Chapter 4

CHARACTERISTICS OF INNOVATIONS FOR MAIZE PRODUCTION

4.1 Introduction

Development and dissemination of improved farming practices has been a major component of the overall development strategy for the semi-arid region. Introduction of the Training and Visit (T & V) program (Benor, Harrison and Baxter 1984) by the Extension and Education Division of the Department of Agriculture was aimed at maximizing farmer awareness of the innovations that are available. At the same time, attempts have been made to improve rural infrastructure including access roads and facilities for storage and handling of farm produce in some districts (e.g., Neunhauser 1980). Despite these developments, adoption of proven innovations has remained low.

The aim in this chapter was to highlight features of the technology that are embodied in the innovations and that may have relevance in explaining the low rates of adoption that characterize smallholder farming in the semi-arid region. This entailed assessments of the viability of the innovations taking into account farmer perspectives. These appraisals utilized data from the farm survey, produce price information obtained from the relevant institutions and technical performance measures that had been determined from the findings of agronomic research. Yield and gross margin probability distributions were derived from the data. Micro-economic theory of stochastic efficiency was used to facilitate pair-wise comparisons of these distributions.

4.2 Objectives

The main objective of the analysis reported in this chapter was to assess the financial and operational feasibility of the innovations that were being promoted for adoption by farmers. To achieve this objective, parameters of the functions which describe the transformation of inputs into outputs needed to be established. First, attributes of the innovations that may be relevant to adoption decisions are sketched out. In so doing, it was recognized that:

(a) Application of the innovations can be perceived to introduce additional risk into the farm's activities.

(b) The farmer may be interested in attributes of the innovation other than or in addition to expected performance (mean) only. For this reason, it was considered appropriate that assessments should attempt to explore entire distributions of outcomes associated with each innovation and to elicit views on non-financial aspects of innovations (e.g., saving time spent in tedious labour).

Using data that were obtained from agronomic field trials that were conducted under both on-farm and on-station settings by NDFRC (Nadar 1984a,b), yield probability distributions were derived for 30 different strategies. Given the high climatic variability that characterizes the semi-arid region of Kenya, it was recognized that yield distributions for a sufficient number of seasons, though necessary for realistic assessments, could not be obtained at reasonable cost through field experimentation. A crop growth model, CM-KEN (Keating, Wafula and Watiki (1992a,b) was used to simulate maize growth and yield in relation to climate, soil, genotype and management inputs. To assess the financial returns that are implied by these strategies, the yield distributions were transformed into distributions of net returns with the aid of input and output price information. Such information had been obtained from the Central Bureau of Statistics of the Ministry of Planning and National Development and KGGCU as part of the field work that was described in chapter three. Yield data were for the period 1978-82.

4.3 Characteristics of Innovations

Adoption of new innovations may stall because of many reasons. The farmer may not know about or understand the new innovation. The innovation may be outside the farmer's managerial competence or it may be socially or culturally unacceptable. The innovation may be embedded in physical items such as seeds and fertilizers which are not readily available. There is a growing body of evidence (e.g., Anderson 1992) which suggests that the apparent (to researchers and extensionists) advantage of an innovation over the traditional practice may not be obvious from the farmer's point of view. If appropriate criteria are applied in the establishment of relative advantage the innovation may be found to be inappropriate. This may be because the innovation is neither technically feasible nor adequately adapted to real farm conditions, or it may not be financially viable.

As the decision to adopt is the farmer's, evaluation that leads to establishment of input-output relationships should, as far as possible, incorporate the farmer's perspectives. Moreover, effort to promote innovations including extension advice is usually based on averages of performance measures as developed at research stations when other performance measures such as variance should also be considered. The farmers 'subjective' assessment of the performance of the new innovation is likely to be different from the 'objective' assessments of research and extension workers. At least three reasons for the differences in assessment by farmers and by promoters can be offered. First, if the innovation is new, it is likely that the farmer has had little experience which would help him make realistic assessments. Secondly as already noted, the innovation will have been developed under (typically) average conditions which may differ from his own. Thirdly, the farmer's valuation criteria may be different from those of the research and extension workers. For example risk considerations may be evaluated differently. Under such circumstances, the real worth of an innovation may be understated or even overstated by farmers. Given that farmers have to operate within a highly unstable climatic environment, risk associated with attaining production as well as income targets is likely to exert significant influences on assessments of the worth of innovations.

Broad categories of attributes of innovations that may have relevance for adoption decisions have been proposed (Collinson[4] 1983; Rogers and Shoemaker 1971; Rogers 1983). The conceptual scheme for examining attributes of innovation within this framework would appear to suffer the same disadvantages that were discussed in chapter three in relation to adopter characteristics. The number of explanatory variables within the scheme tends to be large, and, for any such variables, an intricate network of related variables may be contemplated (Parton 1991, 1992). The main advantage is that such a scheme can offer a better perspective on the complexity surrounding the adoption problem, thereby minimizing the risk of overlooking important variables Four categories of such attributes are reviewed. This chapter is concerned with the various aspects of relative advantage as an attribute of innovations for maize production.

4.3.1 Compatibility

As a measure of 'innovative potential', compatibility of an innovation can be defined in technological, institutional, financial and socio-cultural terms. Compatibility may also be viewed as the extent to which

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[4]Collinson uses somewhat different words to convey what is essentially the same message. His five attribute categories profitability, acceptability and complexity for sustained acceptance; and congruity and divisibility for initial adoption (Collinson 1983, ch. 15).

a particular innovation can enhance or utilize existing flexibility within the farm's productive capacity and the household's consumption patterns. Therefore, compatibility would vary inversely with potential disruption to technological and institutional arrangements. If financial requirements for implementation of an innovation are beyond what the farmer can raise, the innovation is incompatible with production strategies on that particular farm. Similarly, innovations which cannot be sanctioned by custom or usage would be effectively incompatible, even though they fit in well with existing technological, financial and institutional circumstances. For example, tobacco is grown by a number of farmers in the region as a high value cash crop. Some farmers within the same neighbourhood would never grow tobacco and the sole reason is that they belong to a religious sect within which production and use of tobacco products is forbidden.

For the three innovations that are appraised in this chapter, it is hard to establish incompatibility with the existing situation on institutional, socio-cultural or technological grounds. With existing labour availability profiles, however, the first innovation, timing of field operations, may well require upgrading of tools and implements. The second and third innovations, management of plant populations and use of fertilizers, would imply increased working capital requirements. All three would call for additional labour and changes in labour use profiles.

4.3.2 Trialability

Ideas which can easily be tried have usually stood a better chance of being adopted than those that are hard to try out. For example, improved seed can be tried out in small plots at virtually no cost to the farmers. It has been suggested that this is one major way in which farmers develop their expectations about the desirability of an innovation The usefulness of this attribute needs to be qualified in two respects. First, not all problems that call for technological resolution will be served well by innovations that are trialable. Secondly many innovations that are easy to try out on small plots require other inputs which if not used will leave the farmer with the wrong impression about performance of the innovation.

In principle, the task of trying out all the three innovations under consideration should not present insurmountable problems to any farmer. In practice, though, successful implementation of the timing of operations requires that tillage equipment be upgraded. The seed rate innovation would also require changes in the equipment configuration to achieve correct geometry. Even the fertilizer technology is not easy to try out. Fertilizers are packaged and sold in 50 kg units, and, the price per unit can be high relative to farm incomes. Moreover, for all these innovations, the farmer would have to run trials over several seasons in order to form subjective beliefs about performance.

4.3.3 Complexity

Complexity may be defined in relation to the ease with which an innovation is understood, or the actual number of steps, patterns and sequences involved. The higher the complexity of an innovation, the longer the learning curve and the higher the implied costs of information. For the three innovations under consideration in this chapter, none can be said to be complex. However, the timing of operations innovation is likely to become complex when response farming notions are incorporated into the extension message.

4.3.4 Observability

This relates to the ease with which performance of an innovation becomes apparent to potential adopters. The more observable the performance, the greater the likelihood that adoption will take place. Although performance of improved varieties, fertilizers and aspects of pest control should be relatively easy to observe, it is often less easy to ascribe outwardly visible performance to the many possible causes. This is another reason why the farmer may need information collected over several seasons.

4.3.5 Relative advantage

Expected performance in terms of relative advantage for any innovation may differ from farm to farm for many reasons, as already noted. Some of these reasons are listed below.

(a) Differences in skills endowment. More educated households may realize greater advantage from use of an innovation than those who are less educated.

(b) Ecological differences between farms, for example, different soils may cause differences in innovation performance. For some farmers, a very wet season may lead to above average performance if the soil structure can permit efficient drainage. Poorly draining soils may lead to poor performance when rainfall is above average.

(c) Farm size could induce disparity in relative advantage to be realized because of:

- Resource endowment
- Availability of complementary inputs
- Land quality
- Lower costs of information acquisition and higher total returns from such acquisition.

(d) Year-to-year and season-to-season climatic variation may lead to differences in yield performance.

4.4 Agricultural Technology for the Semi-arid Region

One census of smallholdings showed that there were 466 163 individual holdings (ISNAR 1981). Of these, 456 000 were less than 8 hectares. Typically, these smallholders do not apply basic agronomic principles. Combined with the high costs of construction of soil conservation structures on cropland, holding size seems to have precluded any development of a workable field rotation scheme. Crop establishment is poor and highly uneven. Poor germination due to use of unsuitable seed and methods of field operations results in final plant counts that are typically one third of the levels that are required to exploit environmental resources to the farmer's advantage.

Ikombo (1984) suggested that reasonable yield responses can be achieved from them. While mineral nutrient status can be enhanced and soil condition improved through application of organic fertilizer, the quantities available as well as capacity to harvest and apply it at the rates that would satisfy crop needs, let alone arrest decline in soil fertility, are unlikely to be met on the majority of farms. One way of approaching the plant nutrition problem is through synthetic fertilizers.

Although farmers appear to prefer 'local' crop types to recommended varieties, lack of financial resources for purchasing pedigree seed may not be the significant reason. Yield potential of the local types is higher than new varieties under good seasonal conditions but it is more variable.

While smallholder farmers in the region typically use low productivity but perhaps less risky techniques, it is also well accepted that no significant improvements can be hoped for without well adapted varieties, planting at optimal densities, careful timing of field operations and adequate management of pests and diseases (Swynnerton 1961).

To achieve optimal physical and biological responses requires genotypic adaptation, appropriate crop moisture supply, adequate mineral nutrient supply in relation to environmental conditions, and pest and disease management. In addition, measures should be taken to ensure that surface soil loss is kept within sustainable limits. Given this contextual background, it would seem that sustainable strategies for improving crop production should embrace several basic principles. Such a set of principles were proposed by Evenson, O'Toole, Herdt, Coffman and Kaufman (1979).

- Each genotype performs at its biological optimum in a particular environment.
- As environmental elements depart from the biologically optimum state for a given genotype, negative genotype-environment interactions set in, reducing performance.
- The nature of this interaction differs by genotype.
- Therefore, it is possible to develop genotypes to suit different environments.
- Economic and social elements affect performance. Such effects would vary from location to location and from year to year.
- Improvement of genotypes and agronomic practices should be harmonized with the economizing behaviour of farmers. For most farmers, financial viability and production reliability are likely to be important considerations.

Guided by these principles, agricultural research has concentrated on development of crop genotypes, spacing and plant arrangements and other agronomic practices that would maximize potential for the semi-arid region. The challenge for agronomists has been to find workable alternatives that would enable farmers to apply these principles.

Rainfall dictates the timing of land preparation, time of sowing, moisture stress during the growing season and final yield. Market forces exert indirect influences through the grain supply function, the labour supply function and relative wage rate profiles. As already stated, rainfall is a significant influence on farming in the region. For one site, a 27 year rainfall mean was 701 mm with the range of 450 mm (1976) to 1 121 mm (1963). There is little potential for irrigation on technical and economic grounds.

Since farming practices depend on seasonal conditions, success with implementation of crop management strategies may well depend, at least in part, on the possibility of making realistic forecasts about seasonal conditions. A method to enable both forecasts of seasonal potential and recommended tactical response (response farming) was developed at NDFRC (Stewart and Faught 1984; Stewart and Kashasha 1984). Employing the CERES maize crop growth model, Wafula (1989 ch. 6) compared response farming with conventional practice at various levels of inputs. He reached a tentative conclusion that response farming does provide higher mean yield with less chance of failure. McCown, Wafula, Mohammed, Ryan and Hargreaves (1991) assessed the value of the concept as a predictor and compared economic performance of various input allocation strategies with and without such forecast information. Conclusions reached were that farmer's low input practices are inferior to the optimum strategy under response farming using high input levels and that response farming strategies using low inputs were superior to set strategies at the same input levels.

This line of research led to the development of crop production technology that is sufficiently flexible to enable farmers to make tactical responses as seasonal conditions unfold. Basically, the scheme can aid the farmer in four ways.

- Provides a basis for the evaluation of suitability of a particular crop for a given set of seasonal conditions.
- Earliest and latest acceptable dates of onset of the rains for growing the crop can be determined.
- Initial rainfall which should be accepted by the farmer as the signal to sow the crop can be quantified.
- Provides a basis for informed speculation as to expected performance of the crop.

To implement the procedure, the following steps should be followed. The date of onset triggers recommendations on date of planting, initial plant densities and fertilizer (basal) application. Rainfall totals, 50 days after onset in the short rains and 30-40 days into the long rains, permit categorization of season type and determination of the appropriate adjustments in plant densities and fertilizer (top dressing) rates. At 75 days into the season, total season rainfall can be estimated, and predictions of maize yield provided (Stewart and Faught 1984). The crop management scheme that is implied by response farming concepts is summarized in Table 4.1a. for the first season, the short-rains season.

Examination of the rainfall record of 27 years for NDFRC revealed that for the short-rains season, the earliest, median, and latest dates of onset were October 16th, November 2nd and November 23rd respectively. The earliest, median and latest dates of onset for the long rains season were January 23rd, March 6th and April 16th respectively. Up to 25 per cent of crop land can be sown to maize/beans intercrops should the date of onset be early. Maize should be sown at 8 plants/m^2 (Stewart and Faught 1984). Fertilizers should be applied at the rate of 20 kg/ha of nitrogenous (N) and 20 kg/ha of phosphatic regardless of whether onset occurred early or late. If onset occurred early, and the season's potential can be categorized as good (A), plant density should be adjusted downwards to 6 plants/m^2. Additional fertilizer application at the rate of 40 kg/ha (N) is recommended. No additional fertilizers should be applied in low potential early onset seasons. The crop should be thinned back to 2 plants/m^2. For the long-rains season (LR), the pattern is similar to that shown in Table 4.1a. Recommended sequencing of activities following occurrences of particular events is as shown in Table 4.1b. This scheme has not been incorporated into the extension strategy so far. Mainly for this reason, the method has not been adopted by farmers (Stewart 1991). Nevertheless, there are recommended practices concerning planting time, seed rates and final plant stands, and spatial geometry (Weir 1986), which appear to be simplifications of the response farming notions.

Table 4.1a: Agronomic recommendations for maize production

	First Season(SR)			
Date of onset		Early		Late
	October 16th-November 2nd		November 3rd onward	
Crop/Mixture	Maize/Beans≤25%		Beans>Maize, no mixtures	
Date of planting	On receiving 30mm+		Dry plant,Nov 4th	
Seed rate (plants/ha)	80000		60000	
Basal application (Kg/ha)	20-20-0		20-20-2	
50-day rainfall amount	R≥4.8mm/day	R≤4.7mm/day	R≥4.1mm/day	R≤4.0mm/day
Season type	Good (A)	Poor (c)	Fair (B)	Poor (C)
Final stand count (plants/ha)	60000	20000	40000	20000
Side dressing(Nkg/ha)	40-0-0	0-0-0	20-0-0	0-0-0
Expected yield(kg/ha)	5100	1500	2600	1500

Source: Stewart and Hash (1982).

Table 4.1b: Agronomic recommendations for maize production

	Second Season(LR)			
Date of onset	Early		Late	
	Feb 10th - Mar 15th		Mar 16th onward	
Crop/Mixture	Maize/Beans≤50%		Beans>Maize, no mixtures	
Date of planting	On receiving 30mm+		Dry plant	
Seed rate (plants/ha)	80000		60000	
Basal application (Kg/ha)	20-20-0		20-20-2	
50-day rainfall amount	$R \geq 3.2$mm/day	$R \leq 3.1$mm/day	$R \geq 3.6$ mm/day	$R \leq 3.5$ mm/day
Season type	Good (A)	Fair (B)	Fair (B)	Poor (C)
Final stand count (plants/ha)	60000	40000	40000	20000
Side dressing(Nkg/ha)	40-0-0	20-0-0	20-0-0	0-0-0
Expected yield(kg/ha)	5100	1500	2600	1500

Source: Stewart and Hash (1982).

4.5 Planting Date, Plant Density and Fertilizer Application

Although the maize production technology package that is recommended by the extension services for semi-arid eastern Kenya consists of many components, the analysis of this chapter is confined to the three mentioned earlier, timing of operations, plant density and inorganic fertilizers.

4.5.1 Timing of field operations

To obtain maize yields that are close to the genetic optimum, field operations should be performed at optimal dates in relation to the onset of the rains. In smallholder situations however, variability in climate and resource supplies nearly always conspire to constrain the realization of this ideal (Nadar, Chui, Waweru, Bendera and Faught 1982).

Nadar *et al.* (1982) classified crop growth stages according to moisture requirements into three main stages. These were, the vegetative stage (GS1), the floral initiation stage (GS2) and the pollination and physiological maturity stage (GS3). At the NDFRC, (GS1) lasts 28-32 days. In this period, the plant meristem is totally devoted to producing leaves. Compared to GS2 and GS3, evapo-transpiration is relatively low. The plant is not as sensitive to moisture stress.

Flower initiation starts at the beginning of GS2. This stage lasts between 25 and 30 days. Leaf expansion, inter-node elongation and tassel initiation take place. Moisture requirement is high. Should any drought stress occur at this stage, severe penalties in terms of yield reduction can be expected.

The third stage, (GS3) lasts 50-60 days. It starts with pollination and ends with physiological maturity. Moisture requirement is high. Drought stress at this stage will result in reduced seed numbers, and therefore, yield. Careful timing of field operations is essential to successful production of a maize crop in the semi-arid environment.

To assess the effect of planting date on maize yield, agronomic field trials were carried out during 1979-80. The details of these trials are reported in full in Nadar (1984a). His results form the basis of the stochastic efficiency analysis reported later in this chapter. It can be said, however, that farmers who intend to implement this innovation will need to resolve the labour shortage constraint.

4.5.2 Plant population and seed rates

Mean planting densities at the farm level are usually about 2 plants/m^2 even when seasonal moisture is not limiting (IADP 1977; Ockwell *et al.* 1991b). However, agronomic research by Nadar (1984b) has established that increasing plant population from 3 plants/m^2 to 7.5 plants/m^2 leads to increases in yields (peak production was at 6 plants/m^2) (Nadar 1984b). This suggests that considerable production (and perhaps profit) potential is lost on smallholdings because the correct planting strategy is not followed.

Findings of the agronomic field trials that were conducted at the NDFRC formed the basis in the current study for appraising the planting density and seed rate innovation. Planting densities ranged from 3.3 plants/m^2 to 7.5 plants/m^2. Details of these trials are reported in Nadar (1984b). Mean initial plant populations for high, medium and low densities were 6.2, 4.9, and 3.8 plants/m^2 respectively, as shown in Table 4.2a. The data pertain to the period 1978/79 to 1982/83.

Table 4.2a: Plant population (plants/m^2)

Level	Plants/m^2			
	Range	Mean	Yield (kg/ha)	No. of Obs.
Low (SL)	3.3 - 4.2	3.8	4 338.00	5
Medium (SM)	4.3 -5.2	4.9	5 335.00	6
High (SH)	5.5 - 7.5	6.20	5 064.00	5

Source: Nadar (1984b).

Table 4.2b: Inorganic fertilizers

Rate of application (kg/ha)					
	N				
$P_2 O_5$	00	26	52	78	104
00	00,00	00,26	00,52	00,78	00,104
20	20,00	20,26	20,52	20,78	20,104
40	40,00	40,26	40,52	40,78	40,104
60	60,00	60,26	60,52	60,78	60,104
80	80,00	80,26	80,52	80,78	80,104

Source: Nadar and Faught (1984b)

4.5.3 Fertilizers

Seasonal rainfall is often short of the amount required for efficient utilization of fertilizers. Timing and methods of application are also known to influence efficiency of utilization. Agronomic research has indicated that yield response varies according to nutrient source. In the SAT, however, the critical issue is the interaction between moisture and nutrients (Nguluu 1993). Probability of no response and even crop damage following fertilizer application is high when moisture is inadequate. Hence, synchronization of these is important. To assess the economics of the inorganic fertilizer innovation, data from agronomic field trials conducted over seven seasons (1978-82) were used to determine optimum levels of nitrogenous and phosphatic fertilizers. The test cultivar was the KCB variety. Fertilizer rates were set at the levels shown in Table 4.2b. Planting density was set at 5.5 plants/m^2. These trials were conducted between 1978 and 1982. Over this period, there were five good (type A) seasons (two in short rains and three in the long rains), four fair (type B) seasons (one short rains and three long rains) and two poor (type C) seasons, both occurring in the short rains.

4.6 Procedures and Methods

When farmer recommendations are derived from average responses based on results of field experiments conducted over several seasons at given locations, difficulties arise when interpretation of such results is attempted. Such interpretations can be expected to vary with variation in rainfall amounts and seasonal distribution. In addition, site-to-site variability in soils and other ecological characteristics of the farms are also expected to influence performance. Lack of reliable information on the technical relationships among inputs and outputs implied by the recommendations does tend to have a negative impact on the main aim of the extension process, which is to explain and demonstrate the usefulness of the innovations.

The conventional agronomic trials which yielded the data used in the first part of the technology assessments of this chapter were carried out over a period of five seasons (planting density) to seven seasons (chemical fertilizers). These field trials were carried out at two sites only, that is, at NDFRC and at the Kampi ya Mawe site. However, agronomic research for the development of farmer recommendations for the semi-arid lands of Kenya needs to take into account season to season climatic variability as well as site to site differences due to soils and other influences. This, however, is difficult to achieve through the conduct of agronomic field experiments. One way of overcoming these difficulties is to construct a crop growth model that can be used to simulate crop growth and development processes. Crop growth models that relate crop growth to climate, soil, genotype and management factors can assist in the evaluation of strategies for enhancing smallholder productivity. This would help facilitate efficient use of information to advance the knowledge base on varietal responses to management under different conditions.

The aim behind the development of these models is to provide a basis for systematic analysis of all or part of the crop production system. Basically, these models are set up to synthesize information on rainfall, soils and management to simulate yield and profitability levels that may be associated with given production strategies as well as the risks entailed. The crop growth simulation procedure is founded upon two main considerations (Ritchie 1991). First, total biomass of a plant is the product of growth rate and growth duration. Secondly, economic yield of the plant is the proportion of biomass that is partitioned to grain. Basically, simulation of crop growth and or development involves the prediction of these processes. As crop growth models are conceptual representations of simplified crop production systems, it is necessary that the model with the best chance of predicting well is identified. Some desirable attributes of crop growth models were proposed in Ritchie (1991). These were:

- General applicability in space and time. The models should make reasonable predictions for situations other than the specific ones they were developed to cater for.
- Data requirements should not be excessive, and it should be easy to link the model with other models (e.g., soil management process models).
- Amenability to structured programming and user friendliness.

In recent years, a number of crop growth models which meet most of the criteria outlined above have come into existence, and, indications are that more will appear. Ritchie (1991) has listed no less than 37 crop growth models that had been developed over the period 1975-1990 for the simulation of the growth of 13 crops, and, three general purpose models.

A crop growth model which could be used to simulate crop performance under different soils and climatic conditions was adopted for use in the semi-arid eastern Kenya. The model chosen was CERES-Maize. This model was originally developed by the Agricultural Research Service of the United States Department of Agriculture at Temple, Texas (Jones and Kiniry 1986).

CERES-Maize simulates crop phenology, leaf area development, assimilate accumulation and partitioning, soil water balance, soil nitrogen, and grain yield. The inputs which the implementation of the model requires include soil, climate, genotype and management data. These data were developed at NDFRC, following a series of field experiments. Climate data for all the sites described in Table 4.3 was obtained from the Kenya Meteorological Department.

Table 4.3: Locations of yield simulations

Site	Agro-ecozone	Longitude	Latitude	Altitude (MASL)	Farm(s)
Iveti	LH2	37.283E	1.446S	1890.0	105
Katumani	UM4	37.233E	1.583S	1601.0	NDFRC
Kitui	LM4	38.016E	1.366S	1177.0	102
Makueni	LM4	37.616E	1.800S	1204.0	101,104,107,108
Makindu	LM5	37.833E	2.283S	1000.0	103,106
Zombe	LM5	38.233E	1.450S	610.0	Additional site
Konza	UM6	37.133E	1.733S	1655.0	Additional site

Agro-ecozones

- LH2 = Lower highlands zone 2
- UM4 = Upper mid-lands zone 4
- LM4 = Lower mid-lands zone 4
- LM5 = Lower mid-lands zone 5
- UM6 = Upper mid-lands zone 6

The CERES-Maize model that was described in Jones and Kiniry (1986) underwent significant adaptation to the growing conditions that obtain in the semi-arid region of Kenya. The researchers involved in the adaptation and implementation of the model (Keating, Godwin and Watiki 1991; Keating, Wafula and Watiki 1992a,b) recognized the need to calibrate the model for climatic as well as crop attributes that were vastly different from those for which the model had been developed.

However, there was a dearth of soil, management, location or crop specific data that would have been suitable for the calibration. Initially, no less than eight field experiments were conducted between 1985 and 1989 to develop the required data. These experiments were designed to generate data sets for various soils, fertilizers , water and other management treatment responses in the main agro-ecological zones of the region. The experiments were sited at three locations, namely, NDFRC (AEZ[5] UM4[6]), Wamunyu (AEZ UM4/5), and Kiboko (AEZ LM5). Some 159 data sets were generated. Results of these field experiments were characterized by considerable variation. Grain yields ranged from 1600-8000 kg/ha.

In the course of model implementation, it was found that in general, the model performed reasonably well (R^2 values were in the order of 80 per cent). However, some problems were identified, necessitating further adaptations. These were: capacity to simulate plant death in cases of extreme water stress, delayed silking due to severe nitrogen stress and better accounting for total leaf number. Another important enhancement was the development of routines representing a significant management decision support system employing the concepts of 'Response Farming' (Stewart and Faught 1984; Wafula 1989). The Visual interactive capability was also added (Hargreaves and McCown 1988). The crop growth model incorporating these enhancements was named CM-KEN. It was this enhanced version of the Ceres-Maize model that was used to generate data for the analyses that are reported under the 'results of yield simulations' section in this chapter.

In a variable production environment like in semi-arid eastern Kenya, the interactions among the effects of climate, soil, and management are likely to feature prominently in the obtainable outcomes (Nguluu 1993). By way of recognizing the significance that such interactions may have for adoption decisions, four crop production strategies that were considered to have the greatest potential for improving smallholder productivity were adopted as the basis for these simulations. The practices considered were: three cultivars (DLC, KCB and Local); delayed planting (days after onset of the season); plant populations and nitrogenous fertilizers application.

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[5]Agroecological Zones (AEZ) as defined in Jaetzold and Schmidt (1983).

[6]Temperature zones LH, U/LM designate Lower highlands (15-18°C), Upper Midlands, (18-21°) and Lower Midlands (21-24°C). Mean annual temperatures are enclosed in parentheses. Temperature zones are combined with humidity zones 2 (sub-humid), 3 (semi-humid), 4 (transitional), 5 (semi-arid) and 6 (arid) respectively.

The two cultivars, DLC, and KCB are recommended for farmers in AEZ LH2-U/LM4 and U/LM5 respectively. The local cultivar is not recommended because of its late flowering growth habit. Planting was delayed by 5, 10 and 15 days after onset of the season. Test plant populations were: 1.1, 2.2, 3.3, 4.4, 5.5 and 6.6 plants/m^2. Nitrogen fertilizer rates were: 0, 20, 40, 80 and 160 kg/ha. Yield simulations were run for both long and short rains seasons for all the years for which data was available.

Principles of microeconomic theory of production were applied to data generated from agronomic field trials (Nadar 1984a,b; Nadar and Faught 1984a,b) and from the CM-KEN yield simulations, and farm input and produce prices in order to assess the extent to which strategies incorporating innovations represented advantage over traditional practice.

4.6.1 Microeconomic theory of production

It is widely accepted that smallholders in developing agriculture are rational agents seeking to maximize some self-improvement function (Hardaker, Anderson and Dillon 1984). Given the validity of this proposition, farm-level production problems can be analyzed within the contextual framework of the theory of the firm.

Let the production possibilities set be designated $A(a)$ where a (a vector of parameters) is the set of all input-output combinations that satisfy the usual properties. $A(a)$ is a non-empty, closed, convex, monotonic and bounded set. The production function is given by:

$$F(X;a) \equiv \max_Y[Y:(X,Y) \in A(a)] \quad (4.1)$$

where X is an n vector of inputs and Y is an output. The corresponding cost function is given by:

$$C(P_x,p_y,Y.a) \equiv \min_X[p_x^A,p_y^A,X : F(X,a) \geq Y] \quad (4.2)$$

where p represent input prices (p_x) and output prices price (p_y) respectively. The production function describes the technical relationships between the levels of inputs and maximum output that can be obtained for a given technology. It represents the technological restriction on the profit seeking behaviour of the firm. The basic statistical model used is (4.3).

$$Y = X\beta + e \tag{4.3}$$

In keeping with convention, let Y the dependent variable, represent the level of output that is associated with the level of technology (inputs) X. β is a coefficient of transformation of X into Y and e is an error term. Y is a vector of random variables with mean vector $X\beta$ and covariance $\sigma^2 I$ and e is a vector of random variables with mean 0 and variance $\sigma^2 I$.

Smallholders in semi-arid environments may well be interested in various moments of yield and net return distributions that are implied by alternative production strategies. Once uncertainty is brought into the picture, neoclassical measures may no longer be appropriate for the analysis of the firm's allocative behaviour (Batra and Ullah 1974; Pope 1982; Newbery and Stiglitz 1981). For example the neoclassical framework may be inadequate for exploring the relationship between risk and efficiency. The main problem is that isoquants are not defined for stochastic technologies. Therefore, there is a need for a generalized analytical framework wherein risk neutrality, mean-variance analysis and stochastic dominance are special cases.

The logical starting point for the analysis of stochastic production should be derivation of probability distributions of output. Let S^n be a non-negative, bounded subspace of an n-dimensional Euclidean space. The firm's n-element random output vector Y may be defined by the conditional joint probability distribution function $f(Y \mid x) : S^m \rightarrow S$ for given values of x, an input vector.

Further, let the firm's revenue be R such that $R = pY$ (p is a conformable vector of output prices). Another variable, w, (input price vector) has to be defined. Then, net revenue, π, can be determined via equation 4.4.

$$\pi = pY - wx \tag{4.4}$$

Both Y and π are well defined random variables with conditional probability distributions $g(Y|x):s \to S$ and $h(\pi \mid x): s \to S$. When the firm's objective function depends on either R or π rather than Y, it may be more convenient to represent the firm's technology as $g(R \mid x)$ or $h(\pi \mid x)$. Moments of Y, R, and π exist and uniquely determine the corresponding probability distributions.

The firm's stochastic technology is given by equation 4.5. A set of output distributions T are written in relation to its moments.

$$T = f(Y \ x): S^n \to s, x \in X_T \tag{4.5}$$

Thus, a stochastic technology is a set of output distribution functions associated with a given set XT of variable and fixed inputs. For a given vector of fixed parameters α, an input vector x E X_T, and a production process $f(Y \mid x)$ E T, the firm possesses a real valued scalar objective function J (x, α) which is globally concave in x and has an interior global maximum at x^*. The vector α represents all other variables related to the firm's objectives which are not elements of x.

Mathematically, the firm's objective function can be represented as in Equation 4.6.

$$J(x,\alpha) = \int_{-\infty}^{\infty} G(Y,\alpha,x) f(Y|x) dY \tag{4.6}$$

G is usually assumed monotonic increasing in Y. Other restrictions may be imposed on G.

The above definitions provide a basis for the complete ordering of the set T of output distributions when a complete parameterization of the objective function is given.

When G is assumed monotonic increasing in Y, but other properties of G are not specified, technical efficiency is equivalent to first degree stochastic dominance (FSD) (Anderson 1974; Anderson *et al.* 1977). If other derivative restrictions are imposed, then, technical efficiency is equivalent to higher-degree stochastic dominance (Fishburn 1974).

4.7 Stochastic Efficiency Criteria

The most successful paradigm of choice under uncertainty so far is the expected utility hypothesis (EUH). The gist of EUH is that for a decision maker for whom a set of (reasonable) axioms of rational choice apply, a utility function, $U(x)$, which uniquely determines his ranking of an uncertain prospect x, exists. The utility function relates a choice to a single valued index of desirability, an exact representation of personal belief and preference. There are problems of applying these concepts in practice relating to violations of the underlying theorems, estimation of preferences and the personal nature of expected utility. For these reasons the number of studies employing the approach has remained low. Stochastic efficiency criteria can be used to order choices in a wide range of situations without the need to elicit utility functions.

An efficiency criterion partitions decision alternatives into two mutually exclusive sets, an efficient set and an inefficient set (Levy and Sarnat 1972). The efficient set contains the preferred choice of every individual whose preferences conform to restrictions implied by the particular criterion. A number of stochastic efficiency rules have been developed, each for a particular group of decision makers (according to implied restrictions on utility functions). Use of such rules, can permit risky alternatives to be ranked in the absence of detailed information about individual preferences.

Stochastic efficiency rules have been the subject of extensive coverage in the literature in recent years. The literature on stochastic efficiency theory varies greatly in complexity and sophistication. Anderson (1974) presents a compact discussion of the first, second, third and fourth degree stochastic (FSD, SSD, TSD and QSD) dominance criteria via relevant theorems and proofs. The basic structure of the theory is outlined in Appendix C, following his scheme.

The main strengths of this particular approach in relation to smallholder farming are that detailed specification of utility functions or probability distributions is not required. This is in addition to availability of an efficient algorithm along with computer code to implement it (e.g., McCarl 1987).

4.7.1 Evaluation of the stochastic dominance framework

As a framework for decision making under uncertainty, stochastic dominance theory draws strength from the fact that risky choices can be ranked without requiring exact specification of utility functions. For this reason, the concepts can be applied to larger numbers of decision makers, thereby reducing the problem of application of the Bernoullian utility theory to elicit actual utility functions. To take advantage of flexibility that the approach offers, seemingly, there has been a proliferation of applications of SD since the appearance of the first paper on the subject in 1962. The nature of problems to which SD concepts have been applied have been as varied as the subject areas. The most significant subject areas to see large-scale application of SD are finance, economics, mathematics, operations research, statistics, mathematical physics, mathematical psychology and engineering, to list but a few. By 1982, Bawa (1982) was able to publish an 'extensive but by no means exhaustive' listing of not less than 400 bibliographic items on the subject. A wide variety of problems in farming, in general and smallholder farming in particular, involve analysis of choice from among uncertain prospects. SD criteria are particularly suited as analytical tools, given the large numbers of decision makers involved. For this reason, there have been a number of applications in agricultural economics. Analysis of control of a maize insect pest; selection of wheat varieties; adoption decision concerning a package of new maize technology (Anderson 1974); and assessment of varietal performance (Barah, Binswanger, Rana and Rao 1981) are among the earlier applications of SD to agricultural problems. Uses of these criteria as predictors of reduced tillage (Lee, Brown and Lovejoy 1985), and in comparison of water conserving irrigation strategies (Harris and Mapp 1986) are examples of more recent applications.

Several efficiency criteria of differing discriminating power and ease of application have come into existence. In general, discriminating power depends on the nature of restrictions that are placed upon particular classes of utility functions for specified groups of decision makers. However, the number of decision makers for whom an efficiency criterion applies would vary inversely with the number of restrictions on their utility functions. At one extreme, FSD places no restrictions beyond the requirement that decision makers prefer more to less, but it has little discriminating power. By contrast, the Generalized Stochastic Dominance rule (*GSD*) can be applied with the required level of discriminating power, at the cost of more information about the decision makers utility function (exact specification of utility function should lead to exact prediction of choice).

While SD is widely used as a tool for empirical analysis doubts have been raised concerning the requirement that decision makers be risk averse. In cases of risk preference, clearly, SD concepts higher than FSD are not applicable. The concepts are also difficult to apply in situations where non-linear interactions among stochastic factors, non-linear constraints, discrete choice variables and adaptive strategies apply (King and Robison 1981). Particular care also needs to be taken when the alternatives to be compared are not mutually exclusive or they are not perfectly correlated.

It has also been pointed out that SD performs well when there is a finite and small number of choices (Kramer and Pope 1981). Groups of smallholders for whom analyses are required tend to be composed of large numbers. They also tend to operate fairly diverse portfolios.

The SD method operates on probability distributions. For prescriptive analyses, "objective" probability distributions, perhaps obtained from historical data would be sufficient. If, on the other hand, descriptive or predictive use is intended, subjective probability distributions should be elicited from decision makers. Quite apart from the well known difficulties of specification of probability density functions that are appropriate to particular situations, elicitation of subjective probabilities is likely to encounter similar problems as would elicitation of utility functions. In such cases compromises are usually made.

Despite the problems that have been pointed out in this section, SD is still one of the dominant conceptual means for characterizing choice within the expected utility theory framework. The position of SD in this regard is likely to remain unchallenged into the near future, and on-going research on theoretical and empirical fronts can be expected to provide resolutions to some of the concerns raised.

Risk/returns relationships for strategies employing the three innovations were assessed using performance data that had been obtained through agronomic field trials and from the CM-KEN simulations. The GSD method (Raskin and Cochran 1986) was used to identify risk efficient yield distributions. The Arrow-Pratt risk aversion coefficients that were used as bounds on the utility functions were elicited from household heads in the region (see Chapter 7).

4.8 Results and Discussion

Four innovations related to maize production in the semi-arid region of Kenya were assessed for operational feasibility and for expected contribution to farm household income and nutrition. There were three aspects to the procedures and methods used in this assessment. First, it was considered necessary an understanding of the performance of the maize enterprise under traditional management. This aspect was pursued as part of the farm survey. Secondly, the survey could not be relied upon to yield certain types of crop management and performance information. Therefore, direct observations, measurements and estimations on a strategically selected subset of farms had to be resorted to by the researcher and his colleagues at the NDFRC. Thirdly, because of the poor adoption record for the innovations, farms could not be relied upon to supply data on the performance of the innovations under recommended practices at reasonable cost. For this reason, crop performance data were obtained from the agronomic research program at the NDFRC and from CM-KEN yield simulations.

4.8.1 Results of the survey of farm-level performance of innovations

Survey results from 94 farms indicated that farmers knew about the innovations concerning timing of field operations and the associated advantages (98 per cent). The recommendation about plant geometry also appeared to be well understood (1ft by 3ft). The inter-row spacing, however, is generally interpreted in terms of plough passes and would clearly depend on the condition of the shear and mouldboard. Reasons for low plant densities include pest and rodent damage (59 per cent), poor rainfall distribution (14 per cent) and low seed rate (4 per cent). Weed management strategies differed widely among farms. Nearly one half of the farmers stated that they started weeding two weeks after germination. Only 18 per cent start weeding one week after emergence. Some farmers, (27 per cent), stated that they start weeding three weeks after emergence. The number of weeding operations per crop was found to depend on prevailing seasonal conditions. During poor seasons, 62 per cent of the farmers would weed once only and 38 per cent would weed twice. During average seasons, 15 per cent would weed once, 73 and 12 per cent would weed two and three times respectively. Should the season turn out to be good, 58 per cent would weed three times, 41 per cent once and one per cent four times.

More than one half of the farms (57 per cent) believed that all their cropland is deficient in plant nutrients. A further 34 per cent believed that more than half of the cropland is deficient in plant nutrients. Despite farmers awareness of soil fertility problems, few apply inorganic fertilizers (19 per cent). The majority applied organic fertilizers (83 per cent). All the farmers who applied inorganic fertilizers also apply organic fertilizers. For farmers who applied organic fertilizers, 39 per cent had never succeeded in covering more than one quarter of their cropland while 37 per cent covered between one quarter and one half. All respondents cited lack of labour as the reason for failing to cover bigger portions of their cropland.

Survey results showed that most farmers did not possess the knowledge that is required to implement the inorganic fertilizer innovation. The majority were aware that fertilizers can be purchased at the cooperative society's shop (64 per cent). Only three per cent were aware of different types of fertilizers that exist. Few farmers were able to give responses to questions about rates of application, timing of application, carry over effects, storage and care that coincided with extension recommendations. Even farmers who have adopted the fertilizer innovation also showed a lack of effective understanding of this innovation.

4.8.2 Performance of the maize crop under farmer management

For each of the eight farms that were earmarked for participation in the modelling exercise, performance data for the 1989/90 short rains maize crop were recorded. These observations covered six variables, namely, within and inter-row spacing, plant population, seed rates, stover yield and grain yield. Observations on the first two variables, within and inter-row spacing, were intended to give some indication about planting geometry (Table 4.4). Seed rate is a major determinant of plant population which in turn determines grain yield. Observations on stover yield were taken because it has direct economic use as livestock feed.

Table 4.4: Performance measure for maize crops (farmer management)

	Performance measure												
	WRS[1] (cm)		IRS[2] (cm)		PPn[3]		STY[4]		SDR[5]		GRY[6]		No.
Farm	Mean (cm)	cv. %	Mean Nos.	cv. %	Mean	cv %	Mean (kg/ha)	cv %	Mean (kg/ha	cv %	mean (kg/ha)	cv %	of observations
101	48.7	38.77	96.88	25.76	24150.00	42.99	1840.00	50.43	16.31	43.10	1047.00	58.75	16
102	51.11	24.48	100.00	n.a.	20089.00	18.60	1546.00	37.96	13.56	18.54	1213.30	29.81	9
103	37.00	n.a.	1004.00	n.a.	19134.00	57.14	983.67	84.68	13.04	54.86	559.00	102.03	12
104	n.a.	n.a.	n.a	n.a.	14635.00	83.79	1951.00	78.15	10.01	81.04	1155.20	83.49	12
105	61.43	47.39	80.00	17.48	25600.00	61.59	2708.00	67.10	17.29	61.48	1811.40	61.63	7
106	58.67	63.06	100.00	n.a.	25680.00	61.65	1578.70	66.95	17.33	61.62	640.00	52.03	15
107	67.50	59.31	91.67	31.49	16800.00	48.29	1900.00	73.26	11.30	n.a.	797.05	72.74	12
108	64.00	39.11	89.00	24.53	19560.00	37.18	1940.00	47.17	13.22	37.09	1536.00	36.52	10

- 1. Within row spacing
- 2. Inter-row spacing
- 3. Plant population
- 4. Stover yield
- 5. Seed rate
- 6. Grain yield.

4.8.3 Results of assessment of production strategies incorporating the three innovations

Results of the agronomic trials carried out at NDFRC showed that average yield performance of each of the strategies implied by the innovations was higher than that obtainable under traditional management. To obtain measures of financial performance, yield and input/output price information were combined to generate gross margin distributions. The general trend was that most treatments with non-zero input levels outperformed traditional management in terms of grain production and gross margin. The strategies that were based on the inorganic fertilizers innovation tended to be associated with high coefficients of variation.

4.8.3.1 Timing of planting

Assessment comprised only two treatments, before and after onset (Nadar and Faught 1984a). The before onset treatment was by far superior to the after onset treatment. No further comparisons were thought necessary. The results of the CM-KEN yield simulations discussed in section 4.8.4, however, provided a more robust basis for the analysis of the time of planting innovation.

4.8.3.2 Seed rates and plant population

The highest mean grain yield (5 335 kg/ha) was attained following implementation of the medium plant population strategy. This strategy also had the highest mean gross margin per hectare (KShs. 7 541.00/ha). On the basis of mean performance (yield and gross margin) alone, farmers would benefit by adopting the medium seed rate strategy. Of the three levels of seed rate strategies, however, medium seed rate had the highest coefficient (25.65 per cent) of variation while low seed rate had the lowest (8.39 per cent).

4.8.3.3 Inorganic fertilizer strategies

Combinations of nitrogenous and phosphatic fertilizer at the levels indicated were compared with each other and with the no fertilizer strategy. Interactive relationships between Nitrogenous and Phosphatic fertilizer are indicated in Figures 4.1 and 4.2. The effect of increasing applications of nitrogenous and phosphatic fertilizer on the variance of yield were assessed through changes in the coefficient of variation. The trend was that when either phosphatic fertilizer or nitrogenous fertilizer was held at zero level, increasing application of the other type of fertilizer tended to result in higher coefficients of variation. At fixed positive levels of phosphatic fertilizer application, increasing rates of nitrogenous fertilizer had the effect of increasing the coefficient of variation (Figure 4.1).

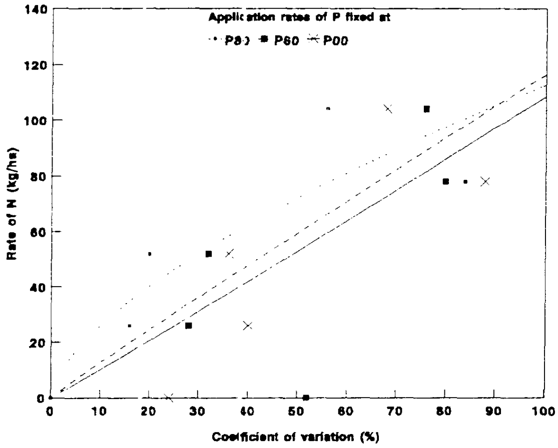

Fig. 4.1 Productior risk associated with N application at fixed levels of P

The reverse appeared to be the case when rates of application of nitrogenous fertilizer were held at fixed level of application while rates of application of phosphatic fertilizer were varied. With nitrogenous held at fixed levels, higher rates of application of phosphatic fertilizer tended to result in lower coefficients of variation. These relationships are summarized in Figure 4.2. These results suggest that in the semi-arid region of Kenya, use of phosphatic fertilizer may reduce the risk of loss of investment in nitrogeneous fertilizer. The need for agronomic research focussing on the underlying mechanisms and how these might be beneficial to farmers is clearly indicated.

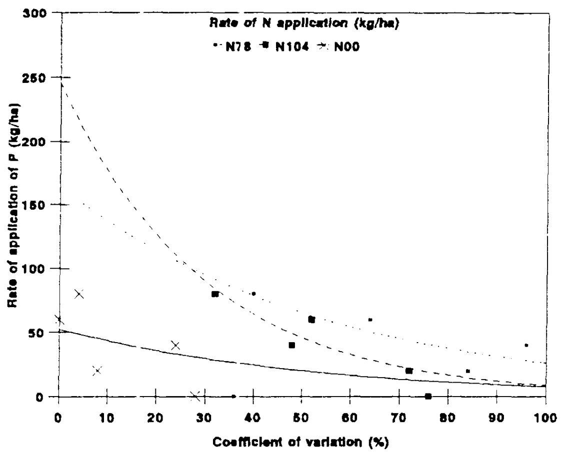

Fig. 4.2 P fertilizer application and associated risk at fixed levels of N fertilizer application

4.8.4 Results of CM-KEN simulations

Through the application of the CM-KEN crop growth model, data sets of yield response for representative sites in major agro-ecological zones in the semi-arid regions of Kenya were obtained. The findings of these simulations are presented in Figures 4.3 - 4.8f.

The measures adopted for expected impact on subsistence, incomes and risk were mean yield, gross margin, and, their respective coefficients of variation. In keeping with convention, gross margins were calculated as the difference between the gross product and total variable costs per hectare. The major variable factor inputs were nitrogeneous (N) fertilizer (Kshs. 58.00 per kg of elemental N); pesticides (Dipterex for the control of stem borers at Kshs 500.00 per hectare) and commercial seed (Kshs. 12.50 per kg). Seed rates were arrived at on the basis that an individual maize seed weighs approximately 320 milligrams (L. Kimotho, 1993, pers. comm.). The most significant item of harvesting costs is gunny bags (Kshs. 12.50 a piece).

In order to determine if there are season-to-season differences among performance measures simulations were carried out for the long and short rains seasons separately for each site. Produce price of maize was Kshs. 188.00 per 90 kg bag. The wage rates at the time of first and second plowing were Kshs. 520.00 and 300.00 per hectare, respectively. Transport costs were estimated at Kshs. 0.90 per 100 kg per km. Labour for singling (2.5); hand weeding and top dressing (10.0); dusting (5.0) and shelling each 1800.00 kg (12) standard adult labour equivalents[7] (SALE) per hectare was assumed to be available. In addition, 10 SALE for hand weeding and top dressing; 5 SALE for dusting and 12 SALE for shelling each 1 800 kg were needed. A discount rate of 15 per cent per year was used in the calculations of net returns.

A wide range of results were obtained over the treatments and sites (Figure 4.3). Expected grain yields were consistently higher for the short rains season than for the long rains season. This was true for all sites except at Katumani and at Konza where the means for the long rains were higher than for the short rains. The highest expected grain yield (1600-1800 kg/ha) was obtained at the Iveti Ranger's Post site (LH2) while the lowest expected grain yield (550 kg/ha) was obtained at the Konza (UM6) site. These assessments also indicated that production risk is higher for the long rains season than for the short rains (Figure 4.4). Production risk was lowest at the LH2 site (0.95) and increased in the more arid agro-ecological zones.

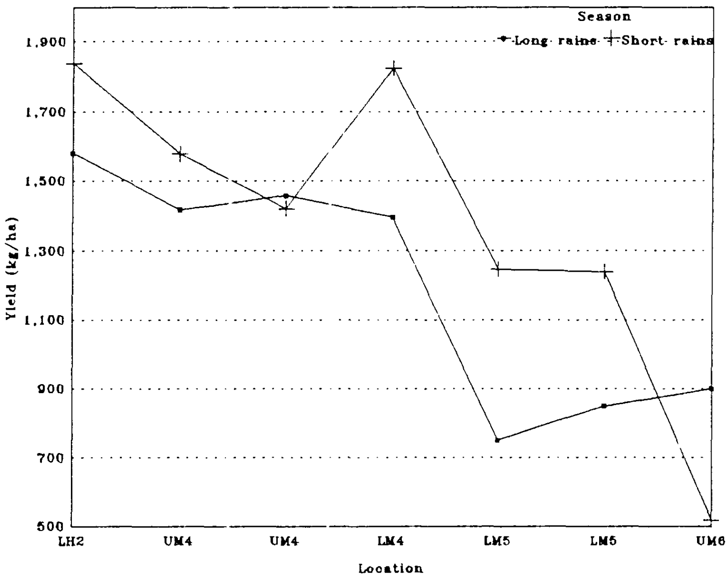

Fig 4.3 Expected grain yield simulations for seven locations

[7] 1 SALE = one adult male (or equivalent) performing normal farm work over an eight hour work day.

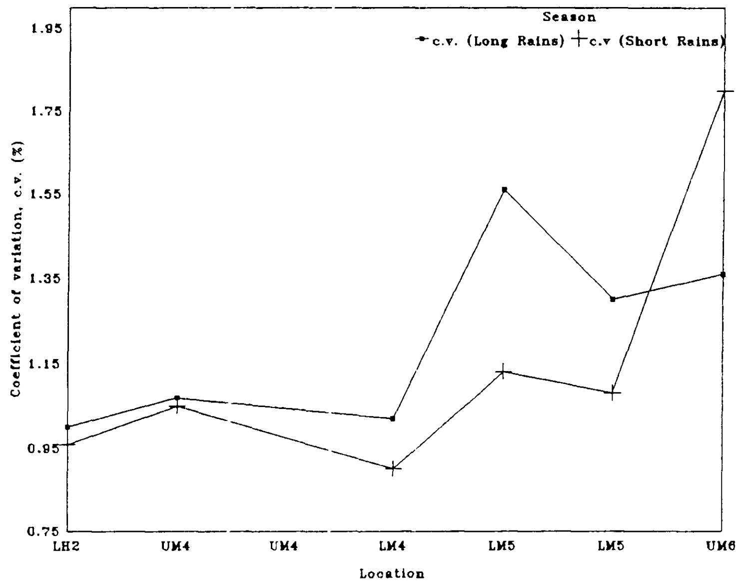

Fig. 4.4 Production risk and associated grain yield in seven locations

The effects of delayed sowing on expected yield and on production risk are shown in Figures 4.5a and 4.5b. Clearly, farmers who sowed their maize crop late stood to lose close to 200 kg/ha if planting was delayed by 5 days after onset. Losses due to delayed planting were higher in UM/LM4 and UM/LM5 than for LH2/3-UM/LM4. Production risk associated with delayed planting was also higher in the more arid agro-ecological zones.

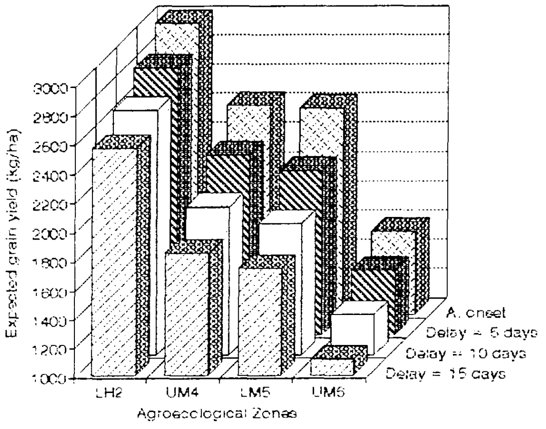

Fig.4.5a Expected grain yield associated with delayed sowing

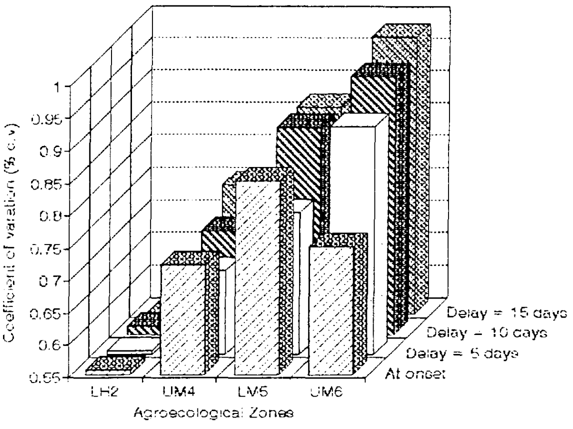

Fig. 4.5b Production risk associated with delayed sowing

The time of sowing innovation is the least complex in the package of extension recommendations for maize production. This innovation is designed to help farmers who adopt it to maximize use of available soil moisture, and to minimize the risk of crop failure. Also, effective weed control, a critical aspect of crop management in semi-arid environment, depends on careful timing of field operations. The majority of farmers are aware of the innovation (Weir 1986), and are practicing it (Tiffen, *et al.* 1994). There is evidence, though, that adoption of the early planting innovation is far from complete. For example, Muhammad and Parton (1992), found that 56 per cent of the farmers in their sample had adopted this innovation.

Expected yield and associated production risk for three maize cultivars were predicted in Figures 4.6a and in Figure 4.6b. Over all the seven sites, expected yield for KCB and local maize were about the same. However, there were significant differences across sites. Thus, there were differences in the yield of about 1 500 kg/ha between the LH2-3, U/LM4 and L/UM5/6 sites. There were appreciable differences in the production risk among the three cultivars considered and among all the sites. Farmers growing local maize would face higher risk than those growing KCB. All the cultivars assessed were of the Open Pollinated Varieties (OPV) classification. It was shown in this study, that about one third of the farmers in the agro-ecological zone U/LM4 have adopted the KCB cultivar. This level of adoption is somewhat less than the 35-50 per cent adoption of OPVs in sub-saharan Africa reported in Byerlee (1994).

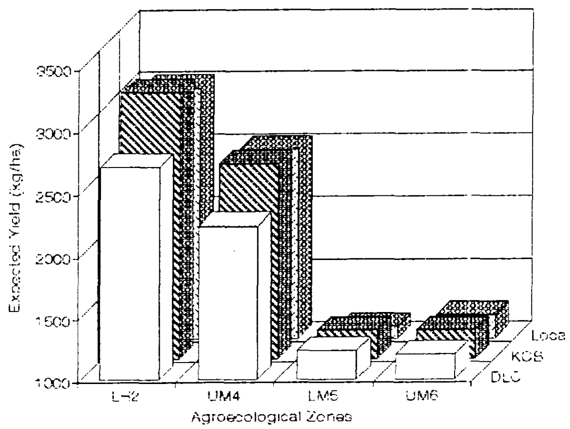

Fig. 4.6a Expected grain yield of three cultivars of maize

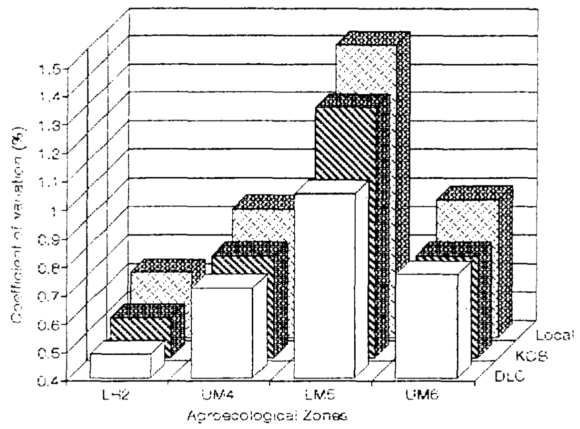

Fig. 4.6b Production risk associated with three cultivars of maize

4.8.4.1 Nitrogen fertilizers and plant population interactions

The interactive effects between nitrogenous fertilizers (N) and plant populations (PP) on maize production were also explored from within the CM-KEN framework. N treatments were: 0, 10, 20, 40, 80 and 160 kg/ha. Plant populations assessed were: 1.1, 2.2, 3.3, 4.4, 5.5, and 6.6 plants/m^2. The results of these simulations are shown in Figures 4.7a-4.8f. With N set at 0 kg/ha, (Figure 4.7a), expected yield increases by about 200 kg/ha as plant populations are increased from 1.1 to 2.2 to 3.3 plants/m^2. Increasing plant population beyond 4.4 plants/m^2 seemed to have little effect on the expected yield. The best yield responses to increases in plant population were obtained when N application was 40 kg/ha (Figure 4.7d). It should be noted that the plant population axis is labelled in thousands of plants per hectare in figures 4.7a-4.8f.

Yield increases were highest in the LH2/3 areas. Yield gains in the L/UM4 sites were modest, while for farmers in the L/UM5 and 6 sites, expected gains from increasing plant populations were low. At fixed levels of plant population, yield increases resulted as rates of N were increased from 0-160 kg/ha. Increasing the rate of N from 0 to 10 kg/ha had little effect on the yield. Doubling the rate 20 kg/ha brought about a 1000 kg/ha increase in expected yield. Raising the rate of N application above 40 kg/ha had little beneficial effect in the LH2/3 and L/UM4 eco-zones, while it had the effect of reducing expected yields in the more arid eco-zones.

Results of the assessments of the impact of the innovations on production risk are presented in Figures 4.8a-4.8f. These results indicated that production risk increased as plant population and the rates of N application were increased. At low levels of N application, coefficients of variation (c.v.) ranged from 35 (LH2/3) to 75 per cent (UM6) (Figure 4.8a.). This increased to 180 per cent as the rate of N application was increased to 160 kg/ha. These results suggest that farmers in the L/UM5/6 areas would face high production risk if they adopted the planting density and N fertilizer application rates as recommended.

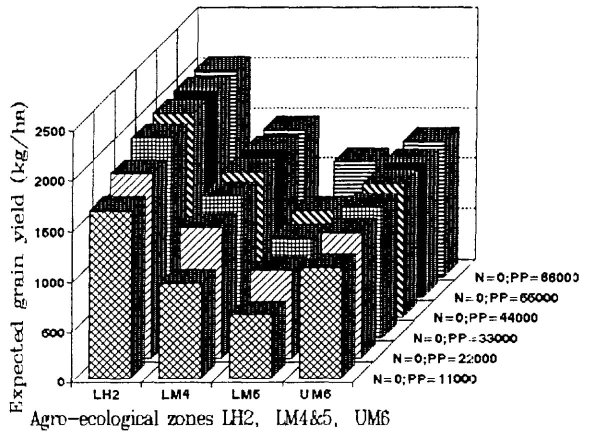

Fig. 4.7a Expected grain yield (N = 0 kg/ha; plant density = 1.1-6.6 plants/sq.m)

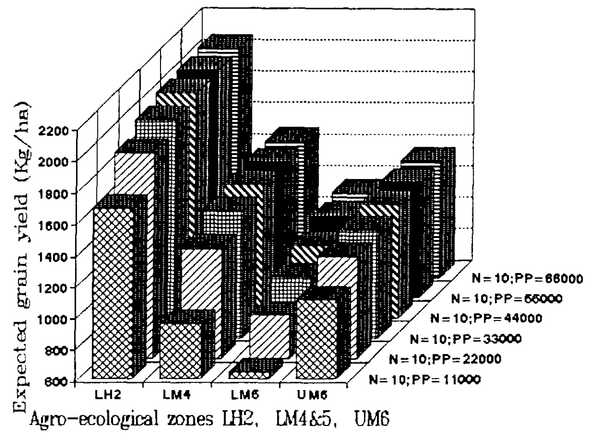

Fig.4.7b Expected grain yield (N = 10 kg/ha; plant density = 1.1-6.6 plants/sq.m)

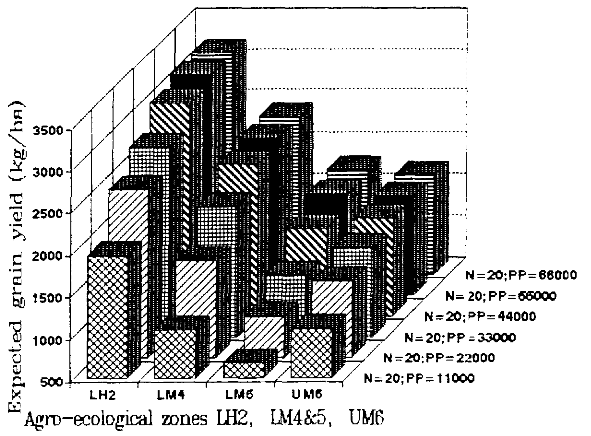

Fig. 4.7c Expected grain yield (N = 20 kg/ha; plant density = 1.1-6.6 plants/sq.m)

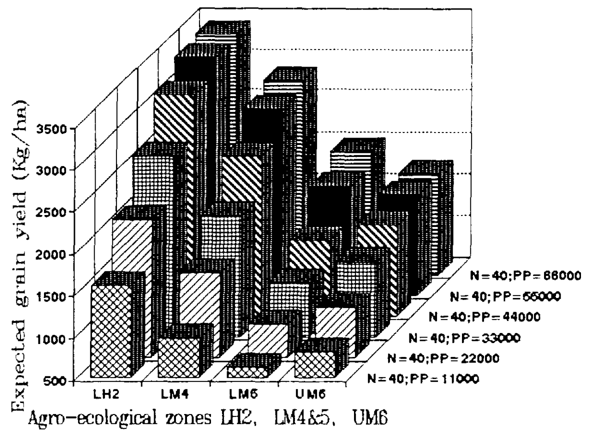

Fig. 4.7d Expected grain yield (N = 40 kg/ha; plant density = 1.1-6.6 plants/sq.m)

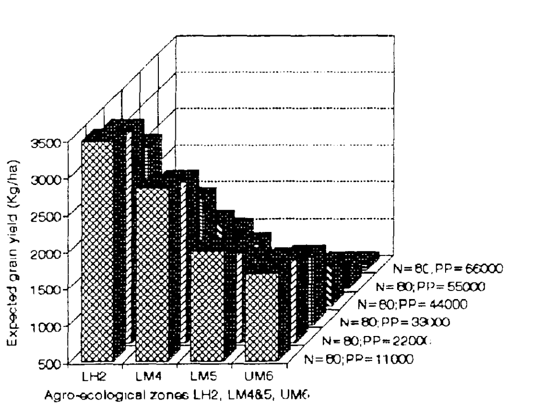

Fig. 4.7e Expected grain yield (N = 80 kg/ha; plant density = 1.1-6.6 p ants /sq.m)

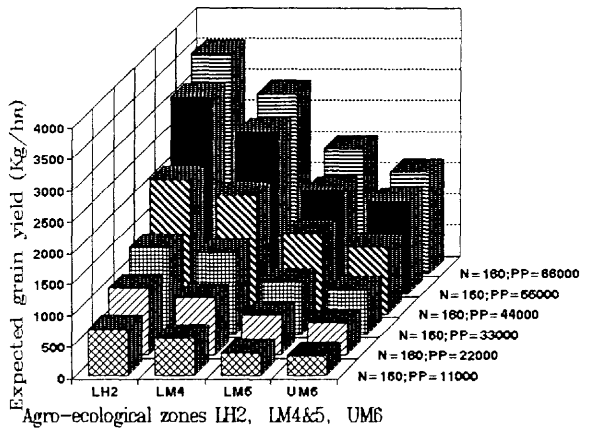

Fig. 4.7f Expected grain yield (N = 160 kg/ha; plant density = 1.1-6.6 plants/sq.m)

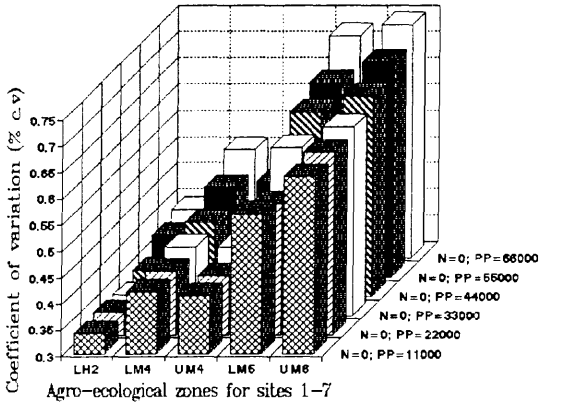

Fig. 4.8a Production risk when N fertilizer is set at 0 kg/ha and plant density range is 1.1-6.6plants /sq.m

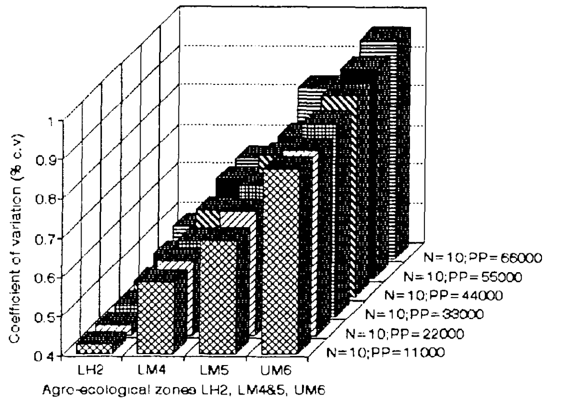

Fig. 4.8b Production risk when N fertilizer is set at 10 kg/ha and plant density is 1.1-6.6plants/sq.m

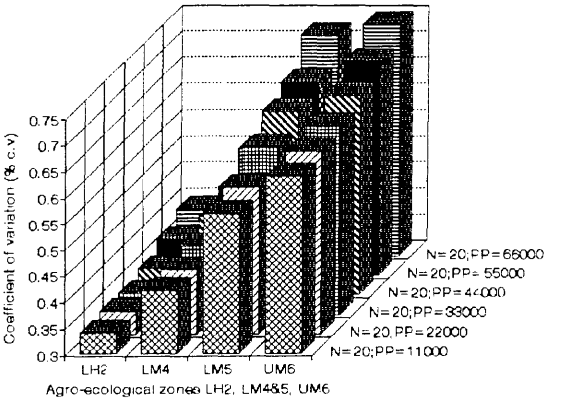

Fig. 4.8c Production risk when N fertilizer is set at 20 kg/ha and plant density range is 1.1-6.6 plants/sq.m

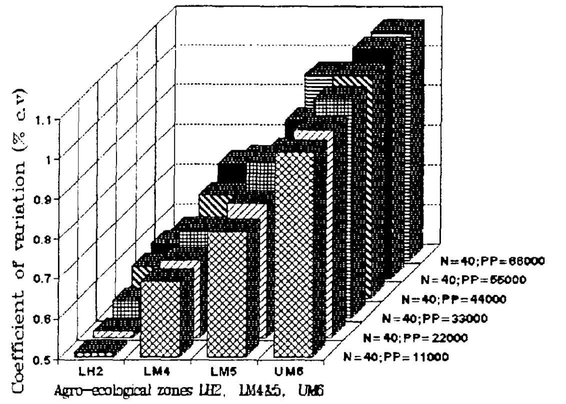

Fig. 4.8d Production risk when N fertilizer is set at 40kg/ha and plant density is 1.1-6.6 plants/sq.m

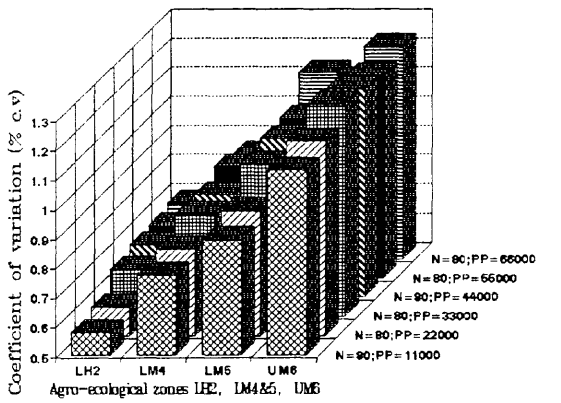

Fig. 4.8e Production risk when N fertilizer is set at 80 kg/ha and plant density is 1.1-6.6 plants/sq.m

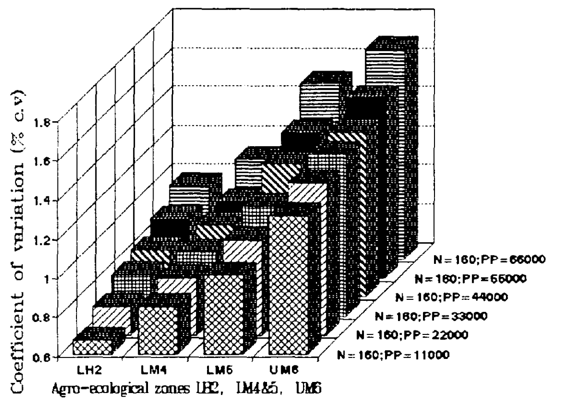

Fig. 4.8f Production risk when N fertilizer is set at 160 kg/ha and plant density is 1.1-6.6 plants/sq.m

4.8.4.2 GSD Efficient sets

Results of the GSD assessments for the cultivar, time of sowing, plant density and the fertilizer innovations are discussed in this section. CM-KEN yield simulations yielded large data sets. From these data sets, yields as well as gross margin distributions were computed. Risk-return attributes of the cultivar, time of planting, nitrogenous fertilizer use and planting density innovations were assessed from within the stochastic dominance theory framework. The aim of these assessments was to select risk efficient strategies for maize production in the semi arid region of Kenya.

The Raskin and Cochran (1986) algorithm was used to generate Generalized Stochastic Dominance (GSD) efficient sets. Upper and lower bounds on the Arrow-Pratt risk aversion coefficients were computed from utility functions which had been elicited from farmers in the region. The lower and upper bounds on the Arrow-Pratt risk aversion coefficients were 0.00007 and 0.023 respectively. For each site, GSD efficient sets were separately generated for short and long rains seasons on both well managed and poor soils. The results of these assessments are presented in Tables 4.6a (cultivars); 4.6b (time of sowing) and 4.6c (planting densities and nitrogen fertilizers).

GSD efficient sets shown in Table 4.5 tended to include later maturing varieties for the long rains season than for the short rains season under well managed soils. Assessments for poor soils indicated that farmers might be advised to use early materials in both seasons. In general, later materials are usually associated with higher production potential, and this might help explain farmers reluctance to adopt recommended seeds of early maturing varieties. GSD efficient sets for the time of sowing innovation included the planting at onset strategy only for all sites and in both seasons (Table 4.6). This highlights the high priority that should be accorded development of technology that can assist farmers to complete field operations in a timely fashion.

Table 4.5: GSD efficient cultivars for good and poor soils

	Good soils						Poor soils					
	SR			LR			SR			LR		
Site	Var	Mean	CV %	Var	Mean	CV %	Var	Mean	CV %	Var	Mean	CV %
Kitui	Local	2561	75.13	Local	3032	60.65	V.early	1544	50.39	V.early	1662	50.48
Katumani	KCB	2560	77.62	V.late	2437	87.20	DLC	2231	73.06	V.early	715	42.24
Makueni	KCB	2390	n.a	Local	3118	61.42	V.early	1631	43.72	V.early	1836	39.16
Makindu	DLC	1230	105.53	KCB	1994	89.42	V.early	1114	89.68	V.early	1409	57.00
Konza	KCB	1552	91.43	KCB	862	140.95	V.early	650	92.46	V.early	274	90.51

Note: Var - Variety
Mean - Mean yield kg/ha
V.early - Very early
V.late - Very late
KCB - Katumani composite B
DLC - Dryland composite

Table 4.6: GSD efficient time of sowing strategies for good and poor soils

	Good soils			Poor soils		
	Sowing	Mean kg/ha	c.v.%	Sowing	Mean kg/ha	c.v. %
Iveti	onset	3133	54.71	onset	2675	56.30
Kitui	onset	2162	77.75	onset	2413	68.21
Katumani	onset	2560	77.62	onset	2560	77.62
Makueni	onset	1064	144.27	onset	942	152.34
Makindu	onset	1066	144.00	onset	962	159.56
Konza	onset	1680	88.10	onset	1680	88.10

The GSD efficient sets for the nitrogenous fertilizers versus plant density strategies are presented in Table 4.7. GSD efficient strategies for all sites except Zombe included fertilizers applied at the rate of 20 kg/ha of N. Even for the Zombe site, efficient strategies for both seasons included fertilizers applied at the rate of 10 kg per hectare. This emphasized the need to make provision for minimum plant nutrient requirements. It may be that plant nutrient requirements of this magnitude are supplied from organic sources. If that is the case, this may account for at least some of the resistance to the use of fertilizers among farmers in the region. If the risk efficient rates of fertilizer (10 kg/ha N) can only result into yield increments that are comparable to a substitute like organic fertilizer, then the farmers incentive to adopt the inorganic fertilizer will be diminished. The plant density innovations differ significantly across sites and between the two seasons. It seems that there should be two planting density recommendations one for the short rains, and the long rains season. The short rains seasons GSD efficient planting populations are higher than for the long rains. Expected responses also differ among seasons and across sites. In places where production is below 1000 kg/ha, incentive to invest in these strategies may not be high.

Table 4.7: GSD efficient nitrogenous fertilizer versus plant density strategies

	Long rains			Short rains		
Site	Rate of N (kg/ha)	Plants/m^2	Mean yield (kg/ha	Rate of N (kg/ha)	Plants/m^2	Mean yield (kg/ha)
Iveti	20	4.4	1917	20	5.5	2044
Katumani	20	4.4	1585	20	5.5	1810
Kitui	20	4.4	1476	20	5.5	1476
Konza	20	4.4	922	20	4.4	1340
Makindu	20	4.4	723	20	4.4	971
Makueni	20	4.4	1459	20	5.5	1688
Zombe	10	2.2	672	10	3.3	1287

4.9 Summary and Concluding Remarks

The objective of this chapter was to assess the cost, profitability and risk attributes of the technology upon which the planting density, time of planting and fertilizer innovations are based. The main findings were:

- If variability measures risk, as is common practice, then all the strategies are associated with higher coefficients of variation, implying higher risk. For nitrogenous fertilizers, when the rates of application are raised, coefficients of variation of yield also increase. For phosphatic fertilizers, when the rates of application are increased, the coefficient of variation of yield is reduced.
- All the strategies that were assessed had skewed distributions and show significant departure from normality.
- Stochastic efficiency analysis showed that relatively large compensations are required to offset the higher risk.

- These observations are made on the basis of the assumption that farmers have already decided that maize is to be grown and the problem is to select among variations in maize technology.
- Analyses that were carried out in the preceding sections of this chapter point to the complexity of the technology development and dissemination in low input, semi-arid agriculture. Given this complexity, and in view of slow rates of adoption, it may be necessary to further assess:
  - (a) Farmer risk aversion
  - (b) The overall goal/strategy structure
  - (c) Other alternative enterprises
  - (d) Resource constraints
  - (e) Farmer knowledge levels.

Chapter 5

LIVESTOCK IN SMALLHOLDER FARMING IN EASTERN KENYA

5.1 Introduction

The place of livestock in smallholder farming in the semi-arid Eastern Kenya has been discussed in preceding sections in relation to the supply of organic fertilizers and as a source of draft for timely crop operations. Dietary, investment and a variety of socio-cultural functions of livestock are just as important in the overall survival strategies of the SAT households (McCown, Haaland and de Haan 1979).

The livestock component performs the vital task of effecting energy flows and nutrient elements cycling within the farming system and in so doing ensures that solar energy which is intercepted and transformed into chemical energy (biomass) on the farm rangelands by primary producers is available to households.

The household survival strategies include risk management mechanisms that entail diversification in income generating activities and a high level of integration among such activities. Inter-enterprise transfers are part of these interactions. When household subsistence requirements cannot be met from cropping activities, livestock are sold to realize cash with which food staples may be purchased. The reverse takes place in seasons during which surplus crop production takes place. Other things being equal, the farmer has to decide whether to commit resources to the purchase of livestock or working capital for the crop enterprise. The purpose of this analysis is to facilitate a comparison of either course of action in a manner that takes into account some of the factors that the farmer might consider.

Results of the smallholder livestock production survey that was carried out as part of this study are combined with experimental data generated by the Kenya Agricultural Research Institute (KARI) to derive measures of economic performance of the livestock enterprise under uncertainty. These performance measures are to be used in the risk programming farm models (chapter 8).

5.2 Aim of Analysis

The aim in this chapter was not to investigate the non-adoption of livestock production technology. Nor was the determination of the best operating conditions a main objective. Rather, the goal was to describe the smallholder livestock enterprise. Part of the description required that the relationships in the production system (grazing land and herbage productivity and their utilization by stock to yield draft, meat and milk) be established. Therefore, the intention was to determine the system parameters and apply economic interpretation of these in the analysis of farmer decision making. These analyses are intended to highlight important aspects of farmers' investment behaviour. For example questions such as why farmers fail to take proven investment opportunities in crop production, and instead invest in livestock can only be resolved with the help of realistic performance data for both categories of enterprise.

5.3 Background

Although the present occupants of Machakos and Kitui Districts (the Akamba) only arrived on the scene during the 17th century with an agricultural and pastoral economy of their own, livestock production has been an integral part of East African agriculture for over 4 000 years (van Eijnatten 1974). The Akamba cultivated a range of crops and kept cattle and small stock close to their homesteads in hill masses. These, together with hunting and apiculture comprised the means of livelihood.

Logistical, climatic and security concerns of the day dictated that it was neither safe, nor profitable to operate large livestock enterprises. Episodes of inter-ethnic warfare are reported to have occurred with high frequency (O'Leary 1984). Customarily, the victors were expected to pillage the property of the vanquished. This meant that operators of livestock enterprises had to contend with risk from this source in addition to climatic risk. Consequently, households kept relatively small herds.

With the establishment of the British administration towards the end of the 19th century, new mechanisms for resolution of conflict were put in place. Changes in the land tenure system brought into being the distinction between 'reserves' and 'state lands'. These developments had a profound impact on the livestock industry. With the main constraints now rendered redundant, the number of stock which the household could keep increased, leading to problems of soil erosion and land degradation.

The local government (LNCs[8]) and the Agriculture Department were concerned about the problems of overstocking, land degradation and soil erosion with each of them adopting different and sometimes conflicting approaches. The Kitui LNC for example, ascribed the problems to lack of dry season water availability. In 1927, they appointed a water engineer and instructed him to construct earth dams and drill bore holes. The drilling of boreholes failed to find sufficient water while the dam construction encountered problems of unsuitable soils and siltation. The policy of de-stocking that was pursued by the Agriculture and Veterinary Departments and the need for low priced stock by the newly built Liebig meat processing plant at Athi River led to the introduction of compulsory livestock sales. The practice was halted after the Akamba protested to the governor and the Colonial Office. Establishment of curing sheds for hides and skins and creameries which were encouraged by the Veterinary Department were also not very well received by the local community.

In 1946, the British Labour government launched a 10-year development plan for Kenya. For the semi-arid lands, soil conservation and preservation of water supplies were the major components of the 10-year plan. Implementation involved dam construction, earth terracing, afforestation of hill tops, range management and grazing control. Dam construction was undertaken at the rate of 50 per year, and several hectares of thick bush were cleared in the Yatta Crown Lands, and 1775 km of new terraces were constructed.

Plans were drawn up for enclosing denuded lands and grazing them according to a recommended rotation scheme. Rangelands within locations were scratch ploughed by teams of oxen and re-planted with grass seeds. In the early 1950s, an auction system was established to facilitate the sale of livestock (Kitui District Annual Reports 1950 and earlier issues).

5.3.1 Traditional livestock management

The home grazing consists of fenced paddocks owned by households and unfenced rangelands in and around the neighbourhood which were usually used communally. The present trend is that where land is adjudicated one must as far as possible utilize own land.

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[8]Local Native Councils were units of local government under the colonial administration.

In parts of Kitui district and, to a lesser extent, Machakos a form of transhumance (*kyengo*), which makes extensive use of state lands, came into existence during the colonial era and has persisted into the present. Cattle are moved into the state lands whenever sufficient rains fall to fill the natural water pans. As soon as reliable reports about the favourable state of the pastures are received, cattle are dispatched.

Camps comprising 1-3 herding units are situated near water pans. These may consist of cattle enclosures, fenced pens for calves and resting places for herders, usually under a tree. In an average year, the water pans begin to dry up in the months of June and July, following the end of the long-rains season and in January and February, following the end of the short-rains season. The herds are then brought back to the home grazing grounds. Pastures on state lands can never be over grazed because their utilization depends on the short seasonal life span of the water pans which in turn depends on seasonal precipitation as well as its usage. Small stock are usually tended within the farm and never as part of the transhumant system.

It must be emphasized that while the *kyengo* system plays an important role in the stabilization of the local livestock industry, only a few farmers are in a position to benefit from it. Not all livestock owners choose to utilize state land however. Those with less than 30 head and those with off-farm employment seldom find it worth their while, preferring instead total reliance on own grazing land and crop residues.

5.3.2 Labour use in livestock production

While small stock are ordinarily assigned to the care of children aged between 7 and 14 and even old men and women, cattle are always herded by men or youths. Households which are not well endowed with labour in suitable categories farm out stock to kin or more commonly, employ herders. In fact, cattle herding is the easiest entry point for youths with less than four years of formal schooling but who set out to enter wage employment. As the accumulation and building up of a herd is a key element in the establishment of a viable household, the skills gained in employment as herder become useful with time.

The livestock enterprise is a labour intensive undertaking. As the dry season progresses so do the difficulties of obtaining adequate supplies of feed and water. Wells have to be dug up, deepened and silt removed on a regular basis. Early in the dry season, two people are needed for watering stock, one to supervise the flow of stock and manage the queue while the other one lifts water to the surface of the trough. Eventually an additional two people are required. In prolonged dry seasons, cattle are watered on alternate days. Attempts to quantify labour use in livestock production on smallholdings have had to content with problems associated with these issues. Tessema *et al.* (1985) recorded labour input rates for various livestock production activities. Rates of labour application for a typical year are indicated in Table 5.1.

Table 5.1: Labour use in livestock activities

Task(s)	Farm size			
Daily input	large (minutes)	Medium (minutes)	small (minutes)	Mean (minutes)
milking	37.00	47.00	40.00	41.00
health care	28.00	9.00	9.00	14.00
feeding	25.00	180.00	38.00	75.00
herding & watering	756.00	900.00	628.00	770
Boma cleaning	90.00	60.00	n.a.	5.00
Total (person minutes/day)	930.00	1116.00	720.0	953.00
Total (person days/day)	1.14	1.69	1.09	1.44

Source: Tessema *et al.* (1985 p. 21)

* Total amount spent on herding each day. Normally, more than one person is involved. Eleven hour working days for livestock are assumed.

** Figures not adjusted to standard adult labour equivalents (SALE).

The most important source of improvement in traditional livestock production is likely to be in better utilization of rangelands. Farmers can also be expected to make greater use of crop residues to supplement natural grazing resources. Both sources of livestock feed are labour intensive. The former requires effective bush control to allow high yielding grass species to grow unimpeded. Crop residues have to be gathered, stored and actively fed. Moreover, productivity of both crop residue and rangeland is subject to climatic variability. Whilst an effective conservation strategy would be beneficial to farmers, this tends to be discouraged by high labour requirements. However, bush clearing requires an astonishing 52 standard adult equivalents (SALEs) per hectare. To ensile five tons of material, 30 SALEs are required to prepare the pit and 140 SALEs to fill it. Even without competition for labour from crops, labour shortage is likely to continue to be a significant constraint on livestock production.

5.3.3 Livestock in the household economy

Well over half of livestock in the country are raised by the farmers and pastoralists in the arid and semi-arid region (Government of Kenya 1990). At the individual household level, cropping activities do not always meet household requirements. Although meat is a luxury item in the diets of smallholders in the African SAT (McCown *et al.* 1979), the bulk of the milk that is produced on the farm is consumed by the household. Stability in the household economy is attained through purchase of subsistence goods when shortfalls in food supplies occur and purchase of stock when surplus food and cash crop production is realized. These selling and buying activities also allow households access to goods and services such as travel, education, clothing and health care which must be obtained from off-farm sources.

5.3.4 Feed resources

Overstocking is generally thought to impact negatively on stock quality, productivity and environmental degradation. These problems could be approached by de-stocking or increasing the availability of feed. As farmers have always shown an unwillingness to de-stock, considerable effort has been spent at KARI research centres on attempts to improve availability of feed (Rossiter and Ndegwa 1974; Tessema and Emojong 1984a; Tessema, Emojong, de Leeuw, and Maluti undated; Wandera 1984; Thairu and Tessema 1985; Potter 1985). In these attempts, the research focus was to resolve the feed shortage constraint. Strategies included were improvement of rangeland productivity, utilization of crop residues and planted pastures and fodder crops.

High yielding species of pasture grasses and legumes and fodder crops which are well adapted to the growing conditions of the region have been identified. The principal planted grass species that are recommended for the semi-arid areas are *Chloris gayana* (Kunth), *Panicum coloratum* L. and *Panicum maximum* (Jacq). Other species that were found suitable are *Cenchrus ciliaris*, *Bracharia brizantha*, *Themeda triandra* and *Cynodon dactylon*. At the NDFRC, many ley grass species were evaluated between 1957 and 1984. *Panicum maximum* (Makueni) and *Cenchrus ciliaris* (Biloela) were found to have the widest adaptability. Large-scale adoption of these materials does not seem to have taken place. Four factors appear to have contributed to non-adoption. Wild fluctuations in productivity, high labour requirements, the need for expensive seeds and fertilizers, and the fact that production falls after the third season seem to have combined to discourage widespread adoption, and prospects for increased adoption are not high.

The livestock industry of the semi-arid region is dependent almost entirely on native pasture supplemented with crop residues, the most important of which is maize stover. Recent studies indicate that a wealth of good grass and browse species, which compare favourably with the best ley species in terms of dry matter productivity, grow in these environments. *Themeda triandra*, *Cenchrus ciliaris*, *Digitaria abysinica and Aristida kenyensis* predominate in a large number of species present in the range lands. Total dry matter yields of 2 500 kg/ha have been recorded (Thairu and Tessema 1985). Natural pastures grow fast with the onset of the rains and by the time the rains stop, these grasses have flowered and set seed. Most grasses complete their life cycle within eight weeks. The rate of growth is highest in May, June, November and December reflecting the effect of precipitation that was received in the preceding weeks.

5.4 Procedures and Methods

Whatever method is applied, its usefulness will depend crucially on whether it is possible to identify and estimate the parameters of the technical relationships involved in the production process. Although the production system that has been described in the background section is relatively simple, depending only on livestock numbers present, amount of grazing land and crop residues, actual technical relations are complex.

Assessment of changes in productivity will rely on realistic estimates of supply of feed and the rate at which these are transformed into products. Feed supply is a mixture of many species which differ in terms of dry matter yield and quality among themselves and across time. Such feed resources can be utilized by four different species of livestock (cattle, sheep, goats and donkeys) which may be in different states of body weight, lactation or gestation with different nutritional requirements and conversion efficiencies. In addition there are at least four different product categories that the farmers would consider useful (meat, milk, draft and fertilizer). Underpinning these relationships is high uncertainty in the economic and production environments within which farmers are obliged to operate.

Given these complexities, attempts to describe the system adequately are likely to be hampered by a plethora of measurements, conceptual and theoretical problems. Development of an appropriate theoretical framework is the main concern of this section.

Data for farm rangelands, crop residue production potential, stocking dynamics, wage rates, product prices and expected rates of stock disposals were obtained through the farm household surveys that were described in chapter 3. The findings of the survey were combined with the findings of the pasture production and animal nutrition research at KARI centres (Rossiter and Ndegwa 1974; Tessema *et al.* 1985; Thairu and Tessema 1985; Wandera 1984; Potter 1985)

Concerning the need to develop innovations for the improvement of the smallholder livestock industry in the semi-arid region of Kenya, a number of issues arose. The review indicated that farmers are likely to respond to innovations that offer real economic benefits despite the socio-cultural constraints. High levels of variability that characterize farming in the region suggest that some sort of feed/fodder/browse conserving strategy should be identified through the research process.

5.4.1 Rangeland productivity

Direct assessments of rangeland productivity are discussed in Tessema *et al.* (1984, 1985) and Thairu and Tessema (1985). The stocking rate trials of 1981/82 and grazing management trials of 1982/83 provided the basis for these assessments. As a result of various field and laboratory tests, dry weight and various aspects of quality were estimated. Monthly patterns of dry matter production and changes in nutritive quality were determined. Average dry matter yields were in the order of 2147 kg/ha. In a parallel line of research (Potter 1985), liveweight gains for livestock that were kept on natural grazing in three sites covering the more arid sub-zones, were assessed, in relation to rainfall.

5.4.1.1 Rangeland productivity and livestock performance

In a year-long study of technical aspects of the traditional livestock system, Tessema *et al.* (1985) recorded stocking rates and body weights changes for different classes of sheep, cattle and goats. Other information pertaining to the performance, covering age at maturity and breeding performance, was also obtained. Liveweight gains data were fitted to a linear function via equation (5.1) using least squares regression.

$$G = A + bM \tag{5.1}$$

where G is the annual weight gain (kg/stock unit), a is the initial body weight (kg), b is a regression coefficient and M is month of the year. Following these assessments, the main results bearing direct relevance to this study were obtained and are presented in Table 5.2.

These results indicate that both productive and reproductive performance of livestock under traditional management are low. Average age at first calving was 42 months for cattle, while mean calving interval was 18 months. Performance information pertaining to milk production is presented in Table 5.3. Average milk production was 448 kg/year, over a lactation period of 286 days. Average milk consumption was 2.98 kg/day. Manure production was estimated at 0.011 kg/kg liveweight per day.

Table 5.2: Productive performance of the livestock enterprise

Activities	Performance measure		
Species/category	birth weight (kg)	Mature weight (kg)	Growth rate gms/day
cattle	26.50 (+/- -3.05)		
cows		202.00 (+/-9.00)	-17.00
heifers		179.00 (+ 27.00)	64.00
oxen		242.00 (+55.00)	n.a
heifers		179.00 (+27.00)	64.00
bulls		209.00 (+17.00)	15.00
young bulls			64.00
weaners			212.00
calves			205.00
Goats	7.20(+/-3.50)		
does		29.00+/-6.00)	17.00
bucks		31.00)+4.00)	6.00
young bucks		n.a.	n.a.
yearlings		n.a.	30.00
kids		n.a.	44.00
Sheep	6.4 (+/-2.40)		
ewes		26.00(+4.00)	4.00
rams		29.00 (+ 4.00)	11.00
young rams		n.a.	24.00
yearlings			18.00
lambs			29.00

Source: Tessema *et al.* (1985 pp. 21)

Table 5.3: Lactation periods and milk production

Performance measure	statistic					
	Mean	c.v. (%)	Minimum	Maximum	Median	Mode
Lactation length (days)	301.31	14.19	256.00	381.00	294.00	263.00
Milk yield (kg/day)	1.55	45.13	0.81	3.10	1.31	1.50
Milk yield (kg/lactation)	448.31	48.70	231.00	970.00	386.00	970.00

Source: Tessema et al. (1985 p. 41)

A related approach to the assessment of the performance of livestock in the semi-arid environment is described in Potter (1985). Field experiments carried out at Kenya Agricultural Research Institute (KARI) suggested that performance may be related to the duration of the season rather than just seasonal rainfall amounts. The reason could have been that both dietary intake and efficiency of feed conversion into liveweight gain is correlated with nutritive value of the feed. As Thairu and Tessema (1985) have shown, feed quality is related to the presence of rainfall while the quantity is related to amount of rain received. Potter (1985) proposed that a linear relationship, as shown in equation 5.2, might represent the relationship between liveweight gain for zebu type cattle and rainfall in a fairly realistic way.

$$G = 11\varphi + b \tag{5.2}$$

where G is the weight gain in kilograms per animal per year, b is a constant and φ is the number of growth periods in the year. According to this scheme, the year was divided into 10 day periods. Any 10 day period in which 20 mm of rain or more is received was defined as a growth period.

5.4.2 Contribution to the household economy by the livestock enterprise

Strategic decisions concerning the partitioning of farmland into cropland and rangeland are usually taken at the fission stage in the household development cycle. Thereafter, the area of rangeland is more or less fixed and so are the quantitative bounds on the feed resource supply. Important tactical decisions have to be made, usually within the year concerning adjustments in stocking rates. Ockwell *et al.* (1991a,b); Mukhebi *et al.* (1991) and Akong'a and Downing (1985) present evidence which suggests that many of the voluntary sales of livestock take place at the beginning of the year to meet the annual upsurge in demand for cash. By January, stocks of grain that would have been harvested during August of the previous year are almost depleted and hence, there is an increased need for supplementation through purchases from the local market. However, the most significant drain on the household cash resources is school expenses which are highest during the first month of the year. That is the period of peak activity in the local market for livestock. It may be assumed that the farmer makes decisions about the type and numbers of stock to sell after considering not only his present need and expected price but also additions to the herd that may have taken place in previous periods as well as expected supply of feed resources.

The farmer may be thought of as seeking to maximize expected 'income' from his livestock enterprise at the end of each year subject to the numbers of stock present, amount of grazing land available and expected production of feed resources. The argument of the 'farmers aspiration function' could include money from sales of stock and stock products, direct consumption of products, services of work oxen and organic fertilizer. Whilst a variety of socio-cultural dimensions of this function may not be ruled out, these can be expected to vary from farm to farm. Moreover, such variables are not amenable to measurement.

To simplify the analysis, let $I = \{x : x \in X\}$. and $N = \{y : y \in Y\}$. Define X, as the set of all 'products' from the livestock enterprise such that I is a subset of X. The membership of I might include direct consumption of livestock products (c), realizable cash from sales (K), organic fertilizer (F), and draft (d). Similarly, Y is defined as the set of all elements which might constrain the realization of X. A subset of Y, N, can be further defined. Likewise, members of N whose influence in the livestock enterprise is likely to be felt most would include herbage production (H), grazing land

ℓ, cropland (C), stock units present (l), and product price ($\wp$). Time (t) and seasonal precipitation (S) variables are explicitly written into the constrains function for more realism. Equation 5.3 depicts a transformation relationship from x into I $(x \rightarrow I)$. Similarly, equation 5.4 represents a transformation relationship $(y \rightarrow N)$.

Pursuit of the livestock sub-goal may be represented as:

Maximize

$$I = f(c,K,F,d) \tag{5.3}$$

subject to:

$$N = g(H,\ell,C,l,\wp,t,S) \tag{5.4}$$

where all the variables are as already defined.

With the necessary observations on these variables available, optimal levels of I can be determined, for example, within a mathematical programming framework. Given data limitations, however, such an approach can only be implemented with great difficulty, even if the conceptual and theoretical problems of applying mathematical programming techniques to the analysis of smallholder farming were satisfactorily resolved. Such problems notwithstanding, various approaches varying in complexity and data requirements have been proposed. Examples include Heady and Dillon (1961); Dillon (1977); Christian, Donnelly, Freer, Davidson and Armstrong (1978); Bernado and Engle (1990); Hertzler (1991) and Wang, Richmond, Hacker, Hertzler and Lindner (1989).

Most of the authors cited considered the determination of the best operating conditions. Dillon (1977, Ch. 3) suggested how the rate of pasture production and deterioration, feed consumption and production and profitability may be specified. Application of marginal analysis to the result would then be applied in the usual way. A more complex treatment of the biological system, managerial control of the biological system and optimization of managerial control based on computer simulation is reported by

Christian *et al.* (1978). Biological functions that were considered to represent plant and animal performance most closely were used in a search for higher levels of the objective function. Wang *et al.* (1989) used an integrated model (IMAGES) to derive rangeland dynamics and implied long-term best operating conditions.

5.4.3 Livestock productivity

In order to relate rainfall received, herbage production and stocking rate to performance, the Potter (1985) formulation (equation 5.2.) was adopted. Effective rainfall was defined as the number of growth periods per year. Three Fortran subroutines were developed to facilitate the transformation of rainfall data from the Kenya Meteorological Department into growth periods and cumulative weight gains. The source code for these routines is included in Appendix D. In addition a dBASE III™ program to compute milk production and organic fertilizer yields was developed.

Daily rainfall data for recording sites that are closest to the case-study farms had been obtained from the Kenya Meteorological Department. A total of five recording sites were considered. The number of observation varied from 5 years (Katangi) to 22 years (Matiliku), while the average number of observations over all the five sites was 14 years.

Initial body weights for different types and classes of stock used in this section are due to Tessema *et al.* (1985). The procedure for assessing contributions to annual income from livestock, given the current position of the household and the stated expectations of the farmers, is summarized in equations 5.5 and 5.6. Expected annual production in standard stock units was computed via equation 5.5.

$$E(\nu) = \frac{11(E[\varphi] + b) + l}{250} \tag{5.5}$$

For each farm in the case-study group, expected sales as a proportion of total numbers present ϱ / ν and expected prices $\wp$ were elicited from the principal decision maker. Expected contribution to the household in form of money was calculated via equation 5.6.

$$E(\iota) = E(\varphi) . E(\rho / \nu) \tag{5.6}$$

Other contributions were computed according to the following scheme.

$F = \nu . 0.011$ kilograms of organic fertilizers per year
$m = 149\ \nu$ kilograms per year.[9]

Consumption of livestock products c was assumed to be determined within each households according to specific needs and desires. Similarly, production of animal traction d was taken to depend on the presence of work oxen on the farm.

5.5 Results and Discussion

In the first part of this presentation, the key elements of the livestock enterprise on the case-study farms and in the farming community in the region are described. Next, the results of the profitability estimates are presented. For the farming community as represented by the sample of farms, all households except those who do not own enough grazing land have some livestock (85 per cent). Mean ownership for cattle was about seven head. Average value of cattle was KShs. 7 689.29, (KShs. 1 098.47 per head). Mean annual variable costs for cattle stood at KShs. 141.71 for draft and pack cattle, and KShs. 564.66 for other cattle. Variable costs included veterinary services, feeds and other miscellaneous items. Average productive life was stated as three years for oxen and four years for other cattle. Although local types form the basis of these estimates, a few farmers now own "grade" cattle. Mean value for grade cattle was KShs. 4 303.33 per head. Small stock (sheep and goats) and poultry are an integral part of the industry. Average prices were KShs. 345.64 (sheep), KShs. 381.23 (goats) and KShs. 66.70 (poultry).

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[9]Expected milk production m was calculated on the basis of two assumptions, that is, that average yield and calving interval were 448 kg/cow/year and 18 months respectively.

5.5.1 Stocking rates and feed supply potential

5.5.1.1 Realizable feed supplies

Estimates of the capacities of the farms to supply feed during different seasons are based on the area of grazing land and cropland sown to maize. Season types are defined on the scale of good, fair and poor as defined by Stewart *et al.* (1984). In Table 5.4, quantities of feed availability incorporate the sum of crop residues and herbage from grazing land. Assessment of herbage yields are based on results of grazing trials at the NDFRC (Tessema *et al.* 1984).

Table 5.4: Potential feed supply

			Annual production (kg)		
Farm No.	grazing land (ha)	crop land (ha)	good season	average season	poor season
101	4.5	3.5	13205	11462	360
102	25.5	6.5	59542	54748	n.a.
103	4.0	1.8	8500	8500	n.a.
104	12.5	3.5	26837	26837	n.a.
105	3.2	3.28	9570	9570	360
106	5.3	4.1	13170	13170	1800
107	2.6	4.0	5644	5644	360
108	4.5	2.5	11504	11504	360

5.5.1.2 Stocking levels

Most of the farms had at least four head of cattle and some sheep and goats. There is clear evidence of efforts to upgrade the genetic potential of cattle on some of the farms. Predictably, grazing pressure on all but one of the farms was above the recommended rate. Table 5.5 shows the distribution of livestock in standard weight units (1 standard unit, L.U. = 250 kg).

Table 5.5: Stocking characteristics

Farm	LU (Nos.)			Stock disposals (%)			Price (Kshs/beast)	
	Actual (1980)	Highest (1980-90)	Lowest (1980-90)	good season	fair season	poor season	high	low
101	8.8	13	4	20	40	60	3000	1500
102	18.4	27	12	30	40	60	3000	2000
103	7.8	15	3	30	50	70	2000	1300
104	13.1	34	8	10	40	60	3000	1000
105	5.4	40	3	10	30	40	2400	800
106	7.0	84	3	10	40	60	2200	900
107	8.4	60	5	20	40	60	2000	600
108	7.1	10	2	30	40	40	4000	1800

5.5.2 Contribution to household income

By applying the Potter (1985) method, discussed in section 5.4.3, it was possible to combine information on feed supplies and rainfall to determine the contribution to each household's income of the livestock belonging to that household. Three sets of performance measure for the livestock enterprise (gross margin per unit, milk yield per unit and organic fertilizer production per farm) were estimated. Because of instability in the parameters of the climatic variables, yields of these products are subject to significant levels of variation. None of the farmers in the sample had a risk neutral preference function (see Chapter 7). While expected values of these products may form the farmers' basis for assessing returns for the enterprise, other moments of the probability distributions for these products may be considered. Therefore, as well as mean performance, the results of the analysis are also presented in terms of coefficients of variation (c.v.) and coefficient of relative skewness (α_3). These estimates are reported in Table 5.6.

Table 5.6: Productivity of the livestock enterprise

	Productivity Measures								
Farm No.	GM*			Milk			OM**		
	Mean	c.v.(%)	α3	mean	c.v.(%)	α3	mean	c.v.(%)	α3
101	557.0	44.35	0.50	139.0	43.38	0.458	116228.0	13.08	-0.46
102	743.0	39.33	0.88	168.0	27.09	0.380	23219.0	7.73	1.44
103	430.9	34.50	0.04	178.0	3.45	0.04	10219.0	1.53	0.02
104	996.0	3.45	0.04	178.0	37.95	0.04	12644.0	3.45	0.02
105	242.0	50.30	2.18	157.0	33.19	0.12	14031.0	31.93	-0.17
106	273.0	100.00	1.57	106.0	80.90	0.99	8635.0	8.20	0.94
107	190.0	60.80	2.43	157.0	33.19	0.12	15568.0	33.41	1.25
108	690.0	52.90	0.625	139.0	43.38	0.46	17823.0	38.49	0.09

- *Gross margin per livestock per unit per year (Kshs.)
- **Organic fertilizers production calculated according to Tessema *et al.* (1985). On this basis, OM yields is 0.011 kg per kg. body weight, 80 per cent of which is 'fertiliser' and 20 per cent is soil.
- Milk production is calculated at 415 per cow per lactation (Tessema *et al.* 1985).
- α3=Coefficient of relative skewness.

Results showed considerable farm to farm variation for all the three performance measures. Mean gross margin varied from KShs. 190.00 (farm 107) to KShs. 996.00 (farm 104) per unit (mean 515.1 KShs.per unit). Gross margin distributions showed significant departure from symmetry except for farms 103 and 104, which also had the lowest coefficients of variation. These mean gross margins appear to be low in absolute terms, but if considered in relation to costs, expected returns per SALE or per Shilling spent may be higher than for the crop enterprises. Clearly, expected returns per unit of resources spent are higher on the higher productivity farms; and the higher the number of units, the higher the expected return.

Milk production is less variable than gross margin, but more variable than production of organic fertilizers. Expected production of milk per stock unit was 152.8 kg/year. The lowest expected production was 106 kg/unit while the highest production was 178 kg/unit. Coefficients of variation ranged from 3.45 per cent on farm 103 to 80.90 per cent on farm 106.

Organic fertilizer yield was assessed over the total number of stock units present at the end of the year. For that reason, direct comparisons between farms may not be appropriate. Expected production over all farms was 27295.9 kg. If applied at the rate of 8 000 kg/ha as recommended by Ikombo (1984), this amount is sufficient for 1.706 ha. This amount was found to depend very much on the number of stock units present. Thus, for farm 102, it would have been possible to cover 2.90 hectares (44.62 per cent of cropland). By contrast, farm 106 would cover only 1.01 hectares (24.63 per cent of cropland). This assumes that organic fertilizer is applied at the rate 8 000 kg/ha, as suggested in Ikombo (1984, p. 270).

5.6 Summary and Concluding Remarks

Appraisals of innovations intended for smallholder farming often fail to take sufficient account of the farmers' existing investment portfolio. Such appraisals usually fail to indicate the worth of the innovation in relation to existing enterprises. If the existing activities and the innovation compete for similar resources, this is likely to lead to a lower level of adoption. The aims in this chapter were to describe the livestock enterprise and to derive some measures of performance. Following exposition of the contextual background to livestock production in the semi-arid region of Kenya, data from NDFRC and other KARI research centres was combined with survey results to describe the livestock enterprise and to derive some performance measures.

The livestock enterprise was found to perform the main role of transforming primary production from farm rangelands into products that households can use. The actual process is complex. No analytical scheme that could handle such complexity and be implemented at reasonable cost was available for use in the research that is reported in this chapter. The simple formulation that had been proposed by Potter (1985) was used to derive performance measures. Gross margin and milk production per unit were found to be low. However, expected gross margin per unit of labour input, was higher than for some of the crop enterprises. The livestock enterprise was characterized by high fixed costs (purchase of replacement stock) but low working capital.

The main weaknesses of the methods on which the analyses of this chapter were based were pointed out in the sections in which the methods were first introduced. The main shortcoming was non-availability of reliable data on performance of the enterprise over time. For this reason, the required data were estimated using methods which need to be developed further. Nevertheless, the following observations on the traditional livestock enterprise can be offered.

First, neither the review of historical development nor examination of contemporary operation of the livestock enterprise could support the view that farmers are not rational. There was little support for the widely held belief that cultural factors may be more important than economic considerations in the management of the enterprise. Over the last seventy years or so, overstocking on smallholdings has been a main concern. However, as the analyses in this chapter have indicated, the level of stocking is not fixed. Rather, it responds to the dynamics of the production environment. If this is taken into consideration, it may be that the farmers are operating close to optimum stocking densities. Concerning organic fertilizer production, it was shown that none of the farms had enough to cover more than 45 per cent of cropland.

The widely held belief that the livestock enterprise is more important than other enterprises as a source of money income on smallholdings could not be examined in this chapter. Such analysis can only be undertaken within the whole farm context.

Concerning the need for develop innovations for the improvement of the smallholder livestock industry in the semi-arid region of Kenya, a number of issues arose. The review indicated that farmers are likely to respond to innovations that offer real economic benefits despite the socio-cultural constraints. High levels of variability that characterize farming in the region suggest that some sort of feed/fodder/browse conserving strategy should be identified through the research process.

Chapter 6

THE NON-FARM ENTERPRISE, LABOUR AVAILABILITY AND USE

6.1 Introduction

In many parts of the developing world, traditional farming is no longer regarded as the sole provider of the needs of farm families. Some of the factors which are thought to contribute to this outcome have been falling land/labour ratios in the wake of virtually stagnant technology, rising material expectations and the opening up of non-farm opportunities for supplementing household income. Survival strategies of rural households in such areas tend to include both farming and non-farm enterprises (Dixon 1990). As well as having impacts on agriculture, these trends have been observed to be intricately linked with creation of employment and income distribution in Colombia (ILO 1970); Ceylon (ILO 1971) and Kenya (ILO 1972).

From the point of view of small-farm development, the significance of the non-farm sector in Kenya is that it functions in a dual mode, providing alternative employment opportunities on the one hand and using up resources which could be used in farming on the other. Clearly, an understanding of the operational and functional aspects of the non-farm sector in relation to resource use and income generation patterns is a necessary component of any analysis of farmer decision making. Descriptions of the context in which farm decisions are made that do not take full account of the non-farm aspects are likely to be incomplete.

6.1.1 Objectives of the chapter

Despite the importance of the non-farm enterprise, it is usually treated as a minor aspect of analysis of smallholder farming. And yet the linkages between the non-farm and farm enterprises have implications for investment into farm development. A better appreciation of the nature of such linkages can serve to clarify some of the factors that impede adoption of proven innovations for farming. The aims of this chapter are:

(a) to describe the non-farm enterprise;

(b) to describe the local wage market; and

(c) to record the performance measures for this enterprise both for the farming community and for case-study farms from farmer responses.

6.2 The Rural Non-farm Enterprise

The rural non-farm enterprise has two main components: self-employment and wage-employment based activities. A good appreciation of the investment linkage between the farm and non-farm activities can lead to a better understanding of farmer behaviour in relation to labour and capital allocation between the farm and non-farm undertakings.

Rural non-farm enterprises typically require relatively little capital, often from family savings. Typically, they provide their own training in technical and entrepreneurial skills. They also foster the spread of positive attitudes to change among rural people. Small-scale manufacturing concerns are largely dependent on local agricultural, forestry and other natural resource extraction industries as sources of raw materials. Others recycle spent or scrap material, thereby conserving scarce foreign exchange. By facilitating local trade in farm inputs and farm produce, fabrication and sale of tools and implements, maintenance of vehicles and equipment, agriculture is thereby supported. Through the activities of these industries, rural people gain access to inexpensive goods and services. These self-employment activities include retail and wholesale trade, small-scale manufacturing, construction and provision of services. Next is the wage employment category which, for convenience, is discussed as salaried and nonsalaried employment.

6.2.1 Non-farm enterprises based on self-employment

For centuries, a number of traditional societies of Eastern Africa have had well developed systems of production and exchange of ornaments, cottage and craft industry, and pottery products. The Akamba were particularly skilled in craftsmanship, hunting and gathering ivory, and in commerce. They traded with the Kikuyu, Embu, Meru, Mbere and Masai communities to their immediate north-west and south-west, while long distance trade took them as far as the East African coast and the shores of Lake Tanganyika (Lamphear 1970). Livestock, ivory, ornamentals, food staples, medicines, arrows, poisons and an assortment of household goods formed the basis of local and long distance trade. By the end of the nineteenth century, the Arabs, Swahilis and Asians had made serious inroads into what had been traditional Kamba territory. Growth in trading activity between 1900 and 1950 appears to have been slow. Quoting from the Kitui District Gazetteer, O'Leary (1984) gives an account of the development of trade in the area during the period. Up until 1931, there were no Akamba-owned shops in the district. By 1950, there were 166 shops and 28 lorries and buses. Soon after the attainment of independence, development was greatly accelerated following the policy of indigenisation of commerce and industry. More households took up small-scale manufacturing, retail and wholesale trade, hawking and construction. Those who were not able to raise large sums were content to supplement farm income with earnings from cottage industries and other miscellaneous activities.

6.2.1.1 Cottage industries, petty trading and miscellaneous services

The range of activities within this grouping is very wide. Rope and basket making are the favourite occupations among women. On the other hand. apiculture, making poles and building houses are male-dominated undertakings. Provision of miscellaneous services such as preparation of food and drinks and local entertainment is another type of non-farm activity. These activities draw upon the time and skills of members of the households who have little potential for well paid wage employment. Such activities would bring in more income than general wage employment would. They require small amounts of money and can be undertaken during slack periods. Mean annual earnings are KShs. 1 040.00-1566.00. Non-farm activities of this type are probably unlikely to influence farm adoption decisions in a significant way.

6.2.1.2 Small-scale manufacturing, commerce and services

This grouping includes relatively higher skills and capital intensive activities. The main types of enterprise are listed in Table 6.1. Manufacturing of food, beverage and tobacco products has the highest frequency of occurrence (23.3 per cent). The mean annual earnings vary from KShs. 2448.00 (resource extraction) to KShs. 5 064.00 (wholesale and retail trading).

Table 6.1: Small-scale businesses

Type of enterprise	Households %	Mean annual earnings (kshs)
Food, beverages and tobacco product manufacture	23.3	4148.00
Services	17.8	3588.00
Wood products manuf.	14.0	4800.00
Plant and animal fibre products, weaving and cloth	12.4	2520.00
Resource extraction	12.1	2448.00
Wholesale and retail trading	9.3	5064.00
Metal productions	n.a.	4476.00
Construction materials	8.4	4992.00
Kiosks, entertaining & traditional healers	1.7	n.a.
Pots plates etc	1.0	n.a.

Source: Norcliffe and Freeman (1984).

More than two thirds of these businesses are owned and operated by individual family members. The average work force per establishment is three workers, of whom 44 per cent are owner/managers and 56 per cent are employees or members of the owner's household. A minority of owner managers have no formal education at all. In contrast, 16 per cent have at least 10 years of formal education.

6.2.1.3 Capital requirements

A major constraint that must be overcome by prospective entrepreneurs is lack of financial resources. Recent studies indicate that the most important source is own savings (90 per cent of the loans) followed by loans from relatives (5.5 per cent) with the official sources playing significant roles in cases of large investments (Freeman and Norcliffe 1985). As an indication of the amounts of capital required to establish several types of business. Table 6.2 lists average amounts spent.

Table 6.2: Small-scale businesses: Typical value of assets

Type of enterprise			
Low capital requirement	Value Kshs.	High capital requirement	Value Kshs.
Wood cutters	9.00	*Dukas*	20235.00
Traditional healers	855.00	Taxi operators	21415.00
Food *kiosks*	3852.00	*Posho* mills	23424.00
Cloth vendors	5303.00	Blacksmiths	7950.00
Pombe brewers	8248.00	Cloth repairs	1039.00
Furniture making	16001.00	Car repairs	12144.00
Bicycle repairs	3555.00	Tool repairs	400.00

1. *Pombe* brewers make and sell liquor from locally available ingredients
2. *Dukas* are small retail businesses
3. *Posho* mills mill small quantities of grain.

Source: Freeman and Norcliffe (1985).

6.2.2 Wage employment

Undoubtedly, wage employment is the one institution that was created entirely by the modernizing forces and has had the most enduring and profound impact on all aspects of the lives of Kenyans. Traditionally, attendance at councils, maintenance of public works, reciprocal assistance to kin and doing military service without direct personal gain were the only forms of off-farm employment that were readily sanctioned by custom. Not surprisingly, attempts to recruit labour that was needed for the construction of roads and other public projects earlier this century were usually frustrated by lack of interest. Legislative measures and the levying of taxes were resorted to in an attempt to secure a steady supply of labour, but again with little success.

Available evidence suggests that the local population were able to obtain sufficient income from agricultural production to meet tax payments. Tax returns for Kitui district, for example, show that in the first year (1901/2), Rs. 1 501 (Rupees) were collected. These amounts rose steadily to Rs. 109 800 during 1911/12 and in 1923/24, Shs. 696 088 (approximately Rs. 600 000) remaining at that level into 1950s. These legislative and tax measures appear to have had little impact on inducing voluntary seeking of paid employment outside their locality as intended.

The depression of the 1930s forced a drastic fall in traditional local exports. As if the depression was not gaunt enough, a succession of droughts occurred between 1931-36, culminating in the virtual decimation of livestock. One strategy for coping with the hardships that arose following these problems was outmigration into other areas in search of wage employment. Part of the wages earned were remitted back to their home areas to help with the reconstruction of the local economy. Attitudes to wage employment changed radically. By the late 1930s, the local economy had ceased to be self-sustaining and was increasingly dependent on the national economy. From about that time onwards, wage employment has become an accepted way of earning income.

Post-independence developments have tended to reinforce this trend. The manufacturing, transport, construction, tourism and agriculture sectors have registered reasonable growth rates. The whole economy achieved an average annual growth rate of GDP of 7 per cent (Livingstone 1981). This lent support to government efforts in the indigenization of the economy and the expansion of public sector employment.

Reliance on wage employment for at least some period in a person's working career has since become universal and for many households, a necessary strategy for survival. According to the CBS (Republic of Kenya 1981) the majority of men (and women) aged 27 and over have spent at least some time in wage employment. Youths who have attained seven or eight years of formal education and who are not needed for farm work invariably set out in search of wage employment unless they plan to enter secondary school. The common entry point is as low paid workers in plantations, public works projects and in security, building, transport and manufacturing industries. The favourite occupations, though, are: mechanic, shop assistant, carpenter, and tailor. Entry into salaried employment such as a government official, tradesperson, or teacher, is more competitive and generally better paid and harder to obtain.

A tradition has evolved whereby those in off-farm employment return home to assess investment opportunities and inspect their projects whenever opportunities to do so present themselves in preparation for final return on retirement.

A number of institutions have been established for the purpose of the regulation of industrial relations in Kenya. In 1962, the government and representatives of workers and employers signed an industrial relations charter. Soon after, an industrial court was set up to settle trade disputes referred to it either by parties to the dispute or the ministry of labour. Ten years later, the Federation of Kenya Employers (FKE) and the Central Organization of Trade Unions (COTU) came into existence. The Ministry of Labour maintains employment exchange registers of job seekers and vacancies in their respective district offices. These registers are intended to serve as sources of information from which signals from the labour market about the demand and supply situation could be generated.

6.2.2.1 Development of opportunities in formal education

The role of education in the investment linkage from non-farm to farm activities in developing countries has been the subject of several studies. In a study of the productivity of schooling effects in rural Burkina Faso, Ram and Singh (1988) concluded that the rate of returns to schooling is 'broadly in the order of 10 percent'. In Kenya, increments in monthly income amounting to KShs. 36.20 result for every additional year spent in primary school and KShs. 135.00 for each additional year spent in secondary school (Livingstone 1981). This in part explains the high priority accorded to education at the government, community and household levels.

The post-independence years have seen a phenomenal expansion in education facilities at all levels. Enrolment in primary schools, for example, has topped five million. According to Livingstone (1981), out of those who complete the final year at primary school, 14 per cent would proceed to government aided schools, another 14 per cent would enter private (Harambe) schools, 35 per cent would repeat the final year and 35 per cent would simply drop-out. Education typically absorbs more than 20 per cent of the national budget. At the rural household level, the proportion is higher.

6.3 Procedures and Methods

The principal source of the results that are reported in this chapter was the farm household survey. The data obtained from the survey were supplemented with informal discussions with farmers. In the absence of a more sophisticated analytical procedure, the results from these assessments were presented as simple cross-tabulations. Data for wage employment in the formal and informal sectors, as well as participation in the wage market and trends in job seeking, were obtained from the jobs register that is maintained by the Ministry of Manpower Development and Employment (MMED). These were supplemented with informal discussions with district officials.

6.3.1 Rural wage and adoption of innovations

On family farms that do not hire-out or hire-in workers, labour should be employed up to the point at which marginal physical product equals disutility of extra work (the value of forgone leisure). In such situations, when one worker leaves, there will be loss of production equal to the departed worker's marginal product. Assuming that the law of diminishing returns holds, removal of one worker may cause the marginal product of the remaining members of the family, who will increase their effort until marginal product equals disutility of effort, to increase. If this marginal disutility is constant over the relevant range of hours worked per man, the net effect on output will be zero.

New practices often call for increased work effort either because more work hours are required at the same rate of work, for example, sowing maize at higher seed rates, or the task is more arduous, for example, sowing seed before the rains start. Disutility of this increased effort can be measured by the difference between labour supply price for the new and old tasks. This supply price represents the wage that must be paid to induce the worker into that particular class of employment having considered all aspects of the task. Labour supply price would equal the market wage in a perfectly competitive labour market. In practice though, in the Kenyan rural labour market, supply price may never fall below a certain level, even for an unemployed person. To secure the participation of such a person, a wage that is at least equal to subsistence requirements has to be offered. Thus the higher the additional income earned by the new technology, above what is needed to offset increased input of effort, the higher the chances of adoption. These assessments will vary from farm to farm depending on both preferences and particular circumstances.

6.3.1.1 Rural casual employees

The rural labour market for casual employment in parts of the semi-arid lands is well developed. Demand for this type of labour is brought about and sustained through the existence of a variety of agricultural and nonagricultural tasks. Supply is fed by new entrants into the general wage market, farm operators, those who are unable to find employment elsewhere and retirees. Expected earnings differ geographically and also, according to particular tasks.

6.3.1.2 Salaried employment

Virtually all studies of small farmer decision making classify all types of labour into a single category. This study recognizes that casual wage employment has vastly different implications for adoption decisions than does salaried employment. There are two main differences. First, the magnitude of expected income for the latter type exceeds that of the former by a large margin. Second, preparation for participation in salaried employment invariably calls for substantial investment in education in the form of financial resources and forgone production. In the assessment of earnings from salaried employment, an assumption is made, that households make deliberate investments of resources in anticipation of income streams to be earned at a future date.

In individual households, a decision to invest in preparation for entry into the more permanent forms of wage employment is based on what is perceived to be the expected income stream as well as subjective assessment of the chances of success. A given level of expected wage would largely depend on, among other factors, scholastic achievement. Probability of securing employment at a given wage depends on the number of people seeking to be employed at that level as well as on capacity of the economy to create employment.

Table 6.3: Educational attainment and expected earnings

Level	scholastic attainment	expected wage
e1	< 7-8 years	8400.00
e2	9 - 12 years	13000.00
e3	> 12 years	32000.00

The number of school leavers who join the reserve army of job seekers every year has now topped 100,000 (CBS 1989). As the rate of job creation in the formal sector has tended to lag behind increases in numbers of job seekers, probability of securing a desired job must be on the decrease. Once one secures a job in the formal sector then, the starting wage is fixed almost entirely with reference to scholastic achievement.

6.4 Results and Discussion

Average local wage is just below the minimum legal wage (KShs. 1.76 per hour for employees aged 18 and below and KShs. 2.45 if the employee is over 18 years old). This labour market is characterized by fluctuations which follow seasonal patterns.

Expected earnings for members of respective farms who participate in wage employment described here were directly elicited from farmers. Further analyses on the wage rates are not considered necessary.

6.4.1 Demographic characteristics and potential labour supply

One of the aims of this study was to gain an understanding of how demographic characteristics interact with the socio-economic environment to determine labour supply for the farm and non-farm enterprises. There are at least three reasons for this. First, adoption of any of the innovations that are being promoted would imply additional labour inputs and, typically, radical reorganization of labour utilization profiles at the farm-level. Rational farmers may be expected, therefore, to commit additional labour for the innovation if expected return is considered worthwhile. Second, there are qualitative differences in labour supply categories within particular households according to gender, age, status (seniority), educational attainment and innate abilities. These differences will tend to be reflected in wage earning capacity for particular categories. Since adoption of purchased farm inputs has been shown to be associated with higher wage income, determination of categories of household labour supply can be useful in understanding adoption decisions. Third, strong associations among attitudinal and informational variables of labour categories among households have been hypothesized. Although results of the study that are reported in this section concern the second set of points, implications for one and three can be inferred indirectly, as shown in chapter 3.

6.4.2 Demographic characteristics

Some of the demographic characteristics that may bear relevance to adoption decisions were analyzed in chapter 3. Standard statistical test criteria showed that the hypothesis of no relevance for the age of head of household and gender variables should be rejected. In this section, as well as age, and gender, results of observations on occupation and education profiles for some households are presented in greater detail than was possible in chapter 3. Characteristics for all members of household with no off-farm occupations are summarized in Table 6.4 while those with off-farm occupations are recorded in Table 6.5.

Table 6.4: Demographic structure of selected farm households - 1989/90

Farm No.	Attribute	Demographic category					
		Age(years)					
		Under 11		11-15		Over 16	
		Male	Female	Male	Female	Male	Female
101	Number	n.a	n.a	n.a	n.a	1	2
	Mean age	n.a	n.a	n.a	n.a	27	21
	Formal education	n.a	n.a	n.a	n.a	16	10.5
	Type of education						
102	Number	n.a	n.a	2	n.a	5	n.a
	Mean age	n.a	n.a	12.5	n.a	52.4	n.a
	Formal education	n.a	n.a	3.5	n.a	4	n.a
103	Number	n.a	n.a	n.a	n.a	3	4
	Mean age	n.a	n.a	n.a	n.a	27	25
	Formal education	n.a	n.a	n.a	n.a	4.3	n.a
104	Number	n.a	n.a	n.a	n.a	6	2
	Mean age	n.a	n.a	n.a	n.a	20.2	44
	Formal education	n.a	n.a	n.a	n.a	7.4	5
105	Number	n.a	n.a	n.a	n.a	2	n.a
	Mean age	n.a	n.a	n.a	n.a	54.5	n.a
	Formal education	n.a	n.a	n.a	n.a	11	n.a
106	Number	n.a	n.a	n.a	n.a	1	2
	Mean age	n.a	n.a	n.a	n.a	n.a	n.a
	Formal education	n.a	n.a	n.a	n.a	15	n.a
107	Number	n.a	n.a	n.a	n.a	n.a	n.a
	Mean age	n.a	n.a	n.a	n.a	n.a	n.a
	Formal education	n.a	n.a	n.a	n.a	n.a	n.a
108	Number	1	2	2	n.a	n.a	3
	Mean age	8	7	13	n.a	n.a	27
	Formal education	3	2	7	n.a	n.a	8.3

Table 6.5: Demographic structure of selected farm households (1989/90) and occupation

Farm No.	Attribute	Demographic category Age(years) Under 11 Male	Under 11 Female	11-15 Male	11-15 Female	Over 16 Male	Over 16 Female
101	Number/Household	n.a	n.a	n.a	n.a	1	6
	Mean age (years)	n.a	n.a	n.a	n.a	56	33
	Years in education	n.a	n.a	n.a	n.a	3	11.8
	Occupation[a]					16(2)	17(1)
	Mean income(Kshs./year)					30.000	48.000
102	Number/Household	n.a	n.a	n.a	n.a	1	2
	Mean age (years)	n.a	n.a	n.a	n.a	18	38
	Years in education	n.a	n.a	n.a	n.a	11	9.5
	Occupation[a]					n.a	n.a
	Mean income(Kshs./year)					n.a	n.a
103	Number/Household	n.a	n.a	n.a	n.a	2	2
	Mean age (years)	n.a	n.a	n.a	n.a	31.5	44
	Years in education	n.a	n.a	n.a	n.a	5	3
	Occupation[a]					16(1)	16(2)
	Mean income(Kshs./year)					7200	n.a
104	Number/Household	n.a	n.a	n.a	n.a	2	n.a
	Mean age (years)	n.a	n.a	n.a	n.a	34.57	n.a
	Years in education	n.a	n.a	n.a	n.a	3	n.a
	Occupation[a]					16(2)	n.a
	Mean income(Kshs./year)					n.a	n.a
105	Number/Household	n.a	n.a	n.a	n.a	4	n.a
	Mean age (years)	n.a	n.a	n.a	n.a	37.75	n.a
	Years in education	n.a	n.a	n.a	n.a	9.75	
	Occupation[a]					17(1)	n.a
	Mean income(Kshs./year)					27600	n.a
106	Number/Household	n.a	n.a	n.a	n.a	2	n.a
	Mean age (years)	n.a	n.a	n.a	n.a	48	n.a
	Years in education	n.a	n.a	n.a	n.a	13	
	Occupation[a]					16(1.2)	n.a
	Mean income(Kshs./year)					30.000	n.a
107	Number/Household	n.a	n.a	n.a	n.a	1	1
	Mean age (years)	n.a	n.a	n.a	n.a	45	65
	Years in education	n.a	n.a	n.a	n.a	8	n.a
	Occupation[a]					17(1)	14(2)
	Mean income(Kshs./year)					54000	5200
108	Number/Household	n.a	n.a	n.a	n.a	1	n.a
	Mean age (years)	n.a	n.a	n.a	n.a	50	n.a
	Years in education	n.a	n.a	n.a	n.a	8	n.a
	Occupation[a]					16(2)	n.a
	Mean income(Kshs./year)					48000	n.a

6.4.2.1 Permanent employees

Existence of labour shortage on smallholdings simultaneously with high unemployment in most African countries may seem anachronistic. The problem is commonly brought about by high dependency ratios, the 'urban pull' (Gugler 1968) and seasonality (Feder *et al.* 1984; Anderson 1992). Shortfalls in labour availability represent a serious constraint on farm productivity. To cope with labour shortage, farmers often resort to external sources to supplement available household resources. There are four ways in which this is approached. Casual labourers may be employed when needed, provided that the farmer is able to pay the prevailing wage Farmers for whom casual workers are the main source of supplementary labour face greater uncertainty with respect to timely performance of farm tasks and, also labour costs. There are a further two alternatives that farmers can resort to in times of acute labour shortage. First, there are extensive networks of intricate kinship relations within which a farmer may find assistance. Second, farmers who are members of communal labour *mwethya* groups are expected to draw assistance from their group. Use of these last two sources, however, may carry even greater uncertainty with respect to cost and availability. Finally, some farmers employ labourers on a permanent basis.

The survey results showed that 23 farmers had between them, a total of 29 permanent employees (1.25 workers per farm). These were relatively young people, all of them male. The age range was 14-55 years (mean is 27) but 65 per cent were 25 years old or younger. Out of the 29, twelve had no formal education at all, six had five or more years in formal education (mean = 5 years).

All permanent employees appear to have been drawn from the immediate locality. This may be an inbuilt device to ensure that the arrangement works to the mutual benefit of both employer and employee. The normal working day is invariably short. The working year varies across farms (mean = 291 days). Under such working arrangements, the employee has the opportunity to work his own fields too. Compared with the legal minimum wage for rural labourers (KShs. 22.00 per day), salaries paid are low (mean = KShs. 11.25 per day). In addition to this wage, employers typically provide indirect emoluments such as food, clothing or use of farm assets.

6.4.2.2 Wage employment

Although households often fail to realize their farm objectives because of labour shortage at critical periods, the majority have at least one member in wage employment. For convenience, participation in paid employment was classified into five sectors, namely, agriculture, handicrafts, commerce, services and other. While other classifications (e.g., Freeman and Norcliffe 1985) are more comprehensive, they employ concepts that the particular group of farmers were not familiar with.

Not all respondents had detailed knowledge of the circumstances of employment of particular members of the household. Attempts to determine how a particular worker should be classified were often unsuccessful. Information pertaining to age, gender and years in formal education was easier to elicit than data for income, for example. Nevertheless, information that was obtained was considered sufficient to describe the wage income strategy for these households.

A total of 107 persons over the sample were reported to be in various forms of paid employment. Out of this number, one was in agriculture, two in handicrafts, 10 in commerce, 77 in services, eight in light industry, while nine could not be classified reliably. Participants in non-farm employment were drawn from both sexes. The age range for participants was much wider than for farm employees. More than half were aged between 20 and 69, and 41 were less than 20. Mean age was 39, while mean school years was eight. Average wage was KShs. 16 394.00. Age, years in formal education and wage level tended to be strongly related with the particular sector of employment.

The most lucrative sector was services. Average age, years in formal education and wage of employees in services was 32 years, 10 years and KShs. 24 175.00, respectively. For commerce, the figures were 34 years, 9 years and KShs. 17 320.00. Figures for rural-based industry, like agriculture and handicrafts, stand in sharp contrast. Average wage for the agriculture was a mere KShs. 200.00. Mean age, years in formal education and wage for employees in the handicrafts industry were 44 years, 5 years and KShs. 3 000.00, respectively.

6.4.2.3 Self-employment

A large proportion of farmers in the sample operated other enterprises in addition to farming. A total of 125 persons (entrepreneurs) were reported engaged in self-employment type activities. Again, both sexes were represented in all categories. For the services industry, average age, years in formal education and return were 38 years, six years and KShs. 37 350.00, respectively. In commerce, average age and years in formal education for the entrepreneur were 45 and five years, respectively. Average earnings in commerce were KShs. 20 750.00. Compared to commerce and services, the rural based enterprises did not show impressive results. Mean age and years in formal education of entrepreneurs were 44 and five years, respectively. Mean earnings were KShs. 1 624.00.

6.5 Summary and Concluding Remarks

Components of the rural non-farm enterprise that may have significance for adoption decisions were identified and described in this chapter. For expository convenience, production activities that do not involve farming operations were classified as non-farm enterprises. Of these, only the self-employment and wage-employment based activities were considered in this study. Results of the household survey indicated that virtually all households operated various types of non-farm enterprises. Over 80 per cent of the households had at least one person in wage employment. These results are consistent with findings of studies carried out in other regions of Kenya (e.g., Freeman and Norcliffe 1985).

Results of the survey showed that the rural wage market in the region is relatively active. Out of 94 farmers, 23 had at least one permanent employee. For the sample as a whole, no fewer than 107 persons were engaged in paid employment. A further 125 persons were engaged in self-employment type activities at the time of the survey. These observations might seem inconsistent with the findings pertaining to farmers concerns about shortage of labour to carry out farm practices in a timely fashion (chapter 4). However, income earned by these individuals was, by local standards, very high. Average income was KShs. 24 175.00 and KShs. 17 320.00 in services and in commerce, respectively. Contrast this with KShs. 2 400.00 earned by those engaged in farm-related employment. It seems that other things being equal, the non-farm enterprise is likely to compete for labour and financial resources that are potentially available for investment in farming. Capacity to operate non-farm enterprises, however, differed from individual to individual and from farm to farm.