EFFECT OF MAIZE PRICE RISK ON SMALL HOLDER AGRICULTURAL PRODUCTION PATTERNS: CASE OF THE GREATER KAKAMEGA DISTRICT

By

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A THESIS SUBMITTED IN PARTIAL FULFILLMENT FOR THE AWARD OF A MASTER OF SCIENCE DEGREE IN AGRICULTURAL ECONOMICS OF THE UNIVERSITY OF NAIROBI

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DECLARATION

This thesis is my original work and has not been submitted for the award of a degree in any other university.

Signed.....*DAchola*..................................... Date.....*24/08/06*..............................

Diang'a Daniel Achola O

(Candidate)

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

Signed.....*HNyangito*..................................Date.....*22/8/06*..................................

DR. Hezron .O. Nyangito

Signed.....*OLE Mbatia*.................................Date..*August 10th 2006*...........................

PROF. O.L.E Mbatia

DEDICATION

To my parents, Jenipher Otieno and Ibrahim Otieno. For your support in my quest for knowledge and wisdom. You showed me the way, now the sky is the limit!

ACKNOWLEDGEMENTS

This study would not have been possible without a great deal of support given by various individuals and institutions. I wish to express my gratitude first and foremost to the almighty God for the blessings He has granted in my life, and during the period of study.

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A special vote of thanks goes to the University of Nairobi for enabling my study through the provision of a scholarship. My special appreciation is also extended to the Kenya Institute for Public Policy Research and Analysis (KIPPRA) who made the survey possible by funding the data collection exercise.

The contributions of the support staff in the Department of Agricultural Economics cannot go unmentioned, and I sincerely thank you for that. My special gratitude also goes to Sarah Ooro who assisted in literature search and printing.

May the good Lord bless you all!

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ACRONYMS/ABREVIATIONS

AFC	Agricultural Finance Corporation
E V	Mean Variance
GAMS	General Algebraic Modelling Systems
GDP	Gross Domestic Product
IMF	International Monetary Fund
LP	Linear Programming
LM1	Lower Midland 1
SAPs	Structural Adjustment Programs
SEU	Subjective Expected Utility
SD	Stochastic Dominance
UM1	Upper Midland 1
UM4	Upper Midland 4
WB	World Bank
GM	Gross Margins
TOGM	Total Optimal Gross Margins
TCGM	Total Current Gross Margins

ABSTRACT

Liberalization of agricultural commodity markets in Kenya introduced problems related to volatile and fluctuating prices, and thus market risks. Imperfect knowledge regarding commodity prices makes management of the farm more difficult, especially when selecting the range of profitable enterprise combinations. Furthermore, while policy reforms were supposed to ensure availability of food to all people at all times, cases of food shortages are still reported even in areas that were previously food secure, with the most affected being the small-holder farmers. Kakamega district in Kenya is among the regions that have been significantly affected. While this region was formerly a maize surplus area, it has been experiencing a decline in maize production, with farmers shifting productive resources to other competing enterprises. In addition, poverty level is reported to have increased in the region.

Given the importance of farm income in the total household income in the region, the purpose of the study was to evaluate resource use efficiency given the commodity market risk and to suggest some recommendations to help increase maize production and farm incomes in the study area. This study focused on analyzing the effects of maize price risk on agricultural production patterns and farm incomes, among small-scale producers in the greater Kakamega district in Kenya. Following the declining maize output, there was need to ascertain maize price risk, analyze the production pattern trend over time and determine whether farms are operating optimally given the risk.

The study used both primary and secondary data. A total of 208 farmers were interviewed in February 2004 using a single-visit survey approach. A combination of purposive sampling, multistage random sampling, and systematic sampling methods was used to select the farms. Secondary data was collected at the district level.

A combination of analytical techniques was applied, including the F-ratio test, Correlation analysis, Trend analysis, Linear Programming (LP) and Mean variance (E-V) analysis. Results of the F ratio test showed that maize prices in the study area has been volatile in the post liberalization period (1994-2003). Correlation analysis indicated a negative and significant

relationship between price risk and resource allocation to the maize enterprise. Trend analysis showed that maize acreage allocation and output have been declining in the post liberalization period, while sugarcane output and acreage allocation has been on an upward trend. The Mean Variance risk minimization model showed three out of the five model farms operate in a risk inefficient manner. The remaining two model farms, though not optimal, were found to operate within the relevant planning ranges of risk efficiency. Mean Variance analysis also identified the sugarcane and dairy enterprises to have the most stable and profitable incomes in the risk optimal plans for these model farms.

These results can guide policy makers in formulating appropriate and effective policies to address market risks and the resulting low agricultural incomes faced, especially by the rural poor small-scale farmers.

As a result of the need to improve maize production and marketing, to improve farm incomes, the study recommended that investment in modern maize storage structures and practices at the farm level be promoted in the study area, and that farmers be encouraged to spread maize sales over time. The government could also increase the number of major players in maize marketing by mandating the NCPB to operate on a commercial basis, while still retaining its core function of maintaining strategic reserves. These measures may increase the minimum producer prices and reduce the range within which maize prices fluctuate. Given the capital-intensive nature of sugarcane and dairy production, and the operating capital constraint that farmers face in the region, it was suggested that credit access be improved to these farmers to relax the capital constraint to enable them operate optimally. The study suggested opening of more branches of AFC in the rural areas and an increase of funds allocated to the corporation by the government. It also recommended the improvement of the management and operation of the sugar industry and to emphasize and re-orient agricultural extension to improve access to agricultural information in the liberalization era.

CHAPTER 1: INTRODUCTION

1.1 Background Information

Agriculture is the mainstay of the majority of Kenyans with an estimated 62 per cent of the labor force engaged in this sector (Kenya, 2003). The agriculture sector is identified as a key to economic recovery strategy for employment and wealth creation. Among other things, the agricultural sector plays a leading role as a source of food and incomes for the rural people and hence a leading role in poverty reduction.

A diverse range of policies have been used to foster growth of the agricultural sector in Kenya. The first set of post colonial policies (for the period 1964 – 1980) emphasized government intervention in nearly all aspects of agricultural production and marketing (Smith, 1976). This meant that the government had control on almost all institutions involved in agricultural development. Government intervention was more pronounced in marketing, although production was influenced to some degree through restrictions on what types of commodities farmers in different regions could produce (Nyangito and Okello, 1998). The responsibility of controlling these policies was vested in the Ministry of Agriculture while their implementation was undertaken through various state institutions, which were granted a monopoly status in the marketing of the commodities.

In this arrangement, commodities listed as scheduled crops / livestock commodities essential for the country had a board or an authority responsible for their production and/or marketing. The objectives of the boards included price and income stabilization for farmers, efficient and inexpensive nation-wide distribution of commodities to consumers without government subsidies and buyers of last resort. The state intervention had a direct influence only on some crops and intermediaries but this still conditioned the terms of operation for most of the other channels. However, these boards failed to achieve the objectives for which they were set (Swamy, 1994). Further, the prices set by the government were generally lower than the world market due to the numerous deductions along the marketing channel and the controlled exchange rate. The pricing policy also discouraged private sector investment in storage and transportation facilities, particularly for the food crop sector.

1.2 The Cereal Sub-Sector under Prevalent Policies

Majority of Kenyans depend on grain cereals-based diets supplemented with pulses, milk and meat. The most important grain cereals currently are maize, wheat and rice in that order, followed by minor traditional grains like sorghum and millet (Odhiambo, 1994). As Nyoro (1995) notes, maize is the single most important food crop in terms of its contribution to the national development objectives such as income generation, saving of foreign exchange and employment.

In addition, maize is the country's primary food staple and provides 34% of Kenya's total food calorie intake/day. Per capita production in 2002 was estimated at 74 Kg per year. Further, maize is the most frequently produced and marketed commodity, grown and marketed by 90% and 30% of the households respectively in areas where the crop is grown. In total, the sub sector employs over 4 million people. In addition, the sub-sector accounts for about 11.6% of the agricultural GDP and 2.9% of national GDP (Kenya, 2002).

In terms of expenditure, the commodity accounts for approximately 15 to 25 percent of food expenditure in rural households and 5 to 15 percent of food expenditure in urban areas depending on income levels (Nyoro, 1995).

Just as was the case for most sub-sectors, the maize sub-sector was subject to government controls from 1964 to 1980. Maize market control in Kenya like in most other parts of Sub-Saharan Africa evolved out of priority for ensuring national food security and safeguarding producer interests through price support (Gordon and Spooner, 1992) and consumer interests through maize meal subsidy (Mulinge, 1992). The formal marketing of maize was the responsibility of the National Cereals and Produce Board (NCPB), which enjoyed a legislated monopoly in selling maize directly to consumers. The government set prices for the purchase and sale of maize to and from the NCPB depots. Producer price determination was conducted by the Ministry of Agriculture in conjunction with the ministries of Supplies and Marketing, Ministry of Planning and National Development and the Office of the President. The price was set based upon, among other factors, the cost of maize production. The recommended price was announced before the planting period each year, usually in January and became effective at the beginning of the harvest period for that year, usually July. Corresponding selling prices at each level of the marketing chain, including that of sifted maize meal, were also set by the government, again becoming effective after the first harvest of that year.

The second set of policies came in operation from 1980, and emphasized a shift in economic policy towards a reduction of state intervention in the economy and free market operations. In this policy enviroment, market forces of supply and demand would determine producer and consumer prices. Part of the reason for the shift was the high cost of government controls, which became clear with the failure of most publicly owned enterprises (Swamy, 1994). In marketing it became evident that too much government intervention had stifled the private sector and was forcing the government to do what the private sector would have done more efficiently.

Among the advocates of reforms in the agricultural sector was the World Bank. The turnaround from low to high growth in agricultural and economic development for most Sub- Saharan Countries was seen to lie in reforming the policies under the structural Adjustment Programs (SAPs) (World Bank, 1994). The SAPs, promoted by the World Bank and the International

Monetary Fund (IMF) advocated for both a reduction of government intervention in the economy and liberalization of economies. In this arrangement, market forces and the private sector could play a dominant role with the government providing an enabling environment for enhanced participation by the private sector.

The basic theory underlying donor advocacy for market reforms was summarized by Barret and Carter (1994) as thus:

"Once governments free market channels and prices, private merchants will automatically bid up formerly depressed agricultural prices. By virtue of a positive price elasticity of supply, higher prices induce greater production, which further stimulates demand for purchased inputs, including hired labor. Larger agricultural incomes were expected to have significant multiplier effects due to the relatively high marginal propensity to consume for the poor farmers. Thus a liberalized agricultural sector was expected to propagate prosperity across all sectors of the economy in a distributionally progressive manner."

Kenya embarked on grain market liberalization program with a stated objective of changing the role of NCPB from that of a monopoly buyer and seller of maize, to a buyer and seller of last resort. It was argued that maize marketing was operationally more efficient when carried out by the private sector and that this would result in increased producer prices and lower consumer prices (Argwings-Kodhek, 1992 and Gordon and Spooner, 1992). Thus such a change would foster efficiency in the maize market and increase maize production in the country.

With liberalization of pricing and marketing of the food sector, there was a significant increase of producer prices in nominal terms. However, maize production volumes indicate a poor response to this price increase and has shown a fluctuating and declining pattern in the post liberalization period. Between 1994 and 2000, maize production declined by 24 per cent (Kenya, 2000). Maize production pattern from 1963 to 2000 is illustrated in Figure 1.1.

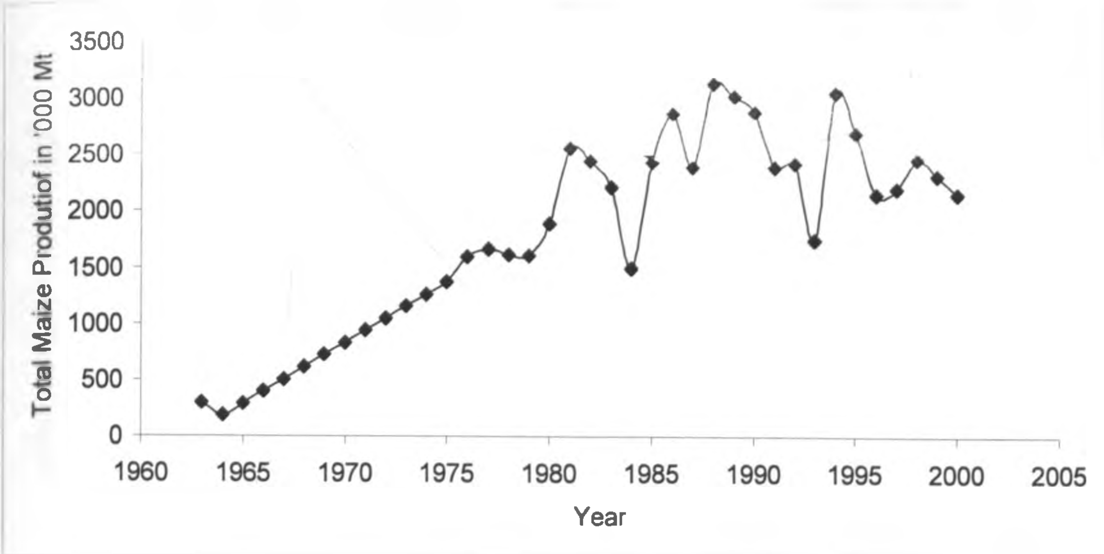

Figure 1.1: National Maize Output pattern, 1963-2000
(Source: Gitu and Nzuma, 2002)

As indicated in Figure 1.1, maize production in the post liberalization period has exhibited a gradual decline, with the biggest decline occurring in the early periods of liberalization.

It is further documented that maize production has frequently fallen short of demand and fluctuations in marketed outputs through formal markets have been observed. While marketed production was reported to be 210.4 thousand tones in 1963, it declined to 201.2 thousand tones in 2000 (Gitu and Nzuma, 2002) as shown in Figure 1.2.

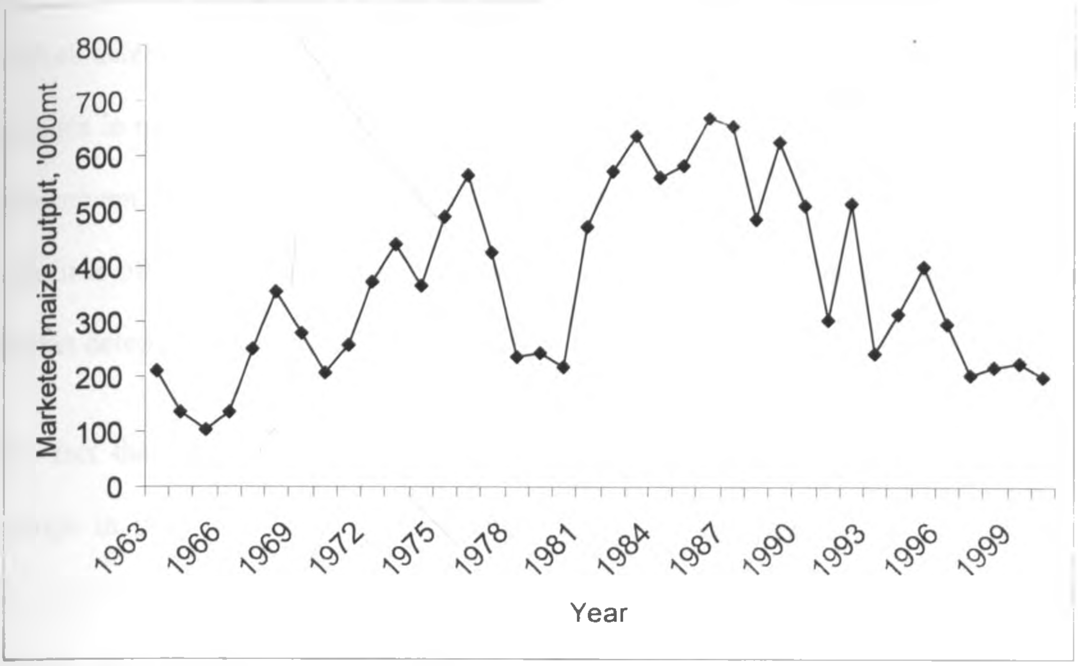

Figure 1.2: Marketed Maize Output Pattern, 1963-2000

(Source: Gitu and Nzuma, 2002)

1.3 Maize Market Risk

The freeing of the agrarian economies of Sub-Saharan Africa to wider markets with liberalization, created at least the potential for gains from trade, but it also introduced both new sources of uncertainty and new constraints on the behavior of producers (Perrings,1996). There are now two major sources of risks and uncertainties to be accommodated – the environment and the market.

Liberalization of the maize market, as with the other scheduled crops, introduced concerns related to volatile and fluctuating prices, and thus market risks. Compared to government fixed prices, market determined prices might be more variable and their values more uncertain in the future. However, when prices are strongly influenced by government policy, their value as indicators of changing demand and supply conditions is lost. In contrast, as conditions change, market determined prices rapidly change to rebalance supply with demand and reflect these changes in market conditions. This improved information content of market prices compared to government set prices can be viewed as a benefit of market determined prices. However this benefit is often contrasted with its economic cost in the form of price volatility associated with market determination of prices.

The fact that smaller shifts in quantity produced will result in a relatively larger percentage change in price for agricultural products, given the inelastic demand for most agricultural commodities, and the tendency of farmers to make individual production decisions based on current prices leads to price variability as the market recognizes the aggregate positive supply impact of the farmers' individual decisions. This result in uncertainty regarding what exactly the future prices will be. This has been observed to be a common feature of the maize market under liberalized market policy in Kenya. This uncertainty lies at the root of the economic cost of price volatility.

According to Weaver and Natcher (2000), price volatility refers to the estimate of the range within which prices might vary at a future time and is given by the annual difference in the highest and lowest monthly prices in specified markets. When the range within which prices might fall at a future time is wider, prices are said to be volatile. When prices are volatile, decisions made today may be unprofitable tomorrow if tomorrow's price is not correctly anticipated, and especially so in the absence of formal devices of risk management in developing countries such as Kenya.

1.4 Research Problem

Policy reforms in the food sub sector were aimed at addressing constraints that prevailed in the past, and which hindered increased production. These included inadequate access to inputs, poor pricing and marketing incentives, lack of suitable varieties and poor adoption of technologies. It was hoped that liberalized markets would provide appropriate policy signals to both producers and consumers to participate effectively in the agricultural sector and therefore overcome the observed constraints.

However, recent research findings indicate that these constraints are still prevalent (Omore *et al.*, 1997). Moreover, liberalization of maize marketing has largely been associated with changes in marketing margins, which has negatively impacted on farm incomes. Furthermore, while policy reforms were supposed to ensure availability of food to all people at all times, cases of food shortages are still reported even in areas that were previously food secure.

In smallholder farms, maize production fits in a complex farming system just as one of the many enterprises. Therefore, commercial maize production means adjustment of the balance of resources and input use among enterprise mixes because of competition for resources and inputs between the various enterprises. The timeliness and stability of their returns affects the cash flow pattern, which is also an important factor in a smallholder economy. A farmer is required to make decisions on what enterprise combinations to have and the level of farm resources to use in each enterprise. The decision is influenced by the availability of resources, productivity of various activities at different scales of production and various risks that face the farmer as s/he strives to raise household food security and income.

The smallholder is aware of these constraints and constantly tries to adjust to a very complex and dynamic situation (Ikombo, *et al*, cited in Wachira, 1997). After incurring losses through low and or uncertain prices, farmers associate different levels of risk with different enterprises, and this affects the amount they are willing to invest in each enterprise. The risk attitude held by the farmer influences the enterprise mix depending on the risk management strategies s/he employs.

Generally, many small-scale farmers cope with price risk through diversification. The decrease in marketed output of maize may be an indication of a shift towards subsistence farming for food crops or a shift to production of cash crops. However, there is no evidence on the nature of the shift in agricultural production in Kenya. Nyangito (1998) observed that the impacts of reform on maize production in Kenya remain unclear. It is however documented that poverty levels have increased in the rural areas as stated in the current Poverty Reduction Strategy Paper (PRSP) for Kenya (Kenya, 2002). Most of the poor are affected in some way or the other by what happens to commodity prices and is one of the most vulnerable groups to commodity price fluctuations, because they mostly live in rural areas with livelihoods depending on production of primary commodities either as farmers or as farm laborers (Appendix 2).

This study aimed at providing information to fill the gap and to assess the link between the changing production patterns and the rising poverty levels.

1.5 Objectives of the Study

The overall objective of the study was to analyze the effects of maize price risk on agricultural production patterns and farm incomes among small-scale farmers in the greater Kakamega district (consisting of the current Kakamega, Vihiga, Butere Mumias and Lugari districts).

To achieve the overall objective, the following specific objectives were set:

1. To determine maize price volatility (risk) in the post liberalization period (1993-2003) in the greater Kakamega district,
2. To examine the changing agricultural production patterns, focusing on enterprise acreage allocation and output for the greater Kakamega district (from 1980 to 2003),
3. To analyze the current farm production systems for the greater Kakamega district, focusing on the costs of production and incomes earned,
4. To determine the optimal risk efficient farm enterprise mix.

1.6 Hypothesis to be Tested

The following hypotheses were tested:

1. That liberalization of maize marketing has not led to maize price volatility in the greater Kakamega district.
2. That there is no significant relationship between maize price volatility and acreage allocated to maize in the greater Kakamega district.
3. That farmers do not make optimal choices when diversifying enterprises as a maize price risk mitigation strategy in the greater Kakamega district.

1.7 Justification of the Study

Agricultural production decisions are generally made subject to the interaction of many factors such as weather, diseases, insect infestations, technology and public policies (Mapp *et al*., 1979; Adesina and Brorsen, 1987). Product prices, yields and, input prices and quantities are not known with certainty when investment decisions are made. These may result in returns displaying high variability of farm income. The situation is particularly burdensome to small holders who constitute the vast majority of the population in developing countries, and who usually lack access to formal market based institutional approaches to risk management. In Kenya, this sector accounts for nearly 75 per cent of total agricultural production, and produces 70 per cent of marketed output (Kenya, 2004). The small-scale sector further employs 57.5 per cent of the labor force (Kenya, 2002), and constitutes the bulk of food crop producers, producing over 70 per cent of maize (Kenya, 2004).

In the past, efforts had been concentrated on transferring some adverse effects of price and yield variabilities from the farmers to the government. Various public institutions were created to implement agricultural policies based on the principle of farm income stabilization. The shift in economic policy towards free market operations introduced output price variability. Given the concerted efforts at minimizing risks, the attitude of farmers and especially small-scale farmers therefore constitutes an important consideration for research. Furthermore, the risks faced by maize farmers are of particular interest to the country's food security, due to the increasing population and therefore increased demand for maize, the country's staple food.

The study results may guide policy makers in the formulation of appropriate and effective policies to address market risks and the resulting low agricultural incomes faced by the rural poor small-scale farmers.

1.8 Organization of the Thesis

This thesis is organized in five chapters. Chapter One details the background information, and introduces the research problem - resource allocation under maize price risk. Chapter Two contains literature review, on methodological development issues and past studies on maize market liberalization; while Chapter Three outlines the methodology of the study. This is followed by presentation and discussion of results in Chapter Four. Finally, summary, results and policy recommendations of the research findings are presented in Chapter Five.

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CHAPTER 2: LITERATURE REVIEW

2.1 Risk in Farming

Agricultural production decisions, especially long term planning decisions are often made in an uncertain/unpredictable environment. McConnell and Dillon (1997) define uncertain decisions as those, which because of the influence of forces beyond the farm manager's control do not have a single sure outcome. Such decisions have an array of possible outcomes which is argued can be specified by the decision maker in the form of subjective probability distribution corresponding directly to his/her personal degrees of belief in the occurrence of the possible outcomes. Risk on the other hand is generated by actions whose outcomes are subject to uncertainty, but only exists when the uncertain outcomes of a decision are regarded by the decision maker as significant (Robinson and Barry, 1987; Fleisher, 1990).

McConnell and Dillon (1997) classified sources of risk into two major groups; (1) the external environment as it impinges on the farm system, and (2) the internal operational environment of the farm system. Major external sources of risk relate to uncertainty in the natural (weather and climate), economic, social, policy, and political environments in which the farm system has to operate (Hardakar, *et al,* 1997; Beal, 1996; Fleisher, 1990).[1] The major internal sources of risk relate to the health of the farm household members, inter personal relations between farm household members, and farm management.

The economic variables through which uncertainty in the farm's external or internal environment is translated into farm system risk are those, which determine the net economic outcome of a

[1] Of most general relevance and importance are risks associated with the natural environment, because of agricultural production's time dependent biological nature (McConnell and Dillon, 1997). Research has also established that the uncertainty generated from commodity price fluctuations have effects on farm resource allocation (Mellor, 1969).

decision. These variables have been documented to include product prices, unit and aggregate yield, the price and quantities used of variable inputs, and fixed costs. Relative to short run decisions, like seasonal farm planning, it is product prices and yields that are uncertain and most important in determining risk (McConnell and Dillon, 1997).

Decision makers, considering the imperfect information available, only make the choice among the available risky alternatives which most appeal to him/her given his/her preference for outcomes and degrees of belief in their occurrence (McConnell and Dillon, 1997).

Risk makes farm managers cautious in their decision-making. Farm household survival demands greater cognizance of possible adverse outcomes (downside risk) than of possible good outcomes. While good outcomes are inherently attractive, for resource poor small-scale farmers, this attraction must be expected to be more than outweighed by concern for the possibly disastrous impact of adverse outcomes. Downside risks challenge farm system survival, particularly if a series of adverse outcomes should occur.

Farm system survival is enhanced by prudent, circumspect and cautious approach to risky decisions on the part of the farmer. Smallholder farmers therefore, because of these uncertainties apply risk averse resource management strategies in their production and marketing activities (Sonka and Patrick, 1984). Perrings (1986) observed that the impoverishment of resource users in Sub Saharan Africa encourages an extreme degree of risk aversion, inhibiting technological innovation. A study by Wolgin (1975) which evaluated resource use efficiency in small scale farming in Kenya found out that risk aversion and risk premiums are important in these farmers' crop decisions in smallholder agriculture in Kenya. These farmers therefore prefer an action with a perfectly certain return to another with an equal but uncertain return.

2.2 Farmers' Risk-Management Strategies

Farmers undertake different production, marketing, and financial strategies to cope with different sources of risk (Sonka and Patrick, 1984). As already noted, resource poor small farmers whose livelihood can be at stake from risk are cautious and circumspect in the face of downward risk. They exhibit considerable risk aversion, as manifested in a variety of operational strategies aimed at risk mitigation (Anderson and Dillon, 1992).

When planning their farms and annual activities, in order to ensure household food security and livelihood, farmers put into consideration all major sources of risk. Many farmers therefore make production, marketing and financial decisions that conform to their perception of the economic and biophysical environments. This is because unlike large commercial farms, small scale farmers do not usually have available to them more formal market based institutional approaches to risk management, such as bank credit, crop or livestock insurance, forward pricing through futures or options contracts (Anderson and Dillon, 1992; Calkins; Fleisher, 1990 and DiPietre, 1983;) or market guarantees through vertical integration.

The strategies used vary with biophysical circumstances. But whatever combination of risk management strategies used, they form an integral part of the farming systems developed by small scale farmers over a long period of time in their particular environments. Anderson and Dillon (1992) observed that farmers have always examined the environment for niches favorable to their own concept of welfare and often through centuries long trial and error, have established farming systems with technologies such as risk spreading multiple cropping, suited to their needs. It can therefore be assumed that farmers, after growing crops and keeping livestock for many years, are able to approximate the optimal levels (level of operation which maximizes profit) of operation given their economic environment and risk attitude.

With the absence of formal devices of risk management in the many developing countries, farmers have to rely heavily on traditional methods of mixed/inter-cropping and or mixed farming practices and in the process have to contend with lower incomes. Further, the subsistence orientation coupled with the risk aversion behavior of the farmer results in suboptimal use of scarce resources (Perrings, 1996), which affects the welfare position of farmers.

2.3 Analysis of Risk in Farm Decisions

Being rational, farmers typically make their risky decisions in a considered way. This, it may be argued implies that on the basis of their experience, traditional knowledge and whatever other information that is available to them, farmers specify: (1) the alternative choices available to them; (2) the set of outcomes associated with each of these alternative choices; and (3) their personal subjective probability distribution for each of these sets of outcomes (McConnell and Dillon, 1997). Personal judgment is then exercised by the farmer to choose that alternative which has the most preferred / attractive probability distribution of outcomes. Such a process of choice is generally carried out by the farmer in an implicit or an informal rather than an explicit or a formal manner. This is particularly so for small-scale resource poor farmers. The decision problem of the farmer is to rank farm plans on the basis of their income distributions and to select the one that best meets his goals (Ibid).

Analysts have used a variety of formal techniques to evaluate risky decisions and guide decision maker's risky choices (Hardaker *et al,* 1997; Dillon and Hardaker, 1993). Most relevant of these formal approaches to risky choice are sensitivity analysis, stochastic budgeting subjective expected utility analysis (including Mean variance analysis and stochastic dominance analysis), risk oriented mathematical programming and Monte Carlo simulation. However, the subjective expected utility theory (SEU)[2] (Von Neumann and Morgenstern, 1975) provides the theoretical basis for choice under uncertainty and has been generally accepted as a normative model of rational choice. The theory assumes the existence of a utility curve for individual decision makers and associates a utility value with a particular level or range of income. The theory allows appropriate choices between farm plans to be made on the basis of their income distributions and decision makers try to balance increasing return against increasing risk, however unpredictable.

Despite the theory's wide acceptance, operational problems often arise in its practical application, especially the difficulty in accurately measuring a decision maker's preference. The most direct way to measure preference is to estimate a decision maker's utility function. A utility function relates the possible outcomes of a choice to a single valued index of desirability. As such, it is an exact representation of preference (Hazell and Norton, 1986). However, an estimated utility function may not be completely accurate. Shortcomings in interview procedures (Officer and Halter, 1968; Binswanger, 1980), problems in statistical estimation (Knowles, 1980), and individual's lack of knowledge about their preferences (Zadeh, 1973), may all hamper the estimation process.

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[2] The SEU is rivaled by the prospect theory (Kahneman and Tversky, 1979), who argue that sometimes-individual preferences go against the utility axioms. However, no application of the theory in mathematical risk programming has been documented.

Hazell and Norton (1986) suggested that some of the problems with single valued utility functions could be overcome by using an efficiency criterion[3] to order choices. Given specified restrictions on the decision maker's preferences, and in some cases, on the probability distributions of feasible alternatives, an efficiency criterion provides a partial ordering of choices.

As Levy and Sarnat (1972) note, the efficiency criterion divides the decision alternatives into two mutually exclusive sets; an efficient set and an inefficient one. The efficient set contains the expected 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 decision makers.

Analysts have frequently employed two methods for modeling choice among uncertain prospects: Stochastic dominance (Levy, 1992; Whitmore and Findlay, 1978) and Mean-risk (Variance) analysis (Markowitz, 1987). Stochastic dominance is based on an axiomatic model of risk-averse preferences and leads to conclusions consistent with the axioms. The mean-risk (Variance) approach quantifies the problem in a more lucid form of only two criteria (moments); the mean, representing expected outcome and the risk (variance), a scalar measure of the variability of the outcomes. The mean-risk model is appealing to decision makers and allows simple trade off analysis, analytical or geometrical.

Porter *et al.,* (1973) state that the theory of stochastic dominance (SD) as developed by Hardar and Rusell (1969), Hanoch and Levy (1969), Rothschild and Stiglitz (1970) and Whitmore

[3] Efficiency criterion are useful in situations involving a single decision maker whose preferences are not known, situations involving several decision makers whose preferences differ yet conform to a specific set of restrictions, and in analyzing policy alternatives or extension recommendations that affect many diverse individuals

(1970) "has been shown to be theoretically superior to the moment methods (The Mean-Variance)". Kousmanen (2001) suggests that SD is attractive because it is effectively non parametric as no explicit specification of the agent's utility function or restrictions on the functional form of the probability distribution are required. Additionally, it considers the entire distribution rather than just selected moments and so may be a more robust approach, especially in times of high market volatility.

However, there is a potential difficulty with implementing SD analysis as described in Levy (1992): "It is well known that one of the disadvantages of SD analysis, in comparison with Mean –Risk (Variance) analysis is that in the SD framework, we do not have yet, an algorithm to find the SD efficient diversification strategies.[4]

EV analysis (Markowitz, 1959) is the most familiar and most widely used analytical procedure. This criterion requires that the outcome distributions be normal or that the decision maker's utility function be quadratic. When these two conditions are met, all relevant information concerning the probability distributions of choices is conveyed by means and variances. The EV criterion is therefore stated in terms of these two moments, means and variances.
Outcome distribution F, with mean E_F, and variance V_F, dominates distribution G, with mean E_F, and variance V_G, if $E_F \geq E_G$ and $V_F \leq V_G$, and if one of these two inequalities is strict. This study therefore utilized the Mean-Risk (Variance) analysis to develop the efficient set, given its computational advantages over SD analysis.

[4] Recent advances in the implementation of these techniques such as by Levy (1998), Kousmanen (2001) and Post (2001) have made SD analysis more accessible and relevant (Meyer et al, 2004)

2.4 Mean Variance Analysis and Quadratic Programming

The mean variance approach, developed by Markowitz (1952) and applied by Britten-Jones (1999), has widely been used for evaluating many economic and financial decisions under uncertainty. It is commonly applied to portfolio decisions such as investment combinations or farm plans (Hardaker *et al.*, 1997). In EV analysis, the value of a choice depends on both its expected value (mean) and variance of that expected value (risk). The decision maker's risk aversion level determines the optimal choice set. The approach allows a decision maker to make trade offs between expected returns and risk (or variance) of returns.

The EV analysis owes its popularity to its adaptability to empirical analysis and its consistency with expected utility results (Robinson and Barry, 1987). Use of the EV model has been theoretically controversial. There has been debate since the introduction of the EV analysis. One of the weaknesses of the model is that it is not capable of modelling the entire richness of various risk averse preferences. Other debates have been on the conditions under which an EV model makes choices equivalent to expected utility maximization. Currently, the general agreement is that when either the outcome distribution (profits) is normally distributed or the investor's utility function is quadratic, the EV efficient set encompasses the expected utility (EU) maximizing results (Robinson and Barry, 1987). Some empirical studies (Levy and Markowitz, 1979; Kroll and Markowitz., 1984; Reid and Tew, 1987) have also shown the closeness of EV to expected utility maximizing choices. In addition, Tsiang (1972, 1974) showed that EV analysis provides an acceptable approximation of the expected utility choices when the risk taken is small relative to total initial wealth. However, Robinson and Barry (1987) argue that the use of the EV model is justified whenever it is able to describe and predict decision maker's behavior under risk, regardless of its inconsistency with EU models.

Mean variance (EV) analysis using quadratic programming (QP) has had numerous applications in empirical analysis. Scott and Baker (1972) used the model to derive a risk efficient set of farm plans for a Central Illinois cash grain farm. The production alternatives were corn, soybeans, oats, wheat, and land conservation. The analysis allowed the farmer to choose a production plan from the efficient set based on his own risk attitude. Bhende and Venkataram (1993), while studying the impact of diversification through dairying on the level of income and magnitude of risk on dry land farms in India, used the Mean variance analysis with QP to develop risk efficient farm plans for risk averse and risk neutral situations. Giles *et al.* (1993) used the EV analysis, to identify risk efficient crop portfolios for a group of subsistence farmers in Morocco. Their study showed that EV approximations could be developed using QP, which provides close estimates to maximum expected utility at various risk aversion levels. The study also identified the appropriate utility function form and an approximation of the level of risk aversion exhibited by small-scale farmers.

2.5 A Review of Past Studies in Kenya

Many studies were carried out in Kenya prior to and at the beginning of the privatization and liberalization process to predict its outcome. The results of most of these studies predicted better producer prices, reduced marketing margins, efficient flow of maize from surplus to deficit areas, and reduced government expenditure in maintaining maize stocks for food security.

Omamo (1994) in a study assessing the impact of maize market reform on mixed farmers in Southern Siaya district, (Kenya), analyzed cropping choices and used the household model to consider responses of farming households to maize market liberalization in maize deficit areas. The study focused on farmer choices among food and cash crops. The experimental simulation results revealed that subject to availability of seasonal credit, market reforms that lower marketing margins and thus food prices could induce expanded cash crop production and higher farm incomes. For net buyers of maize, a lower maize price raises purchasing power and permits greater reliance on the market for food needs. For net sellers of maize, the higher relative profitability of the cash crops causes shifts in resources toward it and lowers the production and sale of food. The study concluded that the regional implications of these household level responses to reduced maize prices are lower aggregate maize production and greater regional import demand. The study, carried out at the beginning of liberalization, based its argument on reduced maize prices resulting from liberalization using experimental simulation. The current study utilized data from the ten (10) years of maize market liberalization to assess whether there have been shifts in productive resources from the maize enterprise.

Nyoro (1994), in the study entitled Maize Production: Impacts of maize market reform, observed that because maize production is rain fed, it is subject to weather induced supply fluctuations. In a poor production period, maize production decreases and maize price increase, while in a good production year, maize production increases and price decreases. He therefore observed that this fluctuation in production causes instability in maize prices. The study pointed out that maize production decrease when risk averse farmers reduce production. In this same study, it was postulated that expansion of area under maize was unlikely to have a significant impact on production in the liberalization period. The study predicted that intensification of dairy production would release some additional area for maize production in the maize surplus production areas. The study concluded that in the context of maize market liberalization, farmers would increase maize production through intensification in their use of inputs like fertilizer and use of improved technologies. The study further pointed out that farmers would shift from other enterprises to maize production depending on relative profits between maize and competing crops. This study however did not assess the effect of price uncertainty on maize production.

Nyangito and Okello (1998), while assessing Kenya's agricultural policy and sector performance from 1964-1996 observed that marketed agricultural output growth had fluctuated over the years since 1982. The study noted that only the export crops had shown, on the average, an increase in growth for the whole reform period and that levels for marketed output for food, industrial crops and livestock had tended to be below what was achieved in 1982, with the steepest decline occurring between 1990 and 1994. The study attributed the fluctuations in growth to producer price change from the era of price controls and foreign exchange regulations to market determined prices and exchange rates. Other factors identified by the study included low input use among smallholder farmers due to increased input cost arising from the removal of exchange rate regulation, reduced direct government provision of production support services and drought. However, the study did not assess the effect of price uncertainty on maize or other agricultural commodity production.

Nyangito (1998) analyzed the efficiency of pricing maize output, the competitiveness of producing maize and the efficiency of the incentives structure for producers to shed light on the effectiveness of using the self-sufficiency strategy for achieving food security in Kenya. The study results indicated that domestic prices of maize were lower than the world market prices inclusive of import costs, but the gains from maize output were more than the value of tradable inputs and hence adequately compensated for the costs of the domestic resources used in its production. The study therefore concluded that it is economically appropriate to pursue the policy of increased domestic production of maize for achieving food security. The study also observed that the low output - high input prices and market distortions create disincentives to increased production by individual producers, although the economy at large gains from maize production. The study recommended that these distortions be removed. The study pointed out the enhancement of output pricing efficiency in particular, through stabilizing maize supply in the domestic market. This, it argued, could be achieved through the storage or the export of excess maize during the surplus years.

Despite the fact that the liberalization process is 10 years old, discussions of grain marketing policy in the post liberalization period have often taken place in an information vacuum (Nyoro *et al.*, 1999). Nyangito (1998) also observed that the impacts of reform on maize production in Kenya remain unclear. As such, the additional source of risk resulting from farm price volatility occasioned by liberalization and the management strategies used by farmers, and its effect on the farm enterprise and household income have not been considered, especially in maize surplus areas.

CHAPTER 3: METHODOLOGY

3.1 Conceptual Framework

Farmers maximize welfare, which could be profits or utility, subject to resource constraints. Farmers are assumed to be price efficient and to have a positive supply response. However, risk and uncertainty influence the efficiency decision making process of farmers. Wolgin (1975) indicated that risk plays an important role in farmer decision-making. As such, the decision maker's behavior towards risk and uncertainty has been recognized as an economic phenomenon and the importance of both price and production related risks in determining agricultural production decisions acknowledged (Just, 1975).

The risk situation is acute for the majority of small scale agricultural producers in Sub Saharan Africa. The low and highly erratic rainfall (Sivakumar, 1988), and the absence of institutional arrangements (e.g. crop insurance, disaster payments, emergency loans) to shift part of the risks from the private sector to the public sector, makes risk management a critical part of farmers' decision making (Malton, 1990; Adesina and Sanders, 1991; Shapiro *et al.*, 1993). When the farmer is exposed to price and production risks, the problem becomes more complicated. This is the common setting for farmers and other primary commodity producers.

Individuals react to risk in different ways; one could be a risk taker, risk neutral or risk averse. However, various empirical studies (e.g. Hazell and Norton, 1986), have demonstrated that farmers typically behave in risk averse ways. Farmers often prefer farm plans that provide satisfactory level of profits/utility even if this means sacrificing income on average.

There are alternative courses of action that these farmers employ to earn income, given their resource endowments and operating constraints. These include crops, livestock, mixed farming, and labor selling, among others. In order to maximize own welfare, expressed in utility or money income, the small-scale farmer who is risk averse, chooses levels of these activities in various combinations with respect to security. The problem of determining the optimal farm plan for the risk averse competitive small- scale farmer is therefore a problem of considerable importance.

The Mean Variance (EV) decision criteria as a means of choosing among portfolios of assets has been widely applied in decision theory under risk. It is based on the assumption that, given any two distributions with equal means, a risk averse decision maker will prefer the distribution with the smallest variance. The decision maker makes tradeoffs between expected returns and risk (or variance) of returns. This decision theory was used to assess whether farmers in the study area produce optimally under risk.

3.2 Survey Design and Implementation

Information and data used in this study is drawn from both primary and secondary sources.

3.2.1 Primary Data

Primary data was gathered on:

- Farm enterprise mix,
- Acreage allocation to each enterprise,
- Input and output levels from each enterprise,
- Farm household land holding (including rented), and
- Input and output costs

This data was required for the determination of production costs and farm incomes.

3.2.2. Secondary Data

Data included district time series data on:

- Commodity acreage,
- Commodity output and prices from 1980 to 2003 for the district.

In addition, maize monthly prices in the study area for the same duration was also collected. The data sources included the Ministry of Agriculture annual reports for Kakamega, Vihiga, Butere/Mumias and Lugari districts; and Lugari, Kakamega and Butere/Mumias Districts Farm Management Reports, Ministry of Agriculture.

Monthly maize prices was required to determine whether prices in the post liberalization era are more variable than during the pre liberalization era, while data on commodity acreages and output was required to assess the enterprise changes over the same period.

3.3 The Study Area

The study was conducted in the greater Kakamega district (kakamega, Vihiga, Butere/Mumias, and Lugari districts)in Western Kenya, and is part of the belt usually referred to as Kenya's granary of maize. However in the recent past, the district has been reported to experience a decline in maize output. The district experienced a big decline in maize income in 1995 (Kenya, 1994), and since then, there has been a steady decrease in maize output and acreage allocated to maize production reported in the districts.

This area was selected for the study because of its high agricultural potential. It has a diverse mix of crop-livestock enterprises. Consequently, changes in enterprise combinations could reflect farmers' response to various risks, including market price changes.

The region covers 3250 square km and ranges in altitude from 1250 m in the west around Mumias to 1500 m. in Lugari in the east. Rainfall is high, between 1250 mm and 2000 mm per annum and is highest in the central and southern parts of the region, where there is no defined dry season. The three main agro-ecological zones in the region include Upper Midland 1, Upper Midland 4, and Lower Midland 1, having distinct different agricultural systems (Jaetzold and Schmidt, 1982)

3.4 Sample Selection

Three sampling procedures were used in this study. These were: (i) Purposive sampling of the study area and divisions; (ii) Multistage random sampling to select the locations, sub locations and villages; and (iii) Systematic sampling to select the individual farms.

Four divisions from the larger Kakamega district were purposively selected. The major maize producing divisions as documented in the District Development Plans (1994-1996) for the region were visited. These divisions fell within three districts which include: Lugari division (Lugari district), Kabras (Kakamega district), Lurambi division (kakamega district), and Khwisero (Butere/Mumias district).

Two locations were then randomly selected from each division selected, followed again by a random selection of two sub locations from each of the selected divisions. A single village was then randomly selected from each sub location selected.

Systematic sampling was finally used to select the farm households. Here, a sampling interval of four farms was maintained after every successful interview. 52 farm households were visited in each division.

The approach adopted in data collection involved personal interviews of the selected farm households. Before data collection began, the questionnaire was pretested using eight (8) farmers. The study relied heavily on farmer recall but farm records were used where available. Only farmers who had been engaged in farming for, at least, the last ten years were selected for the study in order to capture experiences with maize price variations. A summary of the selected villages is indicated in Table 3.1.

Table 3.1: Primary Data collection Sites

District	Division	Location	Sub-Location
Kakamega	Lurambi	North Butsostso	Eshumeya
			Shikomari
		South Butsotso	Emukhaya
			Matioli
Kakamega	Kabras	Central Kabras	Kakunga
			Matsakha
		East Kabras	Butali
			Manda
Lugari	Lugari	Chekalili	Kolomeiti
			Musembe
		Lumakanda	Munyuki
			Mwembe
Butere/Mumias	Khwisero	East Kisa	Emasatsi
			Munjiti
		Central Kisa	Mundekhu
			Wambulishe

3.5 Data Analysis

The data generated by this study was analyzed using descriptive statistics, gross margin analysis, Linear Programming (LP) and quadratic programming (EV).

Descriptive statistics were used so as to describe patterns of resource utilization and investment in the various enterprises over time to assess the production pattern trend as identified by the model farms. The statistics used were frequency distributions, means and variances.

3. 5.1 F ratio test

It was hypothesized that liberalization of the maize market has not led to price volatility. Price volatility refers to the estimated range within which prices might vary at a future time and is given by the annual difference in the highest and lowest monthly prices. When the range wider, prices are said to be volatile. Monthly price movement in the maize market during the pre liberalization era, (represented by the period between 1980 and 1993), and the post liberalization era, (represented by the period between 1994 and 2003), were compared to assess price volatility in the market. Difference in variance of the maize price ranges in the two periods was analyzed using the F- ratio test.

3.5.2 Correlation analysis

The study hypothesized that there is no significant relationship between maize price volatility and acreage allocation to the maize enterprise between 1980 and 2003. Correlation analysis was used to assess the relationship between the two variables. A negative and significant relationship would indicate that the two variables move in opposite directions, therefore volatility in maize prices would be associated with a reduction in acreage allocation to the maize enterprise

3.5.3 Trend analysis

Trend analysis is an aspect of technical analysis that tries to predict the future movement of a variable based on past data. It is based on the idea that what has happened in the past gives an idea of what will happen in the future. Past data on enterprise acreage allocation, output and price movement for the major enterprises in the study area was analyzed using trend analysis. The data for the various variables exhibited a monotonous trend (consistently increasing/decreasing) and therefore the trend was approximated by a linear function. These were then described using various figures.

3.5.4 Gross Margin Analysis

This study focused on evaluating farm profitability on a short-term basis (in the 2002/2003 crop season). Since fixed costs are ignored in the short run since they constant in the short run, net returns were defined as gross margins per unit of activity, and expressed in Kenya shillings per acre. The variable costs (expenses on seed, fertilizer, pesticides and insecticides, machines and implements hired among others), were deducted to arrive at the gross profit.

Gross Margin of an enterprise *equals* Gross Income *less* Variable Labor Costs and Variable Input Costs

NB: Family labor was not valued and so the gross margin here presents returns to family labor, management and fixed costs.

3.5.5 Linear and Quadratic Programming

Risk efficient farm plans for four model farms and a sample average farm were obtained using a modification of the Linear Programming (LP) model referred to as quadratic programming using Mean Variance model. In this model, the farmer is assumed to evaluate risk on the basis of expected returns and variance (risk) of the returns. Two computational procedures of the model were employed. A conventional LP model was formulated to compute the maximum return without the risk constraints. This gives the highest point on the risk-return efficiency frontier.

The LP model was specified as:

$$Max\ TGM = C_j X_j \qquad (3.1)$$

Subject to: -

$$a_{ij} x_j \leq b_i$$

$$x_j > 0, for\ \ all\ j = 1, 2, \ldots, n$$

Where: -

TGM is the Total Gross Margin

C_j *is returns from producing* X_j;

X_j *is activity*;

b_i *is supply of resource i*

a_{ij} *are technical coefficients*;

The sought to maximize total gross margin in the 2002/03-crop season, subject to the resource constraints, of land, labor, operating capital. Some minimum enterprise levels were generated to serve household food security levels..

The real activities included in the model were the present enterprises as observed in the model farms, while the resource constraints used were the supply levels of the various resources. In this study land, labor and operating capital were the constraints considered. The total amount of cash expenditure in the 2002/03-crop season was assumed to be the amount of working capital available. These included expenses incurred in purchasing farm inputs. This approach was adapted from Nyikal (2000).

Minimum enterprise acreages constraint was also incorporated into the model in accordance with the survey data (farmers were asked if they had minimum acreage requirement for the enterprises per crop season).

Each activity was presented in the model on the basis of one acre. This is because many smallholder land sizes are more easily expressed in acres than in fractions of a hectare. It should be noted that 2.49 acres approximates 1-hectare.

3.6 Empirical Model Specification

Markowitz (1952) observed that investors only place a portion, not all, of their resources in the highest yielding investment. This he argued indicated that a linear programming (LP) formulation is inappropriate since an LP would reflect investment of all resources in the highest yielding alternative in the case of a single constraint. The divergence between observed and modeled behavior led Markowitz to include a variance term resulting in the expected value variance (EV) model.

In this study, Quadratic programming was used to develop the EV efficient set. Stochastic programming techniques generally treat risk in the objective function coefficients, technical coefficients, or right hand sides, separately or collectively. This study treated risk in the objective function as follows;

Given a linear objective function;

$$Z = C_j X_j \tag{3.2}$$

Where X_j are decision variables and C_j are uncertain parameters, distributed with means $\overline{C}_i$ and $\overline{X}_j$ as well as variances $S_{i=j}$ and covariance S_{ij}. Z is then distributed with mean;

$$Z = \overline{C}_1 * X_1 + \overline{C}_2 * X_2 \tag{3.3}$$

variance;

$$S_{i=j} X_j^2 \tag{3.4}$$

and covariance;

$$2S_{i\neq j}X_j \tag{3.4}$$

In matrix terms, the mean and variance of Z are;

$$\overline{C}X \text{ and } XSX \tag{3.5}$$

Where;

$S^2_{i=j}$ is the variance of the objective function coefficient of X_i calculated as: -

$$s^2_1\ \Sigma(c-\overline{c})/N; \tag{3.8}$$

Where C_i is the K^{th} observation on the objective value of X_i and N is the number of observations.

$S_{i\neq j}$ is the covariance of the objective function coefficient between X_i and X_j, and is calculated as;

$$\Sigma(c_{ik}-\overline{c}_i)(c_{jk}-\overline{c}_j)/N \tag{3.9}$$

$\overline{C}_i$ is the mean value of C associated with X_i and is calculated as:

$$\sum C_i/N \tag{3.10}$$

The general formulation of the resource allocation context of the model is:

$$\text{Maximize } \overline{C}X - \lambda X'\sigma X \tag{3.11}$$

Subject to:

$$AX \leq B$$

$$X \geq 0$$

In the case of three activities and three restrictions, the model is formulated as:

$$\text{Max.}\ \left(\bar{C}_1,\bar{C}_2,\bar{C}_3\right)\begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix} - \left(X_1,X_2,X_3\right)\begin{pmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{pmatrix}\begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix}$$

Subject to: (3.12)

$$\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix}\begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix} \leq \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix} \quad \textit{and} \quad \begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix} \geq 0$$

Time series data of prices from 1997 – 2003 was used to compute the average prices and Output of the 2002/03-crop season used as the activity levels.

Where:

X is the vector of activity levels and included the different farm enterprises as observed in the model farms;

The coefficient λ (from equation 3.11) is the risk aversion parameter and takes the values; $0 < \lambda \leq 1$. In this study, this parameter ranged from some minimum to some maximum value defined specifically for each model farm separately as presented in Table 3.2.

$\bar{C}$ is average per unit returns from producing X_i

σ is the variance covariance matrix of per unit activity returns; and

b is vector of resource constraints, including operating capital, land, labor availability and the minimum acreage requirements.

$X'\sigma X$ is the overall variance associated with the expected returns.

Table 3.2: Risk Aversion Ranges

Risk Aversion Level	Lugari	Khwisero	Lurambi	Kabras	Sample average
Minimum	0.00001	0.000007	0.000008	0.000005	0.00002
Maximum	0.0002	0.00003	0.009	0.0002	0.006

The EV decision rule as formulated by Markowitz results from expected utility theory if a farmer has a quadratic utility function for income $U(y)$. However, a quadratic utility function is characterized by increasing absolute risk aversion, as well as having a maximum value beyond which the marginal utility of income declines (Hazell and Norton, 1986). Many analysts have therefore rejected it (e.g Pratt, 1964). The study adopted an alternative derivation of the model formulated by Freund (1965), which has been widely used and follows if the utility function is of the exponential form;

$$U(y) = 1 - e^{-\beta y} \tag{3.13}$$

and income y is normally distributed.

In this case;

$$E[U(y)] = E[y] - 1/2\beta V[y] \tag{3.14}$$

Where β is a risk aversion parameter. It might be expected that since farm income is often an aggregate of many independent sources of revenue and cost risks, then by central limit theorem, it should be approximately normally distributed (Hazell and Norton, 1986). The set of feasible farm plans, having the property that variance V is minimum for associated expected income level E, are then developed (as explained below).

3.6.1 Empirical model

Considering a short run-planning problem in which only the C_j coefficients are stochastic, farm overhead costs are constant and the income distribution of a farm plan is totally specified by the total gross margin distribution.

Letting X_j denote the level of the j^{th} activity, and Q_{jk} the covariance of gross margins between the j^{th} and K^{th} activities (Q_{jk} is the variance when $j = k$); then the variance of total gross margin is;

$$V = \sum_j \sum_k X_j X_k Q_{jk} \qquad (3.15)$$

Equation (3.2) shows that the variance of total gross margin is an aggregate of the variability of individual enterprise returns and the covariance relationships between them. Covariances are fundamental for efficient diversification among enterprises as a means of hedging against risk (Markowitz, 1952; Heady, 1952). To obtain the efficient EV set, it is required to minimize V for each possible level of expected income E, while retaining feasibility with respect to the available resource constraints.

A version of the model outlined by Hazell and Norton (1986) was adopted for this study as follows;

$$\text{Min} \quad V = \sum_j \sum_k X_j X_k Q_{jk} \qquad (3.16)$$

So long as;

$$\sum \bar{C}_j X_j = \lambda \qquad (3.17)$$

$$\sum_j a_{ij} X_j \leq b_i, \text{ all } i \qquad (3.18)$$

$$\text{and } X_j \geq 0 \qquad (3.19)$$

Where $\bar{C}_j$ denotes the expected gross margin of the j^{th} activity, and λ is a scalar. Since equation 3.2 is quadratic in the X_j, the model must be solved by a quadratic programming algorithm.

The sum $\sum \bar{C}_j X_j$ is expected gross margin E, and which is set equal to a parameter λ. By varying λ over its feasible range through parametric procedures, a sequence of solutions is obtained which forms the risk efficient frontier of increasing total gross margins and variance until the maximum possible total gross margin under the resource constraints is attained. This maximum value corresponds to the standard linear programming problem of maximizing expected total gross margin subject to constraints 3.16 to 3.19 above. Solutions are obtained for critical turning points in the solution basis such that for the current total gross margin E, determined by λ, the variance V is minimum. The current farm gross margin and enterprise mix for the model farms were then compared with those of the risk efficient farm plans. The hypothesis that farmers do not make optimal choices when allocating resources in the study area was then accepted if a model farm was found not to fall on the risk efficient frontier.

For the risk model, the objective function was the minimization of gross margin risk (variance) subject to the resource constraints and subsistence requirements. The activities, technical coefficients and resource requirements are as specified in the LP model above. However in the risk model, the variance covariance matrix is a predominant feature.

3.6.2Variance-Covariance matrix

The variance of total gross margin is an aggregate of the variability of individual enterprise returns, and of the covariance relations between them. Combinations of activities with large negative income covariates are judged to be stable. Covariances are fundamental for efficient diversification among farm enterprises as a means of hedging against risk (Markowitz, 1952; Heady, 1952 as quoted in Hazell and Norton, 1986). The variance covariance matrix of farm income was estimated using the cross sectional sample data (adapted from Hazell and Norton, 1986).

3.7 Description of Model Farms

From the farm households sampled in each division, farmer characteristics, average values of land sizes, major enterprises, input use and output per enterprise were used to determine the components of a representative farm in each division. These average values were then used to work out the gross margins for the optimization of the model farms (as used by Ceyhan and Cinemre, (2003). A total of five model/representative farms were generated from the sample and are as described below:

The Lugari model farm consisted of a mixed farm with a family size of eight (8). The use of improved technology was observed to be prevalent, with 82 percent and 92 percent of the sampled farmers using certified maize seeds and fertilizer respectively. However, 36 percent used pesticides, while a paltry 4 percent had access to credit in the study period. Only 25 percent of the sampled farmers recalled having been visited by extension agents and another 25 percent had attended an agricultural field day within the past 5 years. This indicates inadequate access to agricultural information. About 46 percent farmers in the division mentioned high input cost as the most pressing constraint. Lack of operating capital highlighted as the second most pressing constraint according to 39 percent of the farmers sampled.

Khwisero model farm consisted of a mixed farm with an average family size of nine (9). 71 percent and 50 percent of the sampled farmers used fertilizer and certified maize seeds respectively in the study period, while 10 percent used pesticides. Only 4 percent of the farmers accessed credit in the 2002/03-crop season. Lack of operating capital was mentioned as the most pressing constraint by 54 percent of the sampled farmers. 50 percent of the farmers reported high input cost as the second most limiting constraint. About 35 percent of the farmers mentioned having been visited by extension agents in the past 5 years, while 31 percent of the sampled farmers said they had attended an agricultural field day in the in the same period.

In Lurambi, the model farm consisted of a mixed farm with a household of ten (10) people. Use of improved technology was observed to be high, with 92 percent and 81 percent of the farmers using fertilizers and certified maize seeds, respectively, during the study period. Majority of the sampled farmers (77 percent) had access to credit in the same period. This was mainly in kind, in form of farm inputs from Mumias Sugar Company. However, only 25 percent of the sampled farmers used pesticides in the study period. 58 percent mentioned having been visited by extension agents in the past 5 years and 48 percent of the farmers said they had attended an agricultural field day in the same period, suggesting a considerably high access to agricultural information compared to the other model farms. The most pressing constraint was identified to be high input cost according to 44 percent of the sampled farmers. About 42 percent of the farmers mentioned lack of operating capital as the second most limiting constraint.

Kabras model farm consisted of a mixed farm with an average family of seven (7). Use of improved technology was observed to be high with 84 percent and 84 percent of the farmers sampled having used fertilizers and certified maize seeds respectively. Use of pesticides was however low with only 25 percent of the farmers using pesticides in the study period. Access to credit was observed to be low, with only 6 percent of the sampled farms accessing credit in the study period. 24 percent of the farmers said extension agents had visited their farms within the past 5 years, while 28 percent said they had attended an agricultural field day over the same period. The most pressing constraint was mentioned by 48 percent of the farmers to be high input cost, while the second most limiting constraint was lack of operating capital according to 44 percent of the sampled farmers.

Land allocation to each enterprise per model farm is as presented in Table 3.2.

Table 3.3: Acreage Allocation on Representative/Model Farms (acres)

Division	Average Size of Residential Farm	Maize/Bean Acreage	Sugarcane Acreage	Dairy Acreage	Maize Acreage	Sweet potato Acreage	Kale Acreage	Banana Acreage	Tea	Cassava	Millet Acreage
Lugari	4.8	2.0	0.0	0.7	0.7	0.1	0.1	0.0	0.0	0.0	0.1
Khwisero	2.4	1.4	0.1	0.4	0.0	0.1	0.1	0.1	0.2	0.0	0.0
Lurambi	5.7	1.4	2.3	0.6	0.1	0.2	0.1	0.1	0.0	0.1	0.0
Kabras	5.1	0.1	1.7	0.7	0.4	0.0	0.2	0.1	0.0	0.0	0.0
Sample Average	4.5	1.5	1.0	0.6	0.3	0.1	0.1	0.1	0.0	0.0	0.0

Source: Survey results, 2004

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Maize Price Risk

Risk makes management of the farm more difficult since the outcome of a management decision under risk cannot be sure. *Ex ante*, outcomes may be good or bad. *Ex post*, with hindsight, there are likely to be regrets about what might have been if the farm manager did not make the right choice. All that the farmer can do, given the imperfect information available is to make that choice among the available risky alternatives which most appeals to him/her given his/her preference for outcomes and degrees of belief in their occurrence. For the farm manager, it implies the difficult task of specifying subjective probability distributions of possible outcomes relative to each alternative choice and then choosing between these distributions.

4.1.1 Maize Price Volatility

The F-ratio results indicate that maize price in the post liberalization era has been volatile. Comparison of the variances of the price ranges showed that the variance of the yearly price ranges for the period after liberalization is significantly higher than that of the period before liberalization at 95 percent level of confidence.

This was corroborated by primary data results, with the survey results showing that a large proportion of those interviewed indicated that maize prices have either been highly erratic or erratic suggesting that they view prices as being uncertain (Table 4.1)

Table 4.1: Farmer rating (%) changes of maize price

Division	Number of respondents (n)	Highly erratic	Erratic	Stable	Rising	Falling
Lugari	52	36.5	36.5	0.0	13.5	13.5
Khwisero	48	22.9	60.4	0.0	14.6	2.1
Lurambi	52	25.0	37.5	0.0	37.5	0.0
Kabras	53	31.4	43.1	2.0	19.6	3.9
Average	207	29.0	43.9	0.5	21.5	4.9

Source: Survey results, 2004

According to results, 73 percent of the farmers in Lugari division said maize prices have been either erratic or highly erratic from 1994-2003. In Kwhisero division, 83.3 percent of the sampled farmers said prices have been variable. Lurambi recorded relatively low percentage mentions of 62.5 percent. In Kabras, 74.5 percent of those interviewed said maize prices have been variable over the same period.

As indicated earlier, farmers employ various approaches to risk management. These include: (i) spreading sales over time; (ii) having forward contracts; and (iii) use of alternative marketing outlets. Farmers were asked how they deal with the observed maize price variability.

Majority of farmers in Lurambi (54.5 percent) and Khwisero (85.7 percent) divisions store their maize until prices rise to a satisfactory level, while majority in the major maize producing divisions in the study area, that is Lugari (59.3 percent) and Kabras (50 percent), sell at the prevailing market price during the harvesting period (Table 4.2). It should be noted that prices are at their lowest during the harvesting period which could partly explain the decreasing maize acreage trend in the districts.

Table 4.2: How Farmers deal with Maize Price Fluctuations

Division	Number of respondents (n)	% With Contracts e.g. with schools	% Who store until price rises	% Who sell at prevailing market price
Lugari	52	3.7	37.0	59.3
Khwisero	48	0.0	85.7	14.3
Lurambi	52	9.1	54.5	34.6
Kabras	53	0.0	50.0	50.0
Sample average	207	3.9	49.0	47.1

Source: Survey results, 2004

The observed variable maize price therefore presents the farm manager with additional problems when allocating the productive resources to various competing enterprises in the farm, especially if the competing enterprises have less variable or stable prices.

4.1.2 Relationship Between Price Range and Acreage Allocation

Results from correlation analysis show a significant negative relationship between maize acreage and maize price range, implying that maize acreage reduces with maize price volatility in the study area. This therefore means that farmers in the study area are shifting productive resources to enterprises that are more profitable. This conforms to risk management strategies of small-scale farmers include: use of stable enterprises, diversification (in crops, livestock, etc), use of risk reducing inputs, among others. Results are as shown in the Table 4.3.

Table 4.3: Correlation Analysis Between Maize Acreage and Price (1980-2003)

	Price	Acreage
Price	1	-0.495*
Acreage	-0.495*	1

* Significant at $\alpha = 0.05$

Source: Survey results, 2004

Where:

Acreage is log of maize acreage in Kakamega district

Price is log of maize price range in Kakamega district

4.2 Agricultural Production Pattern

Beans have had the highest real price per unit of all the crops in the post liberalization era but the prices have also been the most variable, followed by maize. Banana and sweet potato real prices have been relatively stable. This could be because they are not produced for the market, but are be produced basically for home consumption, and therefore their supply and demand does not significantly influence the market price. Sugarcane price has been stable over the years (Figure 4.1).

As indicated in Figure 4.1, sugarcane prices have also been higher than that of maize in real terms from 1993. All commodity prices however show a declining trend in real terms for most of the years apart from 2003. It must be noted here that sugarcane price is normally set by the Kenya Sugar Board and is known to the farmers at planting. This ensures that prices are known early to assist farmers in investment decision-making.

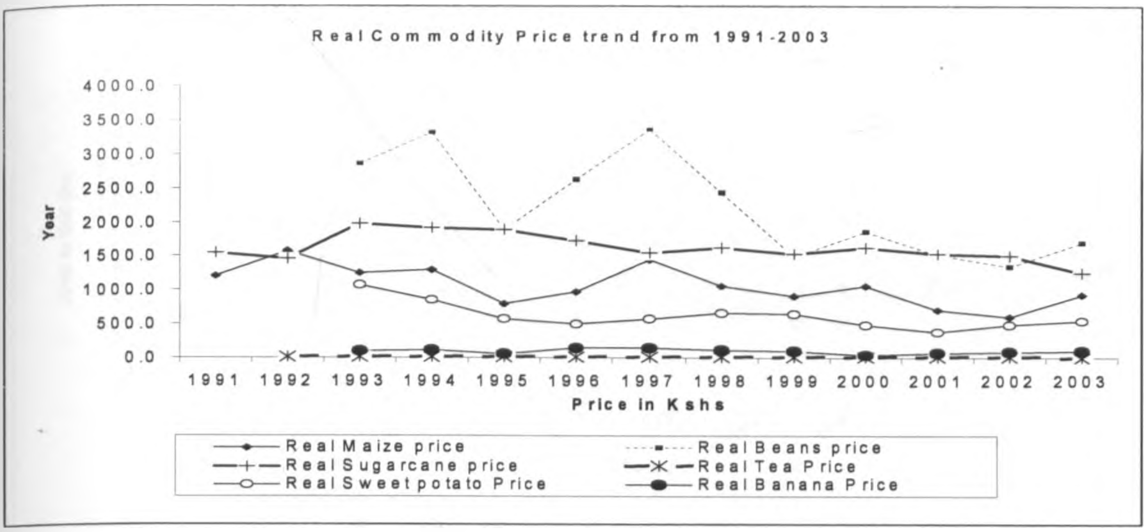

Figure 4.1: Real Commodity price Trend (1991-2003)

Source: Ministry of Agriculture, 2003

Survey results indicate that farmers in the study area have responded to the volatile maize price in a variety of ways. First, there has been a marked decrease in acreage that farmers allocate to the maize enterprise. Secondly a considerable increase in acreage allocated to other competing enterprises has also been observed. At the district level, the general crop acreage trend shows a significant decline for maize from the period just after liberalization with the biggest decline occurring between 1995 and 1997, while other crops, most notably sugarcane, has recorded a steady and sustained increase in acreage as shown in Figure 4.2.

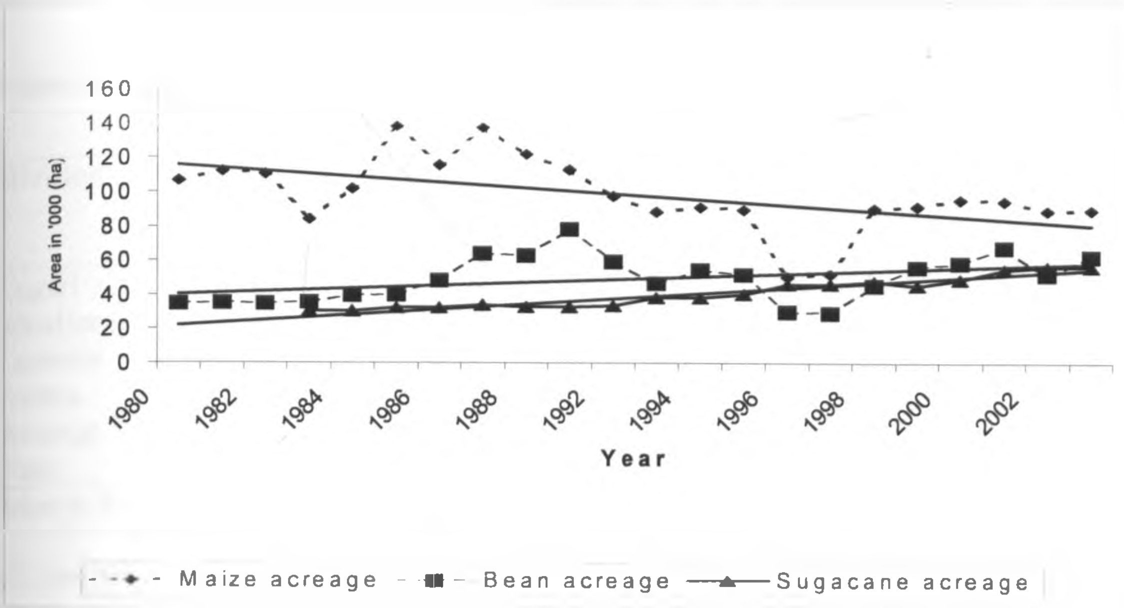

Figure 4.2: Maize, Bean and Sugarcane acreage trend, 1980-2003

Source: Ministry of Agriculture Reports, Various Issues.

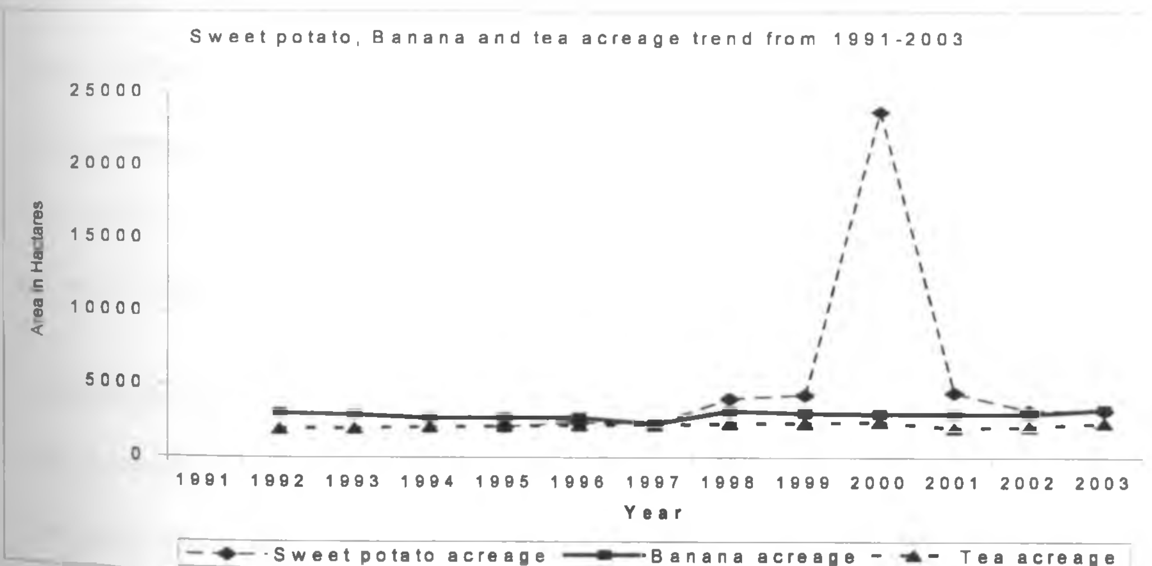

Figure 4.3: Sweet potato, Banana and Tea acreage trend, 1990-2003

Source: Ministry of Agriculture Reports, Various issues.

Most farmers currently produce maize for home consumption as presented in Table 4.4.

Table 4.4: Purpose of Maize Production (%)

Division	Number of respondents (n)	Consumption	Consumption and Sale of surplus	Sale and Consumption	Sale
Lugari	52	26.9	23.1	44.2	5.8
Khwisero	48	68.8	10.4	20.8	0.0
Lurambi	52	75.0	2.1	22.9	0.0
Kabras	53	78.0	8.0	12.0	2.0
Average Farm	207	61.6	11.1	21.2	2.0

Source: Survey results, 2004

Of the four divisions, Lugari has the lowest percentage of those who produce solely for consumption, with a good proportion of the sampled (73 percent) also producing for sale. While the remaining three divisions produce sugarcane as a cash crop, (and Khwisero also produces tea), Lugari division relies on maize as the major crop both for consumption and as a cash crop. This shift to subsistence farming for maize therefore partly explains the decrease in marketed output. Difference of means between the pre and post liberalization eras was tested to ascertain if maize acreage has significantly reduced in the post liberalization era. Results indicate that the two means are significantly different at 0.001[5] level of significance, indicating that maize acreage allocation has indeed decreased.

To ascertain this argument, farmers were asked their maize acreage trend over the last ten years. Survey results indicate that in all divisions apart from Khwisero, majority of farmers have had a decreasing maize acreage trend as shown in Table 4.5.

[5] The two sample T- test was used to test for difference in means.

Table 4.5: Maize Acreage Trend Between 1994-2004

Division	Number of respondents (n)	Decreasing	Constant	Increasing
Lugari	52	50.0	36.5	13.5
Khwisero	48	41.7	43.8	14.6
Lurambi	52	52.1	22.9	25.0
Kabras	53	52.9	39.2	7.8
Average Farm	207	49.2	35.7	15.1

Source: survey results, 2004

Khwisero division, which produces very small amounts of maize, indicated the lowest (42 percent) acreage decrease among the divisions surveyed, but this could be because majority of its farmers (78 percent) produce for consumption as indicated in Table 4.4. The decrease in maize acreage has given way to a gradual and steady increase in sugarcane acreage over the years (Figure 4.2).

Sugarcane prices have generally been stable over the years. Many farmers are therefore substituting maize with sugarcane since the enterprise offers a stable income. Whereas this indirectly contributes to food security, it negatively affects the country's goal of food self-sufficiency, since self-sufficiency in maize production has been an explicit policy goal of the Kenyan government as a way of achieving national food security (Kenya, 1984-88 and 1989-93; Kenya, 1986). Majority of farmers in the study area indicated that the maize harvested does not last them until the next harvest, with only 17.1 percent of the sample saying it takes them up to the next harvest, implying increasing food deficits in an area previously classified as a maize surplus area.

The declining maize acreage trend and output in areas that were previously major maize producing zones (maize surplus zones) impacts negatively on food security, especially due to the high population growth rate, and therefore increased demand of the country's main staple. Other crops, especially tea, banana and sweet potato show a stable area allocation over the years. The decrease in acreage allocated to the maize enterprise was observed to have resulted in a corresponding decrease in maize output (Figure 4.4).

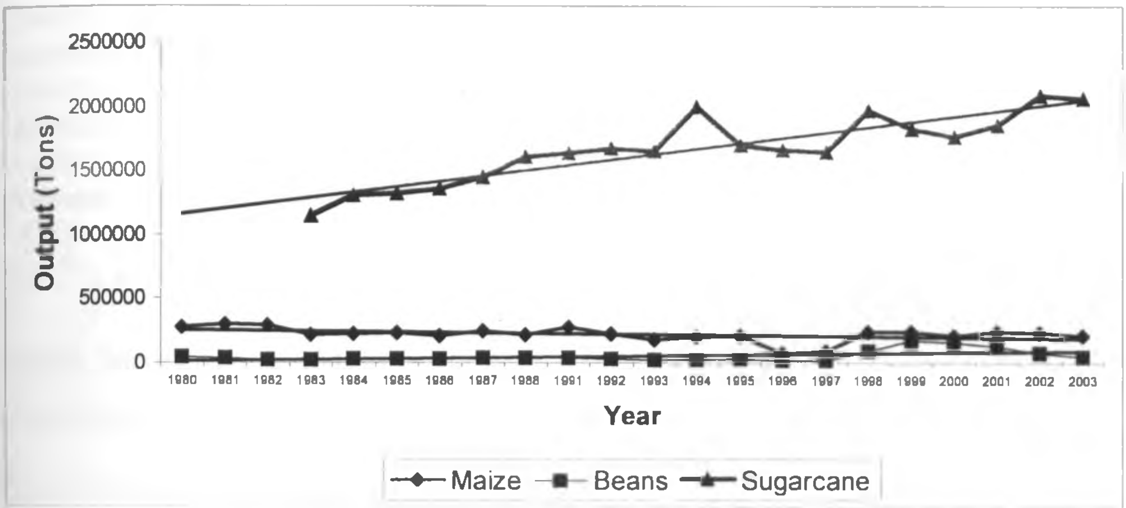

Figure 4.4: Crop Output Trend Over Time

(Source: Ministry of Agriculture Reports, various issues)

As observed in Figure 4.4, sugarcane has had a high and increasing output trend, while maize output has recorded a fluctuating and a downward trend over the years[6]. This has consequently resulted in a change in revenue derived from the maize enterprise in the study.

To assess the market channels through which farmers sell their maize in the study area, farmers were asked where they currently sell their maize. They were then asked whether they have

[6] Difference in means between the post and pre-liberalization periods show that this downward trend in maize output is significant at 95% level of confidence. (The two-sample T test was used to test for difference in means).

changed their maize marketing channel in the post liberalization period. and consequently asked to describe the changes. The results are as shown in Table 4.6.

Table 4.6: Where Farmers sell Maize (2004) in Kakamega

Division	Local mkt.	Middlemen	Neighbors	Middlemen & neighbors	Contracts e.g. schools	Local mkt. & neighbors	NCPB
Lugari (n=34)	35.3	32.4	5.9.0	14.7	5.9	0.0	5.9
Khwisero (n=21)	70.0	10.0	20.0	0.0	0.0	0.0	0.0
Lurambi (n=22)	61.1	0.0	16.7	5.6	5.6	11.2	0.0
Kabras (n=14)	23.1	30.8	38.5	0.0	0.0	7.7	0.0
Average Farm (n=91)	47.1	20.0	17.7	7.1	3.5	2.4	2.4

Source: Survey results (2004)
N is the number of respondents.

The response by farmers revealed the existence of seven marketing channels. In Lugari, market sales lead as the channel mostly used by farmers (35 percent), followed by middlemen (32 percent). In Khwisero, local market dominate as the channel used with 70 percent of the farmers selling through this channel, followed by sales to neighbors (20 percent). In Lurambi, local market leads (61 percent), followed by sales to neighbors (16 percent). In Kabras, sales to neighbors leads as the channel mostly used (39 percent) followed by sales to middlemen (31 percent).

Table 4.7: Changes in the Marketing Channel

Division	Number of respondents (n)	Contract with schools	NCPB	Middlemen	Consumers and middlemen
Lugari	34	3.3	93.3	0.0	3.7
Khwisero	21	0.0	80.0	10.0	10.0
Lurambi	22	0.0	91.7	0.0	8.3
Kabras	14	0.0	90.9	9.1	0.0
Average Farm	91	1.6	90.5	1.6	6.3

Source: Survey results (2004)

NCPB was the dominant maize marketing channel before liberalization, with 91 percent of the farmers saying that they used to sell to the Board. However, during the study period, only 2 percent of the farmers used the channel to sell their maize. Farmers further pointed out delayed payments by the Board and quality requirements as the factors that have influenced their decision to use alternative marketing channels, with the majority turning to the local market.

Given the dominance of local market sales (Table 4.6), the belief that informal maize market channels could be the cause of the observed decrease in marketed maize output is therefore rejected. However, many farmers in the study area have resorted to subsistence maize farming (Table 4.4) while shifting productive resources to other commercial enterprises, most notably sugarcane.

4.3 Crop Production Costs and Farm Incomes

Crop production was observed to be labor-intensive with limited use of capital, except for the sugarcane enterprise in Lurambi division (Mumias Sugar zone), where the sugar company supplies most inputs on credit. Intermediate input use was also observed to be low, and mechanization is limited to land preparation. Even in land preparation, an average farmer was observed to use a combination of draft animal, family labor and casual labor in all the model farms.

The survey results also indicate that in all model farms with sugarcane, the enterprise leads in terms of operating capital use, taking up to 45 percent of the total operating capital in Khwisero, 60 percent in Lurambi, 51 percent in Kabras and 44 percent in the sample average farm. The dairy enterprise also ranks highly in terms of operating capital use, taking up to 54 percent, 28 percent, 20 percent, 34 percent and 29 percent of operating capital in Lugari, Khwisero, Lurambi, Kabras and the whole sample average farm respectively. The maize and maize/bean enterprises rank after the sugarcane and dairy enterprises in all model farms except in Lugari. The maize/bean enterprise ranks first, taking up to 54 percent of operating capital. It should be noted that in Lugari, an average farm does not have the sugarcane enterprise. The enterprise production costs are as presented in the Table 4.8.

Table 4.8: Total Production Costs (Kshs/acre)

Enterprise	Lugari	Khwisero	Lurambi	Kabras	Average Farm
Dairy	7802	12727	10302	10074	15653
Sugarcane	0	15764	17180	4191	14186
Maize	4694	0	3524	5742	1420
Kale	7402	314	3913	936	568
Maize/Bean	5636	3295	4478	3553	483
Sweet potato	289	0	115	350	164
Tea	0	2761	0	0	0
Millet	2786	0	0	0	0
Cassava	0	0	1686	0	0
Banana	0	0	716		2
Total Cost	28611	34862	41917	24847	32498

Source: Survey results, 2004

Farm incomes as given by the Gross Margin analysis are as presented in Table 4.9.

Table 4.9: Total Gross Margins per Enterprise (Kshs)

Enterprise	Lugari	Khwisero	Lurambi	Kabras	Average Farm
Dairy	8866	10081	6979	9443	13229
Maize	7168	0	371	1182	1868
Maize/Bean	7805	7920	1139	123	4690
Sugarcane	0	1192	24427	13953	5038
Sweet potato	1254	197	700	596	598
Tea	0	264	0	0	0
Kale	76	568	1605	2246	1295
Cassava	0	0	248	0	0
Banana	0	1594	2244	538	1522
Millet	183	0	0	0	0
Total Gross margins	25352	21816	37713	28081	28239

Source: Survey results, 2004

The dairy enterprise led as the major farm income earner in Lugari district, contributing 35 percent of the total income, followed by the maize-bean enterprise with 30.8 percent. Maize enterprise ranks third with 28.3 percent. In Khwisero, the dairy enterprise wasranked first, contributing 46.2 percent of the total farm income, followed by sugarcane, which contributed 36.3 percent. The sugarcane enterprise led in Lurambi, contributing 77 percent of farm income, followed by the dairy enterprise with 22 percent. In Kabras, the sugarcane enterprise led contributing 50.7 percent followed by the dairy enterprise, which contributed 33.9 percent. In the whole sample average farm, sugarcane ranks first with 44.4 percent contribution to the total farm income and is followed by the dairy enterprise with 29.4 percent. The maize bean enterprise ranks third with a 20.7 percent contribution. All enterprises not mentioned had a contribution of less than 10 percent to the total farm incomes. These enterprises include sweet potatoes, banana, tea, kale, cassava, and millet.

These enterprises may not be market oriented but serve subsistence needs. Tea may not be an important cash crop in the region. It was also observed that model farms without the sugarcane enterprise (Lugari) or with a very small sugarcane acreage allocation (Khwisero) had the second lowest and lowest farm incomes, respectively, in the study area. This underscores the importance of the sugarcane enterprise in the region. Lurambi division leads with the highest farm income, followed by the sample average farm, while Kabras, Lugari and Khwisero have farm incomes below that of the sample average farm (Figure 4.6).

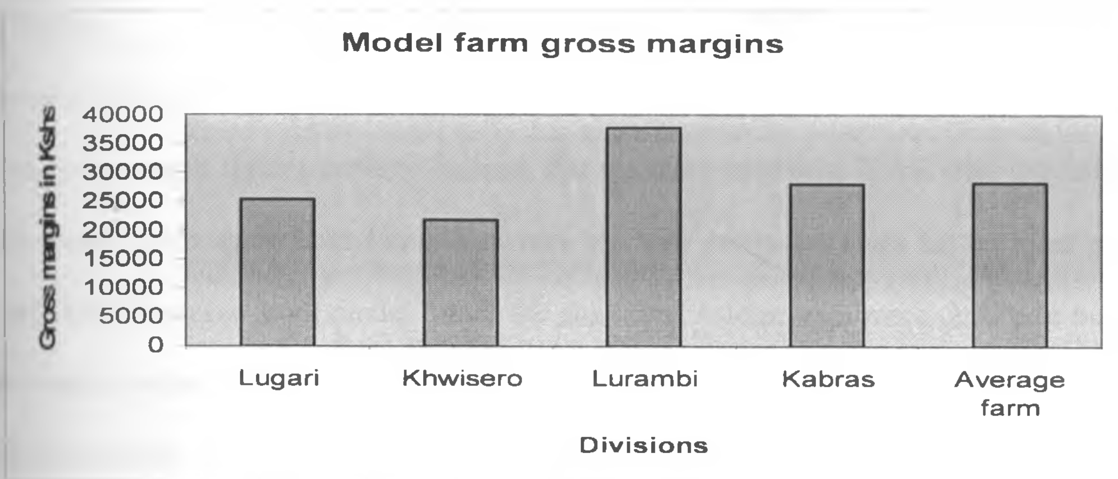

Figure 4.5: Level of farm income per division

(Source: Survey data, 2004)

To assess profitability of the various enterprises, a gross margin analysis per unit (acre) was carried out. The farm gross margins per acre are as presented in Table 4.10.

Table 4.10: Total Gross Margins per Acre (Kshs)

Enterprise	Lugari	Khwisero	Lurambi	Kabras	Average Farm
Dairy	12501	24194	11476	14253	22048
Banana	0	23682	19950	5489	1384
Maize	9809	0	2964	3172	1845
Sweet potato	9082	3376	3245	5960	4281
Maize/Bean	3874	5495	823	1269	343
Millet	1908	0	0	0	0
Kale	1453	5636	15161	13702	2995
Sugarcane	0	11922	10620	4828	5038
Tea	0	1408	0	0	0
Cassava	0	0	4926	0	0
Total Gross Margins	38626	75714	69165	48673	37933

Source; Survey results, 2004

The gross margin figures per acre indicate that the dairy enterprise is the most profitable in all the model farms apart from Lurambi, where the kale enterprise leads as the most profitable enterprise. However in all model farms, the sugarcane enterprise is more profitable than either the maize or the maize/bean enterprises in all model farms that have the enterprise. Given the fact that maize and sugarcane are substitutable in the crop mix in the study area, farmers are therefore more inclined to increase production of sugarcane over maize. To ascertain this argument, the relationship between maize price volatility and acreage allocated to the sugarcane enterprise were correlated. Results are as presented in Table 4.11.

Table 4.11: Correlation between Maize Price Range and Acreage Allocation to Sugarcane Enterprise

	Price	Acreage
Price	1	0.674**
Acreage	0.674**	1
** Significant at α=0.01		

Source: Survey results, 2004

Where: Acreage is acreage of sugarcane in Kakamega district, and

Price is maize price range in kaka mega district

The results in Table 4.11 show a positive and significant relationship implying that maize price volatility and acreage allocated to sugarcane move in the same direction, that is, acreage allocated to sugarcane increases as the maize price volatility increases.

4.4 Optimizing the Production Plans

The gross margins per acre for all the model farms (Table 4.10), were optimized using linear programming (LP) as specified in equation 3.1. The results indicate that the current farm plans are not optimal. Comparison of the current farm gross margins and the optimal gross margins indicate that the difference between the two gross margins is [7]highly significant at 99 percent confidence level for all the model farms. The optimal farm gross margins for the farm plans are indicated Table 4.12.

[7] One sample T-test was used to test for the difference between the two gross margins.

Table 4.12: Optimal farm plans

Enterprise Area (Acres)	Lugari		Khwisero		Lurambi		Kabras		Average Farm	
	O	C	O	C	O	C	O	C	O	C
Dairy	2.2	0.7	1.3	0.4	0.0	0.6	2.06	0.7	2.03	0.6
Maize/bean	1.8	2.0	1.3	1.4	1.2	1.4	0.4	0.1	1.3	1.5
Maize	0.0	0.7	0.0	0.0	0.0	0.1	0.0	0.4	0.0	0.3
Sweet potatoes	0.1	0.1	0.0	0.1	0.0	0.2	0.0	0.0	0.8	0.1
Cassava	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Kales	0 .0	0.1	0.0	0.1	0.0	0.1	1.7	0.2	0.0	0.1
Sugarcane	0.0	0.0	0.0	0.1	0.5	2.3	0.4	1.7	0.0	1.0
Bananas	0.0	0.0	0.0	0.1	3.4	0.1	0.0	0.1	0.0	0.0
Millet	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tea	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
TOGM	35,726		38,595		78,793		59,299		48,458	
TCGM	25,351		21,816		37,712		28,081		28,238	

Survey results, 2004

Where:

O is [8]optimal farm enterprise mix and acreages and,

C is current farm enterprise mix and acreages.

As indicated in Table 4.12, the LP results show that the most profitable enterprise combinations are the dairy, maize bean and sweet potatoes for Lugari model farm; dairy and maize bean for Khwisero model farm; Maize bean, sugarcane and bananas for Lurambi model farm; Dairy, maize bean, kales and sugarcane for Kabras model farm and dairy, maize bean and sweet potato for the sample average model farm. On the other hand, the analysis results show that the most limiting resources for these model farms are land and operating capital for the sample average

[8] A linear programming model output for the Sample average farm model is presented in detail in appendix 4

and Kabras model farms, while land is the only limiting resource for Khwisero, Lugari and Lurambi model farms. This suggests that farmers could operate optimally if these constraints are relaxed. This result is consistent with the primary survey results that identified operating capital as a constraint in production, with 41 percent of all the sampled farmers mentioning it as the most limiting resource.

The optimum plans that were obtained using LP do not take into consideration the stochastic nature of the farm enterprises. To estimate farm plans that reflect farmers' situation, risk must be incorporated. This formed the basis for the use of quadratic programming.

4.5 Development of Risk Efficient Farm Plans

Risk efficient farm plans were developed for all the model farm plans using mean variance analysis (E-V) as specified in equations 3.11 to 3.18. The optimal gross margins for the model farms were used as the expected income in the model specification. Subsequent expected incomes were derived by continuously lowering the optimal values until the farm plans developed became non feasible. The data confirmed that farmers are risk averse. The typical result is that a significant reduction in risk (variance) in net farm income is observed at the cost of relatively little expected income. The efficiency frontier curves were observed to have a positive decreasing slope. As expected income increased, the slopes of these curves were observed to increase at a decreasing rate, indicating the weakening trade off possibilities of expected income with the variability of income. The risk efficient frontiers and farm plans are as shown below in Figures 4.7 to 4.11 and Tables 4.13 to 4.17 respectively.

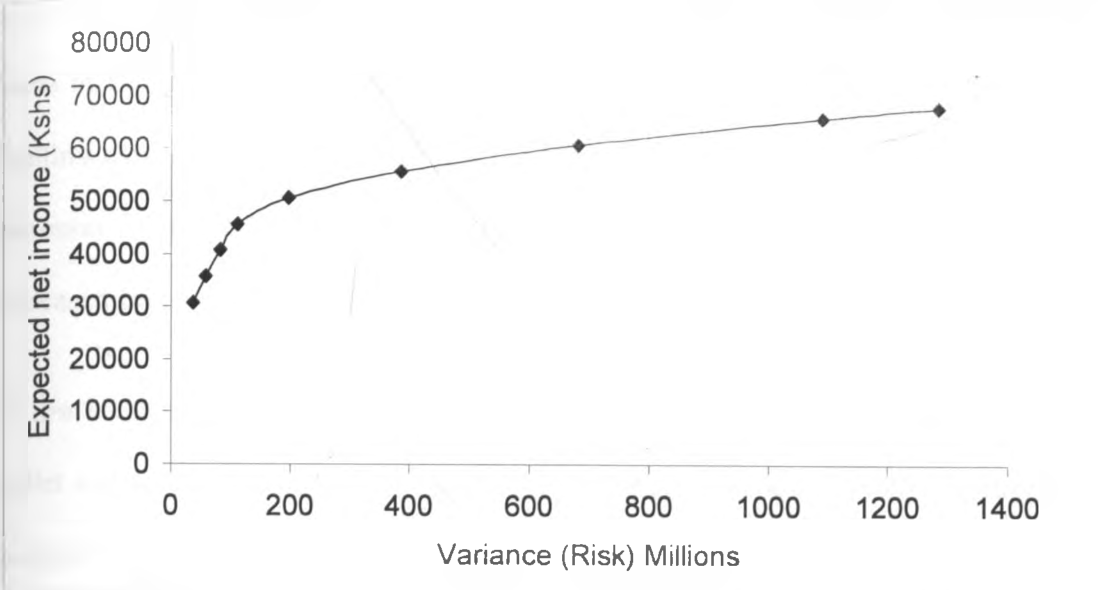

Figure 4.6: Risk efficient frontier for Lugari model farm

(Source: Survey results, 2004)

Table 4.13: Risk efficient farm plans for Lugari model farm

			Activity level (Acre					
R (10^{-4})	E (Ksh)	V (Ksh)	Dairy	Maize/ bean	Maize	Kale	Sweet potato	Millet
-	30726	38413939.4	0.0	2.2	0.0	0.0	0.2	1.7
2.49	35726	58514041.1	0.0	2.6	0.0	0.0	0.3	1.2
2.05	40726	82961437.71	0.0	3.0	0.0	0.0	0.4	0.7
1.74	45726	111756129.4	0.0	3.4	0.0	0.0	0.5	0.2
0.59	50726	196690549.0	0.3	3.6	0.0	0.0	0.2	0.0
0.26	55726	385562922.7	0.8	3.3	0.0	0.0	0.0	0.0
0.17	60726	681561860.8	1.4	2.7	0.0	0.0	0.0	0.0
0.12	65726	1089455171.0	2.0	2.1	0.0	0.0	0.0	0.0
0.10	67726	1283942920.0	2.2	1.9	0.0	0.0	0.0	0.0
-	*25351.50	-	0.7	2.0	0.7	0.1	0.1	0.1

Source: Survey results, 2004

Where;

r is the risk aversion level,

E and V are expected total net farm return and variance (risk) respectively.

* is the current farm enterprise mix, returns and variance of returns

The process of resource optimization with risk minimization resulted in nine (9) efficient farm plans in Lugari. Farmland was fully utilized in all the efficient plans, indicating that land is a limiting constraint in this model farm. As is shown in Table 4.13, risk efficient gross margins increases from Kshs. 30,726 to Kshs. 67,726 for the Lugari model farm as risk aversion levels increased from $1.0 * 10^{-5}$ to $2.49 * 10^{-4}$.

At low incomes and low risk, maize bean enterprise appears in the risk efficient plans, along side millet and sweet potatoes. The maize bean enterprise however is mostly for subsistence, given the fact that an average farmer in the division must have a minimum of 1.8 acres of the enterprise per season for subsistence needs. As farm income becomes more variable (risk increases), the millet enterprise gradually gets substituted by the maize bean and sweet potato enterprises, and is eventually eliminated from the efficient plans completely.

At high-risk high-expected income levels and low risk aversion, the dairy enterprise emerges in the efficient plans, and substitutes sweet potatoes. Farmers therefore could shift productive resources to the dairy enterprise, which is more profitable, as indicated in Table 4.10. The optimal risk efficient plan contains the dairy and maize bean enterprises, with dairy accounting for the bulk of resource allocation. The current gross margin falls below the range of expected income that gives feasible risk efficient farm plans. It was therefore concluded that the current farm plan in Lugari is not risk efficient, and thus do not operate optimally.

The E-V optimization results identify the dairy enterprise as the most profitable enterprise. However, this enterprise requires a high amount of allocation of operating capital as indicated in Table 4.8 given it's capital-intensive nature. The capital constraint that farmers face in this division may therefore explain why they are not operating in a risk efficient manner. During farm surveys, farmers in the division mentioned operating capital as the second most limiting constraint, after high input costs.

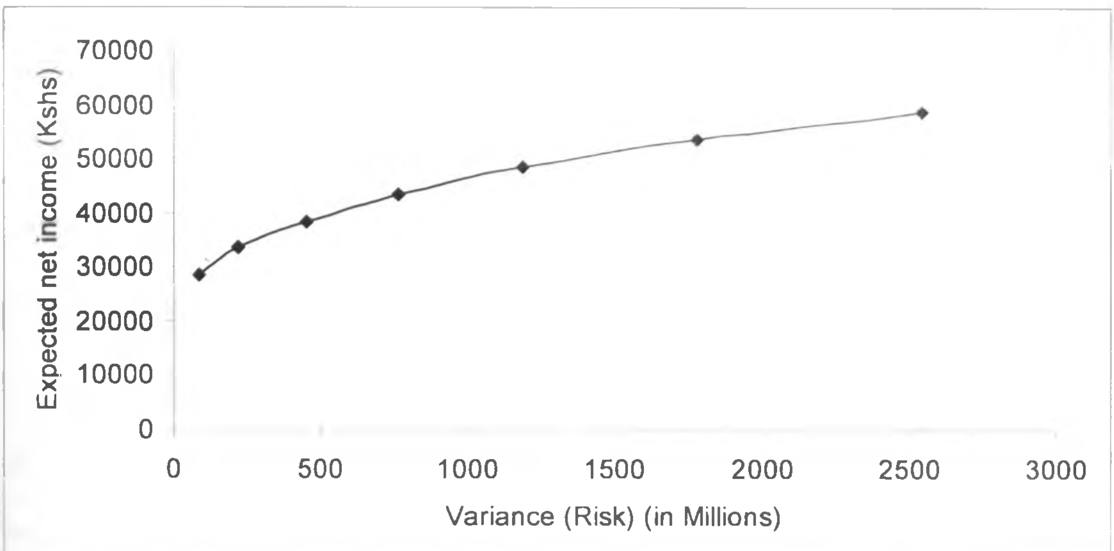

Figure 4.7: Risk efficient frontier for Khwisero model farm

(Source: Survey results, 2004)

Table 4.14: Risk efficient farm plans for Khwisero model farm

			Activity level (Acre)							
R (10^{-5})	E (Kshs)	V (Kshs)	Dairy	M/ bean	Kales	Banana	Sugarcane	S/potato	Tea
-	28596.6	84690531.0	0.3	1.3	1.0	0.0	0.0	0.0	0.0
3.713	33596.6	219363090.0	0.4	1.3	0.9	0.0	0.0	0.0	0.0
2.166	38596.6	450164380.0	0.5	1.5	0.5	0.1	0.0	0.0	0.0
1.590	43596.6	764594279.0	0.7	1.7	0.1	0.1	0.0	0.0	0.0
1.188	48596.6	1185604598.0	0.9	1.7	0.0	0.0	0.0	0.0	0.0
0.848	53596.6	1774922646.0	1.1	1.5	0.0	0.0	0.0	0.0	0.0
0.655	58596.6	2538539624.0	1.3	1.3	0.0	0.0	0.0	0.0	0.0
-	*21816.0	-	0.4	1.4	0.1	0.1	0.1	0.1	0.2

Source: Survey results, 2004

Where;

r is the risk aversion level

E and V are expected total net farm return and variance (risk) respectively, and

* is the current farm enterprise mix, returns and variance of current returns.

In Khwisero, optimization resulted in seven (7) risk efficient farm plans. Farmland also remained fully utilized in all farm plans, confirming linear modeling results, which indicated that land is a constraint in this model farm. Expected income ranged from Kshs. 28,596.60 to Kshs. 58,596.60, while the risk aversion level increased from $6.55 * 10^{-6}$ to $3.713 * 10^{-5}$.

This model farm was observed to comprise of farmers with the lowest concern for risk. At low expected farm income and high risk-aversion levels, the dairy, kales and maize bean enterprises feature in the efficient plans. However, it should be noted that the maize bean enterprise in the plan is purely for subsistence since an average farmer must have 1.3 acres of the crop per season for subsistence needs. As farm income becomes more variable, dairy enterprise consistently increase in prominence, substituting both kales and banana enterprises. The maize bean enterprise acreage allocation also increases with risk but is eventually substituted by the dairy enterprise, which is the most profitable. The optimal risk efficient plan again has the dairy and the maize bean enterprises as the profitable combination.

The current Kwhisero farm plan, as shown in Table 4.14, does not fall on the risk efficient frontier. Just as was observed in the Lugari model farm, the current gross margin falls below the range of expected income that gives feasible risk efficient farm plans. It was therefore concluded that farms in Khwisero are not risk efficient, and therefore do not operate optimally. As observed in the Lugari model farm, the dairy enterprise requires high allocation of operating capital, which may explain why these farm plans are not risk efficient. It should be noted that farmers in this division mentioned operating capital as the most pressing constraint to production.

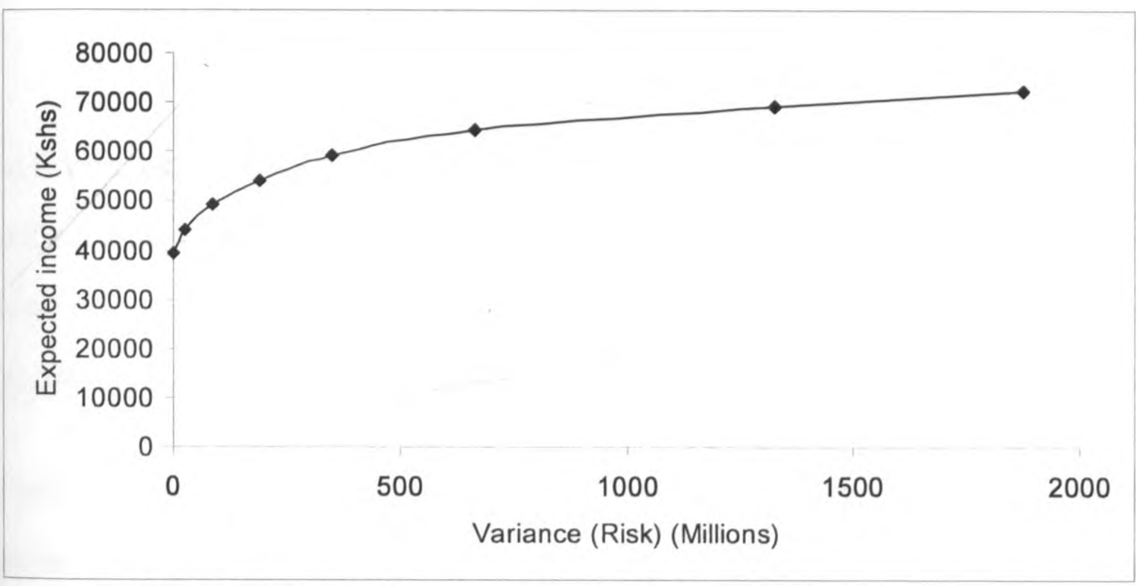

Figure 4.8: **Risk efficient frontier for Kabras model farm**

(Source: Survey results, 2004)

Table 4.15: Risk efficient farm plans for Kabras model farm

			Activity level (Acres)						
R (10^{-4})	E (Kshs	V (Kshs)	Dairy	M/bean	S/potato	Kales	Sugarcane	Maize	Banana
-	39299.4	699589.1	0.2	0.8	0.8	1.2	1.7	0.0	0.0
1.99	44299.4	25870171.4	0.4	0.5	0.5	1.3	1.8	0.0	0.0
0.81	49299.4	87276116.4	0.8	0.4	0.2	1.4	1.8	0.0	0.0
0.49	54299.4	189409612.0	1.1	0.4	0.0	1.3	1.8	0.0	0.0
0.31	59299.4	350907956.0	1.4	0.4	0.0	1.1	1.7	0.0	0.0
0.16	64299.4	663396247.0	1.8	0.4	0.4	0.9	1.1	0.0	0.0
0.08	69299.4	1324260395.0	2.0	0.4	1.3	0.3	0.5	0.0	0.0
0.05	72299.4	1874882064.0	2.2	0.4	1.9	0.0	0.1	0.0	0.0
-	*28081.3	-	0.7	0.1	0	0.2	1.7	0.4	0.1

Source: Survey results, 2004

Where;

r is the risk aversion level,

E and V are expected total net farm return and variance (risk) respectively.

* Is the current farm enterprise mix, returns and variance of current returns.

In Kabras, 8 risk efficient farm plans were realized. In this model farm, farmland was also fully utilized in all the plans. This also confirmed the linear programming results, which indicated that land is a constraint in this model farm. Expected income range from Kshs. 39,299.40 to Kshs. 72,299.40, while the risk aversion level increases from $5.0 * 10^{-6}$ to $1.99 * 10^{-4}$.

The Kabras model farm was observed to be the most commercially oriented farm among all the model farms. At low incomes and low risk, the sugarcane enterprise leads in terms of resource allocation, followed by kales, sweet potato, maize bean and dairy enterprise in that order. In this model farm, resource allocation to the maize bean enterprise is double the subsistence requirements, indicating that even the most risk conscious farmer produces for the market. As risk and expected income increases, the maize bean, kales and sweet potato enterprises gradually get substituted by the dairy enterprise. The sugarcane enterprise shows a stable resource allocation trend with increase in risk, indicating that sugarcane enterprise provides a stable income. However, as it approaches the highest expected income level, sweet potato re emerges in the efficient plans, and together with the dairy enterprise, substitutes the sugarcane enterprise.

At the highest expected income and risk (Optimal farm plan), the dairy enterprise leads in terms of resource allocation, followed by sweet potatoes, maize bean and sugarcane in that order. This enterprise mix is the most profitable combination and gives a stable income. The current gross margin falls below the range of expected income that gives feasible risk efficient farm plans.

It was concluded that farms in Kabras are not risk efficient, and do not operate optimally. In this division, farmers mentioned operating capital as the second most pressing constraint after high input cost. The intensive nature of dairy production may therefore explain why farmers are not efficient in their production plans.

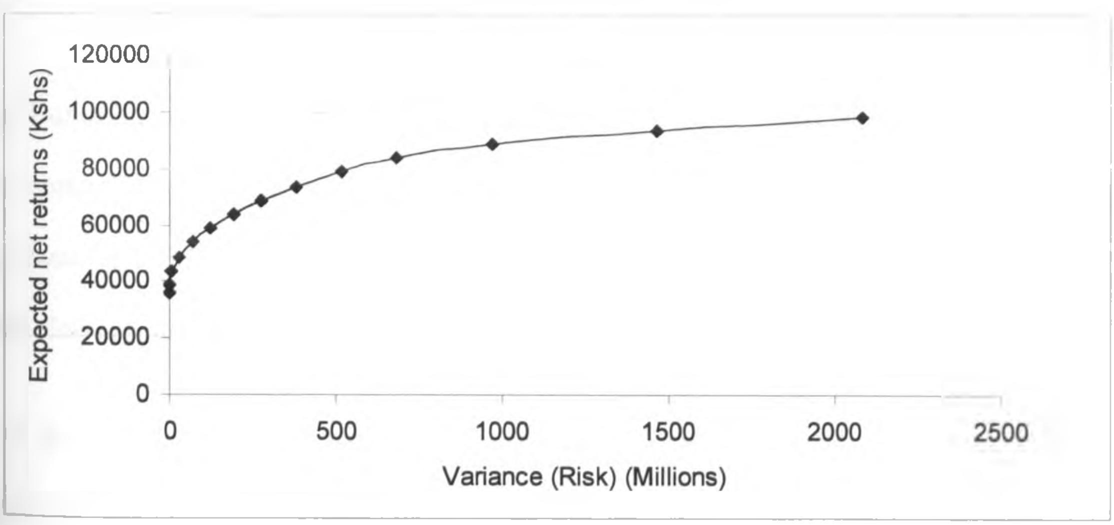

Figure 4.9: Risk efficient frontier for Lurambi model farm
(Source: Survey results, 2004)

Table 4.16: Risk efficient farm plans for Lurambi model farm

			Activity level (Acres)							
R (10^{-3})	E (Kshs	V (Kshs	Dairy	M/ bean	S/ potato	S/cane	Banana	Cassava	Kale	Maize
-	35793.0	1836155.7	0.2	3.0	1.0	0.0	0.0	0.5	0.0	0.0
9.355	38793.0	2156850.9	0.2	3.2	1.1	0.0	0.0	0.6	0.0	0.0
0.774	43793.0	8616669.0	0.2	3.5	0.0	0.1	0.0	1.3	0.0	0.0
0.212	48793.0	32175136.2	0.3	3.0	0.0	0.3	0.0	1.6	0.0	0.0
0.130	53793.0	70745710.1	0.3	2.5	0.0	0.5	0.0	1.8	0.0	0.0
0.093	58793.0	124328390.9	0.3	2.1	0.0	0.7	0.0	2.1	0.0	0.0
0.073	63793.0	192923178.4	0.3	1.6	0.0	1.0	0.0	2.3	0.0	0.0
0.060	68793.0	276759517.1	0.3	1.2	0.0	1.1	0.0	2.4	0.0	0.0
0.047	73793.0	383991382.1	0.4	1.2	0.0	1.3	0.0	2.3	0.0	0.0
0.037	78793.0	518681396.8	0.4	1.2	0.0	1.5	0.0	2.1	0.0	0.0
0.031	83793.0	680829561.1	0.4	1.2	0.0	1.6	0.0	1.9	0.0	0.0
0.017	88793.0	970629638.7	0.5	1.2	0.0	1.7	0.3	1.5	0.0	0.0
0.010	93793.0	1464225846.0	0.4	1.2	0.0	1.7	0.8	1.0	0.0	0.0
0.008	98793.0	2079432634.0	0.4	1.2	0.0	1.8	1.3	0.4	0.0	0.0
*9.492	37712.6	2038389.8	0.2	3.1	1.0	0.0	0.0	0.6	0.0	0.0

Source: Survey results, 2004

Where;

r is the risk aversion level,

E and V are expected total net farm return and variance (risk) respectively, and

* is the optimized current farm gross margin, risk efficient farm enterprise mix.

In Lurambi, 14 risk efficient farm plans were realized. Farmland utilization gradually increased as concern for risk decreased, increasing from 4.8 acres at the highest risk aversion level, to full utilization at the 6th plan. The expected income ranged from Kshs. 35,793 to Kshs. 98,793, while the risk aversion level ranged from $8.0 * 10^{-6}$ to $9.355 * 10^{-3}$.

At the highest level of risk aversion, the maize bean enterprise leads in terms of resource allocation, followed by sweet potatoes, cassava then dairy enterprises in that order. Farmers are relatively market-oriented since resource allocation to maize bean was much higher than for subsistence needs, which stands at 1.2 acres. As risk increases, Cassava and Sugarcane enterprises become more dominant in the risk efficient farm plans, substituting the sweet potato enterprise.

Resource allocation to the maize bean enterprise initially increases, but declines as risk increases and eventually appears for subsistence requirements only. Resource allocation to the dairy enterprise was observed to be relatively stable with increase in risk and income and the enterprise was observed not to play a significant role in this model farm. Towards the highest level of risk and income, banana enterprise appears in the efficient farm plans, substituting the cassava enterprise.

At the highest level of income and risk (Optimal farm plan), sugarcane leads in terms of resource allocation, followed by the banana enterprise, maize bean, dairy and cassava enterprises in that order. This indicates that sugarcane is the most profitable enterprise in this model farm, while the observed enterprise combination provide a stable income at that level of risk. In this model farm, the risk efficient frontier curve was observed to fall more steeply than for any other model farm, indicating that the average farmer in Lurambi need to make a greater sacrifice of expected income to reduce income variance. The gross margin of the current Lurambi model farm, although very low, falls within the range, which defines the relevant portion for planning and is therefore risk efficient. However, the farm enterprise mix was observed to have some enterprises that do not feature in the risk efficient farm plan, making it non optimal.

In this model farm, sugarcane leads as the most profitable enterprise. Sugarcane production was observed to consume the highest amount of operating capital in the model farm as indicated in Table 4.8. Farmers also mentioned operating capital as the second most pressing constraint after high input cost. This explains why farmers are not operating optimally, confirming Schultz's (1976) hypothesis that the farm families in developing countries are efficient but poor.

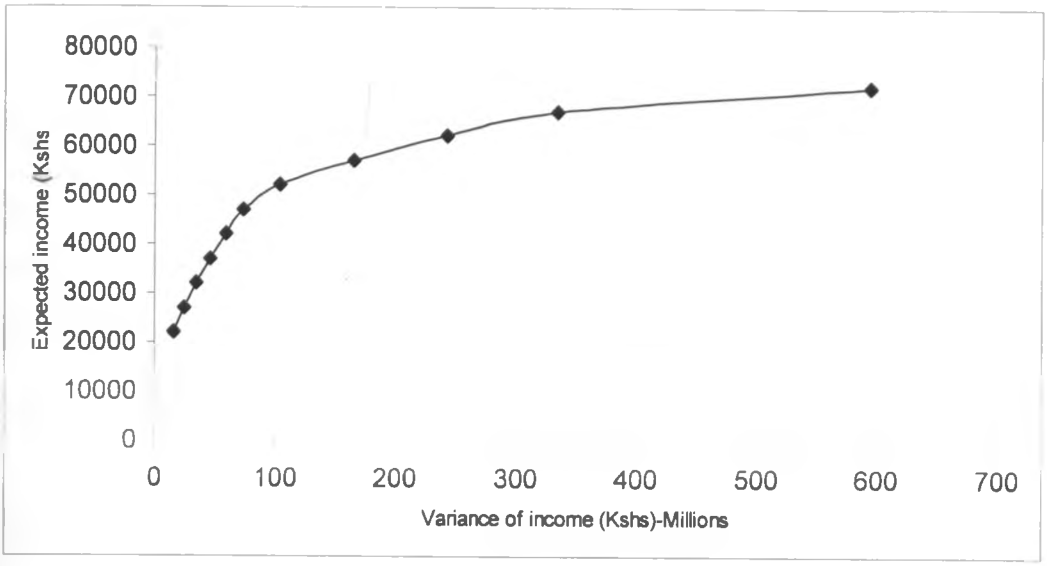

Figure 4.10: Risk efficient frontier for sample average model farm

(Source: Survey results, 2004)

Table 4.17: Risk efficient farm plans for sample average model farm

			Activity level (Acres)						
R (10^{-4})	E (Kshs)	V (Kshs)	Dairy	M/bean	Kales	S/cane	Maize	S/potato	Banana
-	22121.0	16219174.8	0.0	1.5	0.0	0.4	0.0	0.0	0.0
6.1	27121.0	24379828.2	0.0	1.8	0.0	0.5	0.0	0.0	0.0
5.1	32121.0	34197736.2	0.0	2.1	0.0	0.6	0.0	0.0	0.0
4.4	37121.0	45672898.8	0.0	2.5	0.0	0.7	0.0	0.0	0.0
3.8	42121.0	58805316.2	0.0	2.8	0.0	0.8	0.0	0.0	0.0
3.4	47121.0	73594988.1	0.0	3.1	0.0	0.9	0.0	0.0	0.0
1.7	52121.0	103850999.2	0.0	2.9	0.0	1.1	0.0	0.0	0.0
0.8	57121.0	165428859.2	0.2	2.4	0.3	1.3	0.0	0.0	0.0
0.6	62121.0	242617261.6	0.4	1.8	0.5	1.4	0.0	0.0	0.0
0.5	67121.0	335046517.5	0.6	1.3	0.7	1.6	0.0	0.0	0.0
0.2	72121.0	594070737.2	0.0	1.3	0.6	2.2	0.0	0.0	0.0
*5.4	28238.7	26430698.6	0.0	1.9	0.0	0.5	0.0	0.0	0.0

Source: Survey results, 2004

Where;

r is the risk aversion [9]level,

E and V are expected total net farm return and variance (risk) respectively, and

* is the optimized current gross margin, risk efficient farm enterprise mix.

In the sample average model farm, optimization yielded 11 risk efficient farm plans, with land cultivation increasing as the concern for risk decreased. At the highest level of risk, land is fully utilized confirming the LP results, which indicated that land is a constraint in this model farm. The expected income ranged from Kshs. 22,121 to Kshs. 72,121, while the level of risk aversion ranged from $2.0 * 10^{-5}$ to $6.1 * 10^{-4}$.

At low levels of risk aversion, only maize/bean and sugarcane feature in the risk efficient farm plans. In this model farm, resource allocation to the maize bean enterprise at this low level of risk aversion is mainly to meet subsistence needs since an average farmer will allocate 1.2 acres to the enterprise in any season. As expected income and risk increases, resource allocation to the sugarcane enterprise gradually increases, meaning that income from the enterprise is more stable. The dairy enterprise appears in the efficient plans but is substituted along with the maize bean enterprise, by the sugarcane and kale enterprises as risk increases.

The highest risk and income levels (Optimal farm plan) have sugarcane, kale and maize bean in order of resource allocation. This indicates that sugarcane enterprise is the most profitable and provides a stable income in the model farm, while the enterprise combination provides a stable income at the level of risk. The current average model farm gross margin, although low, falls within the range, which defines the relevant portion for planning and is therefore risk efficient.

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[9] An E-V formulation for the sample average farm for one risk aversion level is presented in detail in appendix 5

However, just as was observed in Lurambi model farm, the farm enterprise mix was observed to have some enterprises that do not feature in the risk efficient farm plan, making it sub optimal.

Sugarcane features as the most profitable enterprise in this model farm. As was observed in Table 4.8, sugarcane takes up the second largest amount of operating capital after dairy. This partly explains why most farmers do not operate optimally on average, since majority of farmers mentioned operating capital as the most limiting constraint. This confirms Schultz's (1976) hypothesis that farm families in developing countries are efficient but poor.

The EV curve indicates, given the degree of risk aversion, that the relevant portion for planning lies between the expected income ranges. Beyond the upper levels of expected income, the efficiency frontier curves flatten, indicating no tradeoff between expected income and income variability. Beyond the upper level of expected income, production would be irrational, as no appreciation of income would be observed, while the variability increases to an infinite level.

In all model farms, it was observed that farmers grow higher risk cash crops with higher payoffs, only if their risk aversion is low. It was noted that in the beginning, plans with smaller incomes (gross margins) were expected with greater concern for risk, i.e. high-risk aversion levels. As larger incomes were expected, concern for risk decreased as indicated by the low risk aversion levels in the high variance-high expected income levels. In beginning, plans with less risky crops occupied more area while more risky but remunerative crops started appearing with larger acreages in the later plans. This phenomenon indicated the forward gross margin - risk movement over the efficient plans and is consistent with results from other analysts, such as Ozkan and Akcaoz (2001), who reported that farmers preferred risky crops in farm structures only if they have low risk aversion. Although this type of behavior may be rational for the individual farmer, output levels and product combinations are inefficient from society's point of view (Anderson and Dillon, 1992). These results are also consistent with results from other studies, which showed that risk might play an important role in farm structures (Held *et al.*; 2002; Prevatt *et al.*, 1992).

4.6 Hypothesis Testing

4.6.1: Price volatility

That liberalization of maize marketing has not led to maize price volatility

$$H_O : \sigma_2^2 = \sigma_1^2$$

$$H_1 : \sigma_2^2 > \sigma_1^2$$

$$\textit{Testing Statistic} : \sigma_2^2 / \sigma_1^2 \text{ which is distributed as } F_{11,8}$$

$$\textit{rejection region of } H_o :$$

$$\textit{Iff } F_{\alpha, N_{2-1}, N_{1-1}} > 3.31$$

Where;

N_1= 9,

N_2= 12,

σ = 0.05

Tabulated F statistic= 3.31

Calculated F statistic = 6.96.

The null hypothesis is thus rejected since the calculated F statistic falls in the rejection region. These results show that maize prices have been volatile in the post liberalization period.

4.6.2: Relationship between maize price volatility and acreage allocation to the maize enterprise

That there is no significant relationship between maize price volatility and acreage allocated to the maize enterprise;

Results show a significant and negative relationship between maize price range and acreage allocated to maize at 95% confidence level. This indicates that price volatility and acreage allocation to the maize enterprise move in opposite directions. The null hypothesis is therefore rejected.

4.6.3: Optimal model farm enterprise mix

That farmers do not make optimal choices in allocating resources when diversifying enterprises as a maize price risk mitigation strategy; The hypothesis was tested using the E-V analysis (Tables 4.13 to 4.17).

Three out of the 5 model farm plans were found to be operating in a risk inefficient manner. These were Lugari, Khwisero and Kabras model farms. In these farms, the current gross margins lie out of the risk efficient planning range, as shown in tables 4.13, 4.14, and 4.15, respectively. The Lurambi model farm current gross margin, though not optimal, lies in the risk efficient planning range, indicating that these farmers are risk efficient. The same was observed for the sample average model farm. These are shown in tables 4.16 and 4.17. We therefore fail to reject the null hypothesis for these model farms.

The results imply that farmers in Kabras, Lugari and Khwisero are allocating their productive resources inefficiently given the price risk, while farmers in Lurambi are risk efficient but not optimal in resource allocation. The difference in the results is could be because the sugarcane enterprise, identified by the risk programming results as a profitable enterprise, currently plays a major role in the Lurambi model farm enterprise mix, unlike in the other model farms.

CHAPTER 5: CONCLUSIONS AND POLICY IMPLICATIONS

5.1 Conclusions

This study analyzed the effects of maize price risk on agricultural production patterns and farm incomes among small-scale farmers in the greater Kakamega district. The study area consisted of four districts including Kakamega, Butere/Mumias, Vihiga and Lugari districts.

The output of maize in the study area was relatively stable until the abolition of controls in the maize market, which introduced uncertainty in the maize market. Results from the F ratio test showed that maize prices in the post liberalization period (1994-2003) have been volatile (more variable), while maize output in the study area exhibits a decreasing trend. Results from correlation analysis (-0.495*) further indicate that maize price volatility is negatively related to resource allocation (land) enterprise. This signifies that farmers in the study area have reacted to the observed price risk by diversifying the crop enterprise combination to help stabilize their farm incomes. Subsequently, maize acreage was observed to have significantly decreased in the study area during the post liberalization period.

The sugarcane and dairy enterprises play a significant role in the current farm production plans and incomes in all model farms considered. It was also observed that all model farms with the sugarcane enterprise ranked above those that did not have the enterprise in the crop mix in terms of farm earnings. Further, among the model farms with the sugarcane enterprise, acreage allocation to the enterprise considerably determined farm income levels. A positive and significant relationship was found to exist between maize price volatility and acreage allocation to the sugarcane enterprise, and the sugarcane enterprise acreage in the study area was observed to be on an upward trend in the post liberalization period. In terms of output and income earnings, the analysis results indicate that sugarcane currently ranks first as the main income earner in the study area. This shift from maize to sugarcane production in an area previously a maize surplus area has a negative impact on the availability of the country's staple food. Results further indicate that majority of those sampled currently face maize deficit, with only 17.1 percent indicating that maize harvested takes them up to the next harvest.

To assess efficiency in farm planning, the current production plans were optimized, using both linear programming (LP) and quadratic programming (QP) techniques. The LP results indicated that none of the farm plans were operating optimally. To reflect the real farmer situation, the study incorporated the risk component in the evaluation of farmers' planning efficiency. QP, using Mean Variance analysis modeling results indicated that three out of the 5 model farm plans have gross margins and enterprise mixes that do not fall on the risk efficient frontier, indicating that their current production plans are not risk efficient. However, two of the model farms plans, though not optimal, were observed to have gross margins that lie within the relevant portion of planning in the risk efficient frontier. In all the model farms, the optimal risk efficient plans were observed to contain sugarcane and/or dairy enterprises (where the enterprises existed in the model farm), both of which are capital-intensive enterprises. The non-optimality of these farms therefore explains the high and increasing poverty levels in the study area, given the high contribution of farm incomes to total household income in the study area (Appendix 2).

Survey results also revealed that 40.7 percent of the farmers, on average, lack operating capital, and mentioned it as the most pressing constraint to crop and livestock production. 44.2 percent of the farmers suggested improving access to credit to help solve the problem. The LP analysis further identified land and operating capital as constraints in these model farms, indicating that relaxing these constraints may improve output and incomes in these farms.

It should be noted that the government still has other important roles other than just creating an enabling environment. It is well understood that trade reform typically entails a redistribution of income among various sectors of the economy. Less well understood is how large the redistributions are relative to the efficiency benefits of the reform (Rodrick, 1998). Unchecked liberalization may therefore impact very negatively on some sectors of these economies. It is against this background that the following recommendations were made.

5.2 Policy implications

In order to increase maize production and improve farm income in the study area, the following recommendations were made:

- **Stabilizing Maize Prices**: Maize price in the study area was observed to be volatile, with prices being at their lowest during the harvesting period, and at their highest just before harvesting. Most of the farmers were observed to sell at the prevailing market prices, leading to low incomes and a shift of resources to enterprises with more stable prices. Given the importance of maize to the country as the country's main staple, the government should create an environment that reduces price volatility. These could include advising farmers to spread maize sales over time and promoting maize storage at the farm level by the extension agents. This can be achieved by promoting investment in better and modern maize storage structures and practices. The government should also increase competition in the maize market by mandating the NCPB to operate as a commercially oriented parastatal, while still retaining its core function of ensuring food security, to increase its competitiveness. This will increase the number of major players in the maize market and ensure efficiency. Farmers should also be encouraged to adopt collective marketing strategies, like cereal banking. This may significantly reduce marketing costs, increase their bargaining power, and stabilize maize prices. These measures may increase the minimum prices and reduce the range within which maize price fluctuates and may encourage farmers to allocate more resources to maize production.

- **Increasing access to agricultural credit**: The empirical evidence indicated that the farm plans are sensitive to the risk criteria and farmers' willingness to bear risk in the study area, considering their level of risk aversion. Due to the presence of price risk in the study area, farmers gain less net farm income under present conditions compared to optimum conditions. The sugarcane and dairy enterprises were identified by the study results to be more profitable, with the two featuring in the risk optimal farm plans. However, production of the two enterprises is capital intensive. Operating capital is the most pressing constraint in the study area. In order to have significant improvement in farm income, there is a great need for an efficient agricultural credit system. The study therefore recommends that the government develop a viable and sustainable financial system to service the agricultural system. This includes an improvement in the accessibility of credit to the smallholder producers to relax the operating capital constraint, for farmers to operate optimally. This could be achieved by opening more branches of Agricultural Finance Corporation (AFC) in the rural areas, and allocating adequate funds to the AFC, and ensuring that the corporation advances the loans to the intended beneficiaries. This may help alleviate poverty in the study area.
- **Improving Management of the Sugar Processing and Out growers Companies**: The sugarcane enterprise was identified as an important enterprise in the study area, by its

contribution to the total farm income. However, inefficiency of the sugar companies was identified as a problem negatively affecting this enterprise. These include, delayed payments, non-performing and corrupt out grower companies, and corruption (Survey results, 2004). These should also be appropriately addressed.

- **Access to Agricultural Information**: Extension was identified to be very minimal, judging from the number of farmers who had either been visited by extension agents or attended an agricultural field day. However, cultivating under risk should be made part of farmers' training and the government should emphasize on extension to improve the efficiency of individual farms. Furthermore, agricultural extension should be reoriented to meet the changing situation in the post liberalization period.
- **Areas of further research:** Cereal banking as a concept in grain marketing has been touted as a viable strategy of not only ensuring relatively higher income from maize sales, but for minimizing fluctuations in maize prices. However, the economic benefits of this strategy have not been evaluated. This study therefore recommends an evaluation of the concept, to assess its economic benefits vis a vis its economic costs. The role of NCPB in maize marketing also could be researched further in a liberalized market.

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APPENDICES

Appendix 1: Survey instruments

Farm level Questionnaire

EFECTS OF MAIZE PRICE RISK ON SMALLHOLDER AGRICULTURAL PRODUCTION PATTERNS: THE CASE OF THE GREATOR KAKAMEGA DISTRICT.

1.0 Identification

1.1 Name of Enumerator____________________________________

1.2 Respondent's Name____________________________________

1.3 District_______________ Division_______________ Location__________

Sub-location____________________ Village__________________________

1.4 Date_____________ Start time_________________ End time__________

2.0 Background information

2.1 Age of the farmer_______________________ Years

2.2 Gender of the farmer___________________ **(1) Male; (2) Female**

2.3 Highest level of education attained by the farmer

(a) No formal education
(b) Primary
(c) Secondary (O Level)
(d) High school (A Level)
(e) College
(f) University
(g) Post- University

2.3 For how long have you been involved in farming

2.4 (a) How many members of your family live in the farm?_________________

(b)Among those living in the farm, how many are actively involved in farming activities in the farm?____

(c) How many live away from the farm?______________________________

2.5 (a) What is the size of your residential farm?_________________Acres

(b) (1) Do you have any other farm elsewhere **(1) Yes (2) No**

(2) If yes, what is the size of that farm? _________________Acres

(3) What is the ownership status of that farm? **(1) Own (2) Rented**

(4) If rented, what is the annual payment made for the farm? Kshs.__________

2.7 Please indicate the kind of farming activities that you carried out in the farm(s) mentioned above in the 2002/03-crop season.

Activity	Residential		Other owned farm(s)		Rented	
	Yes/No	Acres	Yes/No	Acres	Yes/No	Acres
Crop Production						
Livestock keeping						
Crop and livestock production						
Other (Specify)						

2.8 (a) Have you in the last ten years, made any changes in your farming activities? **(1) Yes (2) No**

(b) If yes, what activities have you introduced/abandoned________________

____

(c) What are the reasons for the changes________________________

____

____2

(d)Are you intending to make any changes in farming activities in the next few years? **(1) Yes (No)**

(e) if yes, which ones? ________________________

____

____

3.0 Farm enterprises

3.1(a) What crop enterprises/ enterprise mixes did you have in the 2002/03 crop season? (Fill in the table below)

Enterprise/Enterprise mixes	Acreage

(a) Are there some crops/ crop mixes that must be grown each year in your farm? **(1) Yes (2) No**
(b) If yes, list them in the table below showing the minimum area for each of them.

Crop/crop mixture	Minimum acreage

3.3 Please indicate the crop quantities produced, quantities sold and the unit prices at which they were sold for the 2002/03 crop season.

Crop	Total production (specify units)	Amount sold (Specify units)	Unit price

3.3 For what purpose do you produce maize?

(a) Mainly for sale
(b) For home consumption only
(c) For both home consumption and for sale
(d) For home consumption but sell when there is surplus

3.4 (a) Has the fluctuations in maize price over the years affected the acreage

allocated to the maize enterprise? (1) Yes (2) No

(b) If yes, how has it affected acreage allocated to maize production over time?

(1) Decreased
(2) Remained the same
(3) Increased

3.5 (a) Do you have dairy animals in your farm? (1) Yes (2) No

(b) During which months in the 2002/03 were you milking your cows?________

____

(c) How much milk was consumed at home per day in liters/bottles? ____________

(d) How much milk was sold per day in liters/bottles? ______________________

(e) What was the average price per liter/bottle Kshs. ________________________

4.0 Input quantities and costs

4.1 Please provide the following information on inputs you used in the various farm enterprises for the cropping season 2002/03.

4.11 (a) **Fertilizers**

Fertilizer type	Enterprise where applied	Amount applied	Total cost

(b) Describe the patterns of fertilizer application rates for the periods shown below as compared to the cropping year 2002/03.

	Before 1990	1990-1995	1996-current
Much higher			
Slightly higher			
Same			
Slightly less			
Much less			

(c) Please explain the changes (if any) in the fertilizer application rates for the periods indicated above.

____

____

____

4.12 **Seeds**

(a) Do you use certified maize seeds? **(1) Yes (2) No**

Please indicate whether you have been using certified seeds for the periods indicated below?

(1) Before 1990 **Yes/No**
(2) Between 1990-1995 **Yes/No**
(3) 1996 to present **Yes/No**

4.13 (a) **Manure**

Enterprise where applied	Amount applied	Total cost

(b) Describe the patterns of manure application rates for the periods shown below as compared to the cropping year 2002/03.

	Before 1990	1990-1995	1996-current
Much higher			
Slightly higher			
Same			
Slightly less			
Much less			

(c) Please explain the changes (if any) in the manure application rates for the periods indicated above.

____

____

4.14 (a) Pesticides/Insecticides

Pesticide/Insecticide type	Enterprise where applied	Amount applied	Total cost

(b) Describe the patterns of pesticide application rates for the periods shown below as compared to the cropping year 2002/03.

	Before 1990	1990-1995	1996-current
Much higher			
Slightly higher			
Same			
Slightly less			
Much less			

(c) Please explain the changes (if any) in the pesticide application rates for the periods indicated above.

____

____

4.15 **Manual labor**

Please indicate the following information concerning manual labor you used in your farm in the cropping year 2002/03 for the following operations for crop production.

(1) Land preparation

Labor type	Enterprise applied	Amount (Man-hours)	Total cost (Where applicable)
Family labor			
Hired labor (a) Casual labor			
(b) Permanent labor			
Oxen/ Draft animal			

Tractor			

(2) Planting

Labor type	Enterprise applied	Amount (Man-hours)	Total cost (Where applicable)
Family labor			
Hired labor (c) Casual labor			
(d) Permanent labor			
Oxen/ Draft animal			
Tractor			

(3) Weeding

Labor type	Enterprise applied	Amount (Man-hours)	Total cost (Where applicable)
Family labor			

Hired labor (e) Casual labor			
(f) Permanent labor			
Oxen/ Draft animal			
Tractor			

(4) Fertilizer/Pesticide application

Labor type	Enterprise applied	Amount (Man-hours)	Total cost (Where applicable)
Family labor			
Hired labor (g) Casual labor			

(h) Permanent labor			
Oxen/ Draft animal			
Tractor			

(5) Harvesting and primary processing

Labor type	Enterprise applied	Amount (Man-hours)	Total cost (Where applicable)
Family labor			
Hired labor (i) Casual labor			
(j) Permanent labor			
Oxen/ Draft animal			

Tractor			

(b) Describe the patterns of hired labor for the periods shown below as compared to the cropping year 2002/03.

	Before 1990	1990-1995	1996-current
Much higher			
Slightly higher			
Same			
Slightly less			
Much less			

(c) Please explain the changes (if any) in the amounts of hired labor for the periods indicated above.

____

____

4.16 (a) what were the feed costs for the dairy cows per month?

(b)What ere the veterinary drugs and dipping costs per month?

Veterinary drugs per month	Kshs ....
Dipping costs per month	Kshs...................................
Total	Kshs. ....

(d) How many man-hours were spent on dairy cattle per day?

(e) What was the cost of a man-hour?

Man-hours	Rate (Kshs)	Total

5.0 Maize marketing

5.1 (a) Where are you currently selling your maize?

____

(b) What changes have taken place in the marketing system in the last 10 years?

____

____

(c) Please describe the changes____

____

(d) Have the changes in the marketing system affected your activities at the farm level? **(1) Yes (2) No**

(e) If yes, please describe the changes. _____________________

____

____

(f) How would you describe the general pattern of prices of maize in the last 10 years?

(1) Highly erratic
(2) Erratic
(3) Stable
(4) Very stable
(5) Rising
(6) Falling

(g) (i) Has the variability of maize price affected the acreage allocated to other major food crops? **Yes/No**
Tick where appropriate

(ii) If yes, how has it affected acreage allocated to other food crops?
(1) Decreased
(2) Remained the same
(3) Increased

(iii) How do you deal with the problem of price fluctuations with regard to maize marketing?
____
____
____

5.2 Do you have a maize storage facility in your farm? **Yes/No**

5.3 (a) If yes, how many bags of maize can your store accommodate? __________bags

(b) How often does the harvested maize last the family until the next harvest?

(i) Always
(ii) Most of the time
(iii) Rarely
(iv) Not at all

(c) How do you meet the shortage in the amount of maize?
(1) Buying from the market
(2) Use other alternative foodstuffs
(3) Other (Specify) ______________________________

6.0 Coping strategies

6.1 Apart from farming, is any member of the family involved in any other income generating activity? **Yes/No**

6.2 (a) Indicate other non farming activity/ies the family member is involved in;

(a) Formal employment
(b) Casual employment
(c) Business\activities
(d) Formal and casual employment
(e) Formal employment and business activities
(f) Casual employment and business activities

(g) Formal employment, casual employment and business activities

(b) What is the amount of income earned from non-farm activities in Kshs?

(1) Less than 1000
(2) 1001-3000
(3) 3001-6000
(4) 6001-900Over 9000

6.3 (a) Did you obtain credit either in cash or in kind for farming during 2002/03 crop season? **Yes/No**

(b) If yes, what was the source of credit? ________________________________

____

(c) What was the value of credit borrowed in kshs? ________________________

(d) For what purpose did you borrow? ________________________________

(e) Do you intend to get any (more) credit in future? **Yes/No**

(f) If no, why not? ____

____

(g) Please indicate the following information about credit for the periods indicated compared to the current period.

(i) Ease of obtaining credit

Ease of obtaining credit	Before 1990	1990-1995	1996-current
Very easy			
Easy			
Same			
Difficult			
Very difficult			

(ii) Levels of credit borrowed

Level of borrowing	Before 1990	1990-1995	1996-current
Much higher			
Slightly higher			
Same			
Slightly less			
Much less			

7.0 Extension services

7.1 Has extension staff visited your farm in the last 5 years? **Yes/No**

7.2 If yes, how many times in a year do they visit you in a year on average? ________

7.3 (a) Describe the frequency of visits by extension in the periods shown below as compared to the cropping year 2002/03.

	Before 1990	1990-1995	1996-current
More frequent			
Same			
Less frequent			
Slightly less			
No visits			

7.3 (b) have you attended any agricultural field day in the last five years? **Yes/No**

8.0 Problems and comments

8.1Wat are the major problems you have been facing in relation to crop and livestock farming i.e. in regards to labor, inputs acquisition, credit(working capital), Marketing, extension, and such others)

(1)____

(2)____

(3)____

(4)____

(b) What are your suggested solutions to these problems?

District level Questionnaire

(a) Maize monthly prices
Monthly Maize Price in the Greator Kakamega District.

District____

Year	Monthly prices											AYP
	Jan	Feb	March	April	May	Jun	July	Aug.	Sep.	Oct.	Nov.	Dec.	
1980													
1981													
1982													
1983													
1984													
1985													
1986													
1987													
1988													
1989													
1990													
19991													
1992													
1993													
1994													
1995													
1996													
1997													
1998													
1999													
2000													
2001													
2002													
2003													
2004													

(b) **Commodity area and output questionnaire**

AGRICULTURAL PRODUCTION PATTERNS FOR THE GREATOR KAKAMEGA DISTRICT (1980-2003)

District Level Questionnaire II
Commodity ______________________

Year	Output (mt)	Acreage (Ha)	Average price per unit
1980			
1981			
1982			
1983			
1984			
1985			
1986			
1987			
1988			
1989			
1990			
1991			
1992			
1993			
1994			
1995			
1996			
1997			
1998			
1999			
2000			
2001			
2002			
2003			

Appendix 2: Development and Socioeconomic Indicators

District	Agricultural sector's contribution to total household income (Per cent)	Proportion of total population living in absolute poverty (Per cent)
Kakamega	62	57.47
Lugari	90	57.27
Butere/mumias	65	60
Vihiga		61.97

Source: Lugari, Kakamega and Butere/mumias District development Plans (Kenya, 2000); Socioeconomic and Political Profiles of Kenya's Districts (Institute of Economic Affairs, 2002)

Appendix 3: Model Farms' Gross Margin Calculations

Lugari Division model farm

Enterprise	Output/acre (units specified per commodity)	Average price (Kshs per unit)	Output value (Kshs/acre)	Total variable cost (Kshs/ acre)	Total gross margins/ acre (Kshs)
Milk	1,353	15	20,304	7802	12,500
Maize	13	1,088	14,502	4,694	9,808
Maize/bean	8	1,122	9,510	5,636	3,874
Sweet potatoes	11	800	9,371	289	9,081
Kale	29	300	8,854	7,402	1,452
Millet	2	2,250	4,694	2,786	1,907

Khwisero Division Model Farm

Enterprise	Output/acre (units specified per commodity)	Average price (Kshs per unit)	Output value (Kshs/acre)	Total variable cost (Kshs/ acre)	Total gross margins/ acre (Kshs)
Milk	1,845	19	36,727	12,727	24,194
Maize/bean	5	1,542	8,790	3,295	5,494
Sugarcane	15	1,800	27,687	15,764	11,922
Sweet potatoes	5	629	3,376	0	3,376
Tea	448	9	4,168	2,761	1,407
Kale	14	400	5,950	314	5,636
Banana	143	165	23,682	0	23,682

Lurambi Division Model Farm

Enterprise	Output/acre (units specified per commodity)	Average price (Kshs per unit)	Output value (Kshs/acre)	Total variable cost (Kshs/ acre)	Total gross margins/ acre (Kshs)
Milk	1,072	20	21,442	10,302	11,476
Maize	7	850	6,488	3,524	2,964
Maize/bean	4	1,147	5,301	4,478	823
Sugarcane	15	1,800	27,800	17,180	10,620
Sweet potatoes	5	600	3,360	115	3,244
Kale	45	416	19,074	3,913	15,160
Cassava	8	800	6,611	1,686	4,925

Kabras Division Model Farm

Enterprise	Output/acre (units specified per commodity)	Average price (Kshs per unit)	Output value (Kshs/acre)	Total Variable cost (Kshs/ acre)	Total gross margins/ acre (Kshs)
Milk	1,072	14	15,652	10,074	14,252
Maize	7	850	6,488	5,742	3,172
Maize/bean	4	1,147	5,301	3,553	1,269
Sugarcane	5	1,746	9,019	4,191	4,828
Sweet potatoes	5	600	3,360	350	5,959
Kale	45	416	19,074	936	13,702
Banana	8	800	6,611	0	5,488

Sample Average Model Farm

Enterprise	Output/acre (units specified per commodity)	Average price (Kshs per unit)	Output value (Kshs/acre)	Total variable cost (Kshs/ acre)	Total gross margins/ acre (Kshs)
Maize	3	1,067	3,266	1,421	1,845
Maize/Bean	1	1,229	827	484	343
Sugarcane	11	1,800	19,224	14,186	5,038
Sweet potato	8	554	4,446	165	4,281
Kales	10	376	3,564	569	2,995
Banana	12	114	1,405	21	1,384
Dairy	2,218	17	37,701	15,654	22,048

Appendix 4: Linear Programming Results for the Whole Sample Average Model Farm

OBJECTIVE FUNCTION VALUE

1) 48458.8000

VARIABLE	VALUE	REDUCED COST
X1	2.027833	.000000
X2	.000000	3876.201000
X3	1.300000	.000000
X7	.000000	15325.910000
X4	.772167	.000000
X5	.000000	1749.025000
X9	.000000	2732.098000
X18X9	.000000	.000000

ROW	SLACK OR SURPLUS	DUAL PRICES
(2)	.000000	4091.580000
(3)	.000000	1.147055
(4)	197.357100	.000000
(7)	.000000	-4303.525000
(10)	2.027833	.000000
(11)	.000000	.000000
(12)	1.300000	.000000
(13)	.000000	.000000
(14)	.772167	.000000
(15)	.000000	.000000
(16)	.000000	.000000

Sensitivity analysis

OBJ COEFFICIENT RANGES

VARIABLE	CURRENT COEF	ALLOWABLE INCREASE	ALLOWABLE DECREASE
X1	22047.000000	294891.400000	16929.840000
X2	1845.000000	3876.201000	INFINITY
X3	343.000000	4303.525000	INFINITY
X7	5037.900000	15325.910000	INFINITY
X4	4280.500000	17766.500000	1795.879000
X5	2995.000000	1749.025000	INFINITY
X9	1383.800000	2732.098000	INFINITY
X18X9	.000000	.000000	INFINITY

RIGHTHAND SIDE RANGES

ROW	CURRENT RHS	ALLOWABLE INCREASE	ALLOWABLE DECREASE
(2	4.100000	5.253846	.764042
(3	32498.800000	9460.926000	31408.700000
(4	1026.500000	INFINITY	197.357100
(7	1.300000	.788410	1.300000
(10	.000000	2.027833	INFINITY
(11	.000000	.000000	INFINITY
(12	.000000	1.300000	INFINITY
(13	.000000	.000000	INFINITY
(14	.000000	.772167	INFINITY
(15	.000000	.000000	INFINITY
(16	.000000	.000000	INFINITY

Appendix 5: GAMS Model Formulation for the Sample Average Model Farm

```
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farm problem set up as mean variance (ev) quadratic programming problem

SETS

  J ACTIVITIES
   /X1 DAIRY
    X2 MAIZE
    X3 MAIZEBEAN
    x7 SUGARCANE
    X4 SWEET POTATO
    X5 KALE
     x9 BANANA/
  I INPUTS
    /LABOR, CAPITAL, LAND/
  T CROSS SECTIONS
    /1*5/;
  ALIAS (J, JP);

PARAMETER B (I) AVAILABILITY OF INPUTS
  /LABOR 1026.5
   CAPITAL 32498.8
   LAND 4.1/;

TABLE A (I,J) INPUT USE PER ACTIVITY
         X1      X2      X3      X7     X4    X5     x9

 LABOR    364     36     45.5    20.6   41    79     18
 Capital  15653.5  1420.7  483.8   14186.1 164.7 568.8  21.2
 LAND     1       1      1       1     1     1      1
TABLE R(T,J) REVENUES PER ACTIVITY PER CROSS SECTION

       X1      X2      X3      X7      X4      X5      x9
   1  39880   17063.6 12110.1 18772.9 22201.9 7601.5   20792.3
   2  7012    4122.6  8833.3  7074.4  2894.7  12669.2 7208
   3  1776    1362.6  5763.3  34745.9 3092.4  19002   34653.8
   4  15168   3846.7  3881.1  36229.9 10062   1646    1386.2
   5  17376   9565.8  11289.3 21676.9 15462   33270.4 13861.5;

PARAMETER RBAR (J) AVERAGE REVENUE PER ACTIVITY;
 RBAR (J) = SUM (T, R (T, J)) / (CARD (T));
 DISPLAY RBAR;
PARAMETER D (T, J) DEVIATIONS FROM MEAN REVENUES;
 D (T, J)= R (T, J) - RBAR (J);
 DISPLAY D;
PARAMETER V (J, JP) COVARIANCE MATRIX OF REVENUES;
 V (J, JP) = SUM (T, D (T,J)*D(T,JP)) / (CARD(T)-1);
 DISPLAY V;
SCALAR XPINC EXPECTED INCOME (Kshs)/47121.0/;
SCALAR SUBST SUBSISTENCE REQUIRED (acres) /1.3/;
 VARIABLES
   RISK OBJECTIVE variable
   Y (T) cross section item coefficients
   X (J) CROPS ACTIVITY LEVELS (ACRES)
   POSITIVE VARIABLE X;
 EQUATIONS
  OBJ      OBJECTIVE FUNCTION
  SUPPLY (I) INPUT AVAILABILITY
```

```
EXPREV    EXPECTED REVENUE
```

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farm problem set up as mean variance (ev) quadratic programming problem

```
SUBSIST   Constraints for subst;

OBJ.. SUM (JP, X (JP)*(SUM (J, X (J)*V (J, JP)))) =e= RISK;
SUPPLY (I).. SUM (J, X (J)*A (I,J)) =l= B(I);
EXPREV.. SUM (J, X (J)*RBAR (J)) =e= XPINC;
SUBSIST.. X ("X3") =g= SUBST;
MODEL EV /ALL/;
SOLVE EV USING NLP MINIMIZING RISK;
```

COMPILATION TIME = 0.000 SECONDS 0.7 Mb WIN200-121

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farm problem set up as mean variance (ev) quadratic programming problem
E x e c u t i o n

---- 39 PARAMETER RBAR AVERAGE REVENUE PER ACTIVITY

X1 16242.400, X2 7192.260, X3 8375.420, x7 23700.000, X4 10742.600
X5 14837.820, x9 15580.360

---- 42 PARAMETER D DEVIATIONS FROM MEAN REVENUES

	X1	X2	X3	x7	X4	X5
1	23637.600	9871.340	3734.680	-4927.100	11459.300	-7236.320
2	-9230.400	-3069.660	457.880	-16625.600	-7847.900	-2168.620
3	-14466.400	-5829.660	-2612.120	11045.900	-7650.200	4164.180
4	-1074.400	-3345.560	-4494.320	12529.900	-680.600	-13191.820
5	1133.600	2373.540	2913.880	-2023.100	4719.400	18432.580

+	X9
1	5211.940
2	-8372.360
3	19073.440
4	-14194.160
5	-1718.860

---- 45 PARAMETER V COVARIANCE MATRIX OF REVENUES

	X1	X2	X3	x7	X4	X5
X1	2.139131E+8	8.807207E+7	3.249308E+7	-3.46384E+7	1.150154E+8	-4.40511E+7
X2	8.807207E+7	3.941939E+7	1.816019E+7	-2.71794E+7	4.882144E+7	-291627.831
X3	3.249308E+7	1.816019E+7	1.241757E+7	-2.92688E+7	1.899932E+7	1.852574E+7
x7	-3.46384E+7	-2.71794E+7	-2.92688E+7	1.459475E+8	-7.14102E+6	-2.12193E+7
X4	1.150154E+8	4.882144E+7	1.899932E+7	-7.14102E+6	6.854165E+7	-447946.992
X5	-4.40511E+7	-291627.831	1.852574E+7	-2.12193E+7	-447946.992	1.470479E+8
X9	-1.55361E+7	2341272.783	6148455.796	3.745627E+7	-4.73411E+6	5.385755E+7

+	X9
X1	-1.55361E+7

```
X2 2341272.783
X3 6148455.796
x7 3.745627E+7
X4 -4.73411E+6
X5 5.385755E+7
X9 1.663714E+8


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farm problem set up as mean variance (ev) quadratic programming problem
Equation Listing    SOLVE EV USING NLP FROM LINE 64


---- OBJ  =E= OBJECTIVE FUNCTION


OBJ..  - RISK + (0)*X (X1) + (0)*X (X2) + (0)*X (X3) + (0)*X (x7) + (0)*X (X4)

     + (0)*X (X5) + (0)*X (x9) =E= 0 ; (LHS = 0)


---- SUPPLY  =L= INPUT AVAILABILITY


SUPPLY (LABOR)..  364*X (X1) + 36*X (X2) + 45.5*X (X3) + 20.6*X (x7) + 41*X (X4)

     + 79*X (X5) + 18*X (x9) =L= 1026.5; (LHS = 0)


SUPPLY(CAPITAL)..  15653.5*X (X1) + 1420.7*X (X2) + 483.8*X(X3) + 14186.1*X(x7)

     + 164.7*X (X4) + 568.8*X (X5) + 21.2*X (x9) =L= 32498.8 ; (LHS = 0)


SUPPLY (LAND)..  X (X1) + X (X2) + X(X3) + X(x7) + X(X4) + X(X5) + X(x9) =L= 4.1

     ; (LHS = 0)


---- EXPREV  =E= EXPECTED REVENUE


EXPREV..  16242.4*X (X1) + 7192.26*X(X2) + 8375.42*X(X3) + 23700*X(x7)

     + 10742.6*X (X4) + 14837.82*X (X5) + 15580.36*X(x9) =E= 47121 ;

     (LHS = 0, INFES = 47121 ***)


---- SUBSIST  =G= Constraints for subst


SUBSIST..  X (X3) =G= 1.3; (LHS = 0, INFES = 1.3 ***)

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farm problem set up as mean variance (ev) quadratic programming problem
Column Listing      SOLVE EV USING NLP FROM LINE 64


---- RISK OBJECTIVE variable
```

```
RISK
          (.LO, .L, .UP = -INF, 0, +INF)
    -1      OBJ


---- X CROPS ACTIVITY LEVELS (ACRES)


X (X1)
          (.LO, .L, .UP = 0, 0, +INF)
    (0)     OBJ
    364        SUPPLY (LABOR)
  15653.5      SUPPLY (CAPITAL)
    1          SUPPLY (LAND)
  16242.4      EXPREV

X (X2)
          (.LO, .L, .UP = 0, 0, +INF)
    (0)        OBJ
    36         SUPPLY (LABOR)
   1420.7      SUPPLY (CAPITAL)
    1          SUPPLY (LAND)
   7192.26     EXPREV

X(X3)
          (.LO, .L, .UP = 0, 0, +INF)
    (0)       OBJ
    45.5     SUPPLY (LABOR)
   483.8     SUPPLY (CAPITAL)
    1        SUPPLY (LAND)
  8375.42    EXPREV
    1        SUBSIST

REMAINING 4 ENTRIES SKIPPED

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farm problem set up as mean variance (ev) quadratic programming problem
Model Statistics    SOLVE EV USING NLP FROM LINE 64



MODEL STATISTICS

BLOCKS OF EQUATIONS        4    SINGLE EQUATIONS        6
BLOCKS OF VARIABLES        2    SINGLE VARIABLES        8
NON ZERO ELEMENTS         37    NON LINEAR N-Z          7
DERIVATIVE POOL           18    CONSTANT POOL          36
CODE LENGTH              478


GENERATION TIME    = 0.016 SECONDS    1.9 Mb     WIN200-121


EXECUTION TIME     = 0.016 SECONDS    1.9 Mb     WIN200-121

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farm problem set up as mean variance (ev) quadratic programming problem
```

```
S O L V E     S U M M A R Y
 MODEL  EV                    OBJECTIVE RISK
 TYPE   NLP                   DIRECTION MINIMIZE
 SOLVER CONOPT                FROM LINE 64

**** SOLVER STATUS     1 NORMAL COMPLETION
**** MODEL STATUS      2 LOCALLY OPTIMAL
**** OBJECTIVE VALUE        73594988.1340

 RESOURCE USAGE, LIMIT          0.010      1000.000
 ITERATION COUNT, LIMIT         9          10000
 EVALUATION ERRORS              0          0


   C O N O P T     Windows NT/95/98 version 2.043F-008-043
   Copyright (C) ARKI Consulting and Development A/S
                 Bagsvaerdvej 246 A
                 DK-2880 Bagsvaerd, Denmark

 Using default control program.


 ** Optimal solution. Reduced gradient less than tolerance.


 CONOPT time Total                    0.000 seconds
  of which: Function evaluations  0.000 =  0.0%
   Derivative evaluations             0.000 = 0.0%

 Work length = 0.05 Mbytes
 Estimate = 0.05 Mbytes
 Max used = 0.05 Mbytes

                 LOWER     LEVEL     UPPER    MARGINAL

---- EQU OBJ.          .         .        -1.000

 OBJ OBJECTIVE FUNCTION


---- EQU SUPPLY INPUT AVAILABILITY

        LOWER     LEVEL     UPPER    MARGINAL

LABOR      -INF    160.641 1026.500.
CAPITAL   -INF 14021.536 32498.800.
LAND       -INF      4.013     4.100.

                 LOWER     LEVEL     UPPER    MARGINAL

---- EQU EXPREV    47121.000 47121.000 47121.000  3123.660
---- EQU SUBSIST       1.300     3.131     +INF.

 EXPREV EXPECTED REVENUE


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farm problem set up as mean variance (ev) quadratic programming problem


 SUBSIST Constraints for subst
```

```
               LOWER    LEVEL    UPPER    MARGINAL

---- VAR RISK         -INF 7.3595E+7     +INF.

 RISK OBJECTIVE variable


---- VAR X CROPS ACTIVITY LEVELS (ACRES)

    LOWER    LEVEL    UPPER    MARGINAL

X1.       .      +INF 9.1688E+7
X2.       .      +INF 4.3345E+7
X3.      3.131 +INF       EPS
X7.      0.882  +INF.
X4.       .      +INF 7.2842E+7
X5.       .      +INF 3.2261E+7
X9.       .      +INF 5.5882E+7


**** REPORT SUMMARY: 0     NONOPT
                    0 INFEASIBLE
                    0 UNBOUNDED
                    0     ERRORS


EXECUTION TIME      = 0.000 SECONDS    0.7 Mb      WIN200-121


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**** FILE SUMMARY

INPUT      A:\AVERAGE.GMS
OUTPUT     C:\WINDOWS\GAMSDIR\AVERAGE.LST
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