Steers 1-2 years		200.0	210.0	210.0	210.0	210.0
Steers 2-3 years		300.0	315.0	315.0	315.0	315.0
Bulls/Oxen		350.0	367.5	367.5	367.5	367.5
Milk Yield	Kgs/Cow/Year	1260	1575	1575	1575	1512
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.9. Alternative ECF Control Methods for Large Grade Cattle Farm, Kaloleni Division

Item Description	Unit	SCENARIO Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	800	800	400	200	200
ECF Treatment Costs	Kshs/Cow Herd	342.50	17.13	17.13	34.25	34.25
Mortality Calves	Percent	20.0	4.0	4.0	4.0	4.0
Mortality Mature	Percent	10.0	2.0	2.0	2.0	2.0
Liveweight	Kgs					
Calves		65.0	71.5	71.5	71.5	68.25
Heifers 1-2 years		175.0	183.7	183.7	183.7	183.7
Heifers 2-3 years		250.0	262.5	262.5	262.5	262.5
Cows		300.0	315.0	315.0	315.0	315.0
Steers 1-2 years		200.0	210.0	210.0	210.0	210.0
Steers 2-3 years		300.0	315.0	315.0	315.0	315.0
Bulls/Oxen		350.0	367.5	367.5	367.5	367.5
Milk Yield	Kgs/Cow/Year	960	1200	1200	1200	1152
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.10. Alternative ECF Control Methods for Small Zebu Cattle Farm, Kaloleni Division

Item Description	Unit	SCENARIO Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	282	282	141	70.50	70.50
ECF Treatment Costs	Kshs/Cow Herd	90	4.50	4.50	9.00	9.00
Mortality Calves	Percent	10.0	2.0	2.0	2.0	2.0
Mortality Mature	Percent	5.0	1.0	1.0	1.0	1.0
Liveweight	Kgs					
Calves		50.0	55.0	55.0	55.0	52.50
Heifers 1-2 years		120.0	126.0	126.0	126.0	126.0
Heifers 2-3 years		160.0	168.0	168.0	168.0	168.0
Cows		250.0	262.5	262.5	262.5	262.5
Steers 1-2 years		120.0	126.0	126.0	126.0	126.0
Steers 2-3 years		250.0	262.5	262.5	262.5	262.5
Bulls/Oxen		300.0	315.0	315.0	315.0	315.0
Milk Yield	Kgs/Cow/Year	675	844	844	844	810
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.11. Alternative ECF Control Methods for Medium Zebu Cattle Farm, Kaloleni Division

Item Description	Unit	SCENARIO				
		Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	144	144	72	36	36
ECF Treatment Costs	Kshs/Cow Herd	55	2.75	2.75	5.50	5.50
Mortality Calves	Percent	10.0	2.0	2.0	2.0	2.0
Mortality Mature	Percent	5.0	1.0	1.0	1.0	1.0
Liveweight	Kgs					
Calves		50.0	55.0	55.0	55.0	52.50
Heifers 1-2 years		120.0	126.0	126.0	126.0	126.0
Heifers 2.3 years		160.0	168.0	168.0	168.0	168.0
Cows		250.0	262.5	262.5	262.5	262.5
Steers 1-2 years		120.0	126.0	126.0	126.0	126.0
Steers 2-3 years		250.0	262.5	262.5	262.5	262.5
Bulls/Oxen		300.0	315.0	315.0	315.0	315.0
Milk Yield	Kgs/Cow/Year	720	900	900	900	864
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

Appendix III.12. Alternative ECF Control Methods for Large Zebu Cattle Farm, Kaloleni Division

Item Description	Unit	SCENARIO				
		Base	B	C	D	E
Acaricide Costs	Kshs/Cow Herd	172	172	86	43	43
ECF Treatment Costs	Kshs/Cow Herd	45.00	2.25	2.25	4.50	4.50
Mortality Calves	Percent	10.0	2.0	2.0	2.0	2.0
Mortality Mature	Percent	5.0	1.0	1.0	1.0	1.0
Liveweight	Kgs					
Calves		50.0	55.0	55.0	55.0	52.50
Heifers 1-2 years		120.0	126.0	126.0	126.0	126 0
Heifers 2-3 years		160.0	168.0	168.0	168.0	168.0
Cows		250.0	262.5	262.5	262.5	262.5
Steers 1-2 years		120.0	126.0	126.0	126.0	126.0
Steers 2-3 years		250.0	262.5	262.5	262.5	262.5
Bulls/Oxen		300.0	300.0	300.0	300.0	300.0
Milk Yield	Kgs/Cow/Year	360	450	450	450	432
ITM Costs	Kshs/Head	0.00	54.40	54.40	54.40	54.40

APPENDIX IV

SELECTED CHARACTERISTICS OF THE CASE FARMS

Appendix IV.1. Characteristic Features of The Case Grade Cattle Farms in Uasin Gishu District

CHARACTERISTIC FEATURES		FARM SIZE		
		Small	Medium	Large
CROPLAND ON INITIAL FARM - HA				
TOTAL CROPLAND OWNED		2.00	2.40	20.00
PASTURELAND OWNED		1.80	3.40	8.80
INITIAL BALANCE SHEET FOR THE FARM				
ASSETS - KSHS				
TOTAL VALUE OF OWNED CROPLAND & BUILDING		247000.00	187000.00	1426000.00
MARKET VALUE OF OWNED PASTURELAND		117000.00	221000.00	572000.00
MARKET VALUE OF OFF-FARM INVESTMENTS		0.00	0.00	2500.00
BEGINNING CASH RESERVE		6000.00	2000.00	15000.00
MARKET VALUE OF ALL FARM MACHINERY		5800.00	45326.00	165596.00
MARKET VALUE OF ALL LIVESTOCK		21125.00	70250.00	231500.00
TOTAL VALUE OF ASSETS		396925.00	525576.00	2412596.00
LIABILITIES - KSHS				
TOTAL REAL ESTATE DEBT		0.00	0.00	21000.00
TOTAL INTERMEDIATE-TERM DEBT		0.00	0.00	0.00
TOTAL DEBT		0.00	0.00	21000.00
NET WORTH - KSHS		396925.00	525576.00	2391596.00
SUMMARY OF CATTLE INPUT DATA				
COWS	HEAD	3.00	5.00	23.00
FEMALE CALVES	"	1.00	2.00	9.00
HEIFERS 1-2 YEAR	"	1.00	2.00	8.00
HEIFERS 2-3 YEAR	"	0.00	2.00	4.00
MALE CALVES	"	0.00	2.00	8.00
MALES 1-2 YEAR	"	0.00	3.00	3.00
MALES 2-3 YEAR	"	0.00	0.00	3.00
OXEN	"	0.00	0.00	0.00
BULLS	"	0.00	1.00	1.00
SUMMARY OF SHEEP INPUT DATA				
EWES	HEAD	1.00	6.00	8.00
LAMBS	"	1.00	6.00	10.00
RAMS	"	1.00	1.00	1.00
SUMMARY OF GOAT INPUT DATA				
NANNYS	HEAD		2.00	0.08.00
REPLACEMENTS	"	2.00	0.00	6.00
BILLIES	"	1.00	0.00	1.00

Appendix IV.2. Characteristic Features of The Case Zebu Cattle Farms in Uasin Gishu District

CHARACTERISTIC FEATURE		FARM SIZE SMALL	MEDIUM	LARGE
CROPLAND ON INITIAL FARM - HA				
TOTAL CROPLAND OWNED		2.00	3.00	5.00
PASTURELAND OWNED		0.80	5.00	30.00
INITIAL BALANCE SHEET FOR THE FARM				
ASSETS - KSHS				
TOTAL VALUE OF OWNED CROPLAND & BUILDING		177500.00	223000.00	348600.00
MARKET VALUE OF OWNED PASTURELAND		52000.00	325000.00	1950000.00
MARKET VALUE OF OFF-FARM INVESTMENTS		0.00	0.00	0.00
BEGINNING CASH RESERVE		2000.00	4000.00	5000.00
MARKET VALUE OF ALL FARM MACHINERY		3236.00	90528.00	4380.00
MARKET VALUE OF ALL LIVESTOCK		23567.00	30025.00	102175.00
TOTAL VALUE OF ASSETS		258303.00	672553.00	2410155.00
LIABILITIES - KSHS				
TOTAL REAL ESTATE DEBT		0.00	0.00	0.00
TOTAL INTERMEDIATE-TERM DEBT		0.00	0.00	0.00
TOTAL DEBT		0.00	0.00	0.00
NET WORTH - KSHS		258303.00	672553.00	2410155.00
SUMMARY OF CATTLE INPUT DATA				
COWS	HEAD	4.00	5.00	16.00
FEMALE CALVES	"	1.00	1.00	2.00
HEIFERS 1-2 YEARS	"	0.00	0.00	0.00
HEIFERS 2-3 YEARS	"	1.00	1.00	0.00
MALE CALVES	"	0.00	2.00	1.00
MALES 1-2 YEARS	"	0.00	1.00	2.00
MALES 2-36 YEARS	"	1.00	0.00	2.00
OXEN	"	0.00	0.00	2.00
BULLS	"	0.00	1.00	2.00
SUMMARY OF SHEEP INPUT DATA				
EWES	HEAD	2.00	0.00	11.00
LAMBS	"	2.00	0.00	12.00
RAMS	"	1.00	0.00	1.00
SUMMARY OF GOAT INPUT DATA				
NANNYS	HEAD	0.00	0.00	3.00
REPLACEMENTS	"	0.00	0.00	2.00
BILLIES	"	0.00	0.00	2.00

Appendix IV.3. Characteristic Features of The Case Grade Cattle Farms in Kaloleni Division

CHARACTERISTIC FEATURE		FARM SIZE SMALL	MEDIUM	LARGE
CROPLAND ON INITIAL FARM - HA				
TOTAL CROPLAND OWNED		1.80	1.60	4.00
PASTURELAND OWNED		1.20	9.00	5.60
INITIAL BALANCE SHEET FOR THE FARM				
ASSETS - KSHS				
TOTAL VALUE OF OWNED CROPLAND & BUILDING		69000.00	171520.00	146000.00
MARKET VALUE OF OWNED PASTURELAND		24000.00	180000.00	112000.00
MARKET VALUE OF OFF-FARM INVESTMENTS		0.00	0.00	0.00
BEGINNING CASH RESERVE		1000.00	3000.00	1000.00
MARKET VALUE OF ALL FARM MACHINERY		3099.00	615.00	2384.00
MARKET VALUE OF ALL LIVESTOCK		27387.00	37710.00	61130.00
TOTAL VALUE OF ASSETS		124486.00	392845.00	322514.00
LIABILITIES - KSHS				
TOTAL REAL ESTATE DEBT		0.00	0.00	0.00
TOTAL INTERMEDIATE-TERM DEBT		0.00	0.00	0.00
TOTAL DEBT		0.00	0.00	0.00
NET WORTH - KSHS		124486.00	392845.00	322514.00
SUMMARY OF CATTLE INPUT DATA				
COWS	HEAD	2.00	3.00	3.00
FEMALE CALVES	"	1.00	2.00	2.00
HEIFERS 1-2 YEARS	"	1.00	0.00	2.00
HEIFERS 2-3 YEARS	"	1.00	0.00	0.00
MALE CALVES	"	0.00	0.00	1.00
MALES 1-2 YEARS	"	0.00	1.00	0.00
MALES 2-3 YEARS	"	0.00	2.00	5.00
OXEN	"	1.00	0.00	1.00
BULLS	"	0.00	1.00	2.00
SUMMARY OF SHEEP INPUT DATA				
EWES	HEAD	0.00	0.00	0.00
LAMBS	"	0.00	0.00	0.00
RAMS	"	0.00	0.00	0.00
SUMMARY OF GOAT INPUT DATA INITIAL				
NANNYS	HEAD	2.00	10.00	7.00
REPLACEMENTS	"	1.00	8.00	8.00
BILLIES	"	1.00	1.00	1.00

Appendix IV.4. Characteristic Features of The Case Zebu Cattle Farms in Kaloleni Division

CHARACTERISTIC FEATURE		FARM SIZE		
		SMALL	MEDIUM	LARGE
CROPLAND ON INITIAL FARM - HA				
TOTAL CROPLAND OWNED		1.80	1.40	2.80
PASTURELAND OWNED		1.80	3.60	5.00
INITIAL BALANCE SHEET FOR THE FARM				
ASSETS - KSHS				
TOTAL VALUE OF OWNED CROPLAND & BUILDING		46000.00	49500.00	73500.00
MARKET VALUE OF OWNED PASTURELAND		36000.00	72000.00	100000.00
MARKET VALUE OF OFF-FARM INVESTMENTS		0.00	0.00	0.00
BEGINNING CASH RESERVE		500.00	2000.00	600.00
MARKET VALUE OF ALL FARM MACHINERY		3055.00	1778.00	459.00
MARKET VALUE OF ALL LIVESTOCK		32200.00	27510.00	69750.00
TOTAL VALUE OF ASSETS		117755.00	152788.00	244309.00
LIABILITIES - KSHS				
TOTAL REAL ESTATE DEBT		0.00	0.00	0.00
TOTAL INTERMEDIATE-TERM DEBT		0.00	0.00	0.00
TOTAL DEBT		0.00	0.00	0.00
NET WORTH - KSHS		117755.00	800788.00	244309.00
SUMMARY OF CATTLE INPUT DATA				
INITIAL HERD NUMBER OF				
COWS	HEAD	2.00	5.00	7.00
FEMALE CALVES	"	0.00	1.00	1.00
HEIFERS 12-24 MONTHS	"	1.00	0.00	6.00
HEIFERS 24-36 MONTHS	"	1.00	1.00	2.00
MALE CALVES	"	0.00	2.00	1.00
MALES 1-2 YEARS	"	0.00	0.00	6.00
MALES 2-3 YEARS	"	1.00	0.00	1.00
OXEN	"	1.00	0.00	0.00
BULLS	"	0.00	0.00	1.00
SUMMARY OF SHEEP INPUT DATA				
EWES	HEAD	0.00	1.00	5.00
LAMBS	"	0.00	1.00	5.00
RAMS	"	0.00	1.00	1.00
SUMMARY OF GOAT INPUT DATA				
NANNYS	HEAD	4.00	4.00	8.00
REPLACEMENTS	"	6.00	4.00	10.00
BILLIES	"	1.00	1.00	1.00

VITA

Hezron Omare Nyangito was born in Boitangare Village, Bassi Borabu location, Kisii District, Kenya, on September 17, 1957. He attended Borangi S.D.A. Primary School, Kisii. He sat for the.Kenya Primary Certificate of Education in 1972 and qualified to join Kisii High School for his secondary education.

He sat for the East African Certificate of Education in 1976 and passed with a Division one. In 1978, he joined Alliance High School for his high school education. He sat for the East Africa Certificate of Advanced Education in 1978 and qualified to join the University of Nairobi, Kenya.

He joined the Faculty of Agriculture, the University of Nairobi in 1979 for a Bsc. degree in Agriculture. He was awarded an Upper second class, honors degree in June, 1983. After working briefly as an Agricultural Officer for the Government of Kenya, he left to pursue a Masters degree in Agricultural Economics at the University of Nairobi in October, 1983. He was awarded the degree in 1986.

Mr. Nyangito joined the Ministry of Agriculture in October, 1985 where he worked as a Planning Officer in the Projects Planning Unit and the Development Planning Division up to October, 1987. Thereafter, he joined the Department of Agricultural Economics, The University of Nairobi as an Assistant Lecturer.

In August, 1989 Mr. Nyangito was admitted in the Department of Agricultural Economics and Rural Sociology, The University of Tennessee, Knoxville to pursue a Doctor of Philosophy degree. Upon graduation, the author will go back to the Department of Agricultural Economics, University of Nairobi as a Lecturer.