Chapter 7

HOUSEHOLD GOALS AND STRATEGIES

7.1 Introduction

The innovation diffusion literature suggests that there are a large number of factors which influence adoption decisions (Parton 1991). Perceived attributes of innovations, type of adoption decisions, information channels and socio-cultural contexts are but some examples of such factors. The work of Hunt (1978) and Ockwell *et al.* (1991a,b) in the semi-arid Eastern Kenya, for example, has established the relevance of the hierarchical nature of household goals as factors that influence farmer decision making. Neither analysis of socio-cultural and institutional factors that are often associated with smallholder decision making nor the assessment of the economic and operational feasibility attributes of the innovations, adoption of which is the subject of this thesis, have categorically provided plausible explanations for lack of adoption that is often observed in the community. This was taken to suggest that other mechanisms too are exerting influence on decisions in significant ways. A likely set of such mechanisms could be the household goal system itself. The need for analysis of decision making based on household beliefs and preferences is clearly indicated.

A two-stage analysis of the main elements of the decision making in smallholder households has been adopted. The first stage of this strategy is implemented in this chapter. The main elements of decision making processes are clarified and described in the context of modern decision theory. Using elicitation procedures based on these concepts, farmers' goals, strategies and attitudes are derived and presented.

Implementation of stage two of the strategy is taken up in Chapter 8. The costs/returns relationships that were established for the new technology and the crop enterprise (Chapter 4); livestock (Chapter 5) and the non-farm enterprise (Chapter 6) are used to build mathematical risk programming models of representative farms. With the aid of post-optimality analysis, assessment is made of the impact of adopting new technology on the farmers' goals and the earnings from resources. Stage 1 and stage 2 together can provide a sound basis for grouping farms into categories for which specific types of research and development initiatives are appropriate. Probable consequences of such initiatives on the farms could be assessed with greater realism, effectiveness and convenience.

7.1.1 Motivation

The majority of studies on smallholder development in Kenya have tended to isolate and enumerate constant attributes of farming systems as they exist at the time of these respective studies. Very rarely are research problems formulated in terms of structure, relationships and interdependence. However, as in many parts of the developing world, the rural sector in Kenya is undergoing change on an unprecedented scale. Shifts in the parameters of demographic variables and the development of rural-urban linkages have had combined influences on goal setting and formulation of strategies in relation to resource use in farming. These changes seem to harbour profound implications for adoption of innovations and hence, need to be understood more adequately.

Since this study was designed to complement and extend the results of past farming systems research efforts at the NDFRC, a brief review of the methods used as well as the main findings may serve as a useful starting point. NDFRC was among the first of the national research centres in the Eastern, Central and Southern Africa region to introduce a socio-economics service to complement the mainstream agricultural research. Initially, the orientation was diagnostic. In the first phase, an on-farm research program designed to identify production problems in the Machakos and Kitui districts was initiated in collaboration with the CIMMYT Eastern Africa economics program in 1978. Two years later, orientation of the program shifted in favour of descriptions of prevailing farming systems in order to provide a basis for planning activities of the GK/FAO/UNDP and the GK/USAID/USDA dryland research projects (Kunert 1984; LeBeau 1984).

By 1984, diagnostic surveys for Mwala, Mutomo and Ishiara had been completed (Rukandema 1984). A total of 600 farm households were covered. Additional special purpose surveys were performed focusing on farm equipment (Pollard 1981), dryland crops seeds (Muhammad, Steeghs and Scott 1985) and the Training and Visit extension program (Weir 1986). The main findings of these studies have been highlighted in chapters 1 and 2. Basically, farm production and incomes are low, and yet most households appear to have resisted adoption of innovations which could help to raise productivity.

To test the operational viability of the technology upon which innovations were based, 24 farms were chosen so as to represent ecological variation in the region. While on-farm trials established the financial viability of the innovations (Bakhtri *et al.* 1984), adoption of the entire package, even for the 24 farms, was only partial. More information was needed from these farmers on their failure to respond positively to innovations of proven worth.

To obtain the type of information required, a case study of 16 out of the original 24 farms was undertaken as a component of the KARI/ACIAR/CSIRO Dryland Farming Project in Kenya (McCown and Jones 1992). Although the procedural design had elements that bore similarity to those described by Maxwell (1986), it was independently developed by the ACIAR/CSIRO project economist at NDFRC. This undertaking resulted in a detailed record of attributes of farm households and husbandry practices spanning a 15 month period. For the 18 households[10] participating, the following postulates were proposed (Ockwell *et al.* 1991a,b).

- Farmers espouse a definite concept of expectation in relation to the occurrence of events.
- Adoption of innovations with certain characteristics tended to be associated with households with particular demographic and socio-economic attributes. For instance, innovations requiring low financial outlays had been adopted on virtually all farms while 'expensive' ones were adopted by better educated farmers with off-farm income.
- There were indications that farmers may be severely risk averse.

A hierarchical goal system was described for the participating households. Realization of family subsistence was the most important goal followed by education of children, investment in livestock and non-farm enterprises and acquisition of a variety of consumer items.

Concerning the long-term management and continued productivity of strategic assets such as land, the study records that a steady reduction in average farm size is under way, following subdivision of land among off-spring.

In this study, it is sought to extend the findings of the diagnostic surveys, on-farm trials and the case study program to the analysis of observed adoption patterns in several ways. First, it is necessary, if for the sake of clarity, to redefine the goal sets and the set of strategies that may be implemented in pursuit

[10] An additional two farms without prior contact with NDFRC had been selected to participate as controls.

of goal attainment separately. Second, attributes of the innovations under consideration need to be assessed not only in terms of operational feasibility, but also in relation to potential impact on resource use and household income. Third, it is necessary to bring into the picture the role of forces beyond the farm gate. Fourth, as the case study program covered 18 farms out of a 2 million strong farming community, it is worthwhile relating the findings obtained to a larger sample of the farming community. Clearly then, samples of responses of goals and strategies as well as risk aversion measures for the community should be obtained to enable the goal/strategy system for the community to be explored adequately. To complete the analysis, appropriate farm models need to be constructed.

7.1.2 Objectives of the chapter

The aim in this chapter is to present a description of the smallholder household goal-strategy system of relevance to adoption decisions. Beginning with the identification of and presentation of the concepts and theory of household organization, the local context is described next. A search for a suitable theory of decision making is attempted through a critical evaluation of a number of contending alternatives. Methods and procedures that were employed in the assessment of household goals as well as preferred strategies for the pursuit of goals are described next. Recognizing the role of risk in semi-arid farming, an attempt was made to assess both goals and strategies of farmers in relation to risk as well as estimates of levels of risk aversion among farmers.

7.2 Perspectives on the Theory of Decision Making

Choice of technology is a typical decision problem. The minimum configuration of a decision problem may be described by the existence of the following conditions, after Anderson, Dillon and Hardaker (1977).

(a) There has to be some agent who has an objective to be attained (decision maker).

(b) There has to be an objective or goal to be achieved (ends).

(c) There are at least two alternative courses of action available that can lead to the attainment of the goal or at least have a significant probability of facilitating attainment (means).

(d) There is some doubt as to which course of action is best in terms of achieving the objective (uncertainty)

(e) It has to be possible to delineate the environment within which the problem is to be solved, and how changes in the parameters of the relevant environment influence the outcome of whatever course of action is chosen.

(f) The agent must have some capacity to exercise some control over whatever course of action is chosen.

Thus far, a number of terms (decision maker, values, goals, strategies and attitudes) supposed to convey specific meaning to some aspect of decision theory have been introduced. It is considered appropriate that the meaning of each of these terms in this study be explained before discussion of decision theory is taken up again.

7.2.1 Decision makers

An appreciation of the forces that drive farm-level decision making and how such forces are brought to bear on a particular problem facing a household can be sought through careful analyses of the composition and the roles of the individual participants. The logical starting point in such analyses would be description of the structure of the household. In this regard, various definitions of rural households that could be applied to the semi-arid Eastern Kenya (e.g., Republic of Kenya[11] 1981; O'Leary 1984; Ockwell *et al.* 1991a) have been attempted. All three bear more similarities than differences. According to CBS (1989), a rural household comprises:

> ... a person or group of persons generally bound by ties of kinship ... community of life in that they are answerable to the same head. Under this definition would be included spouse(s), scions, sibs, parents and not uncommonly, other agnatic and affinal relatives ...

They go on to define a farm holding as:

> ... all the land and livestock operated by a single holder. The household may in fact operate neither land nor livestock, as in the case of non-agricultural rural households. ... one or more of the senior members of the household may or may not be resident on the farm.

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[11]Report of the Central Bureau of Statistics (CBS) *Integrated Rural Survey* of 1978-79. This survey covered the whole country.

O'Leary's (1984) definition is essentially similar, but with the following addition:

> ... the basic unit of production and consumption is the conjugal family and in case of polygynous families, the *nyumba* (house) which consists of a woman and her children under care of her husband.

Ockwell *et al.* (1991a) also consider the farm-household as a decision making unit and then proceed to describe what is, essentially, an extended family structure. All these definitions espouse the notion of 'principal decision maker' or the farmer.

7.2.1.1 The individual in the household

Although in the mainstream theory of traditional farming a single person (the farmer) is identified as the decision making agent, it is suggested in this study that in most cases, such identification is likely to deviate from reality significantly. Rural households vary greatly in terms of composition, structure and organization.

For a given household, each individual will invariably have needs, compulsions, restraints and interests that are peculiar to him. More likely than not, the individual will develop his own system of habits as well as commitments to groups outside the household (e.g., school friends, church, etc.). Moreover, it is expected that the individual's characteristics will change over time.

Individuals who co-operatively contribute effort into the running of the farm and bear some of the responsibility for the ultimate outcome of their actions are likely to be motivated by elements of their personality which may not always be consistent in all situations. Their propensity to maintain and defend own personality and ego and their urge to pursue discretionary action have to be constantly balanced with the requirements dictated by conditions for survival in a co-operative system. Thus, loyalty and self-sacrifice often stand out as expressions of group egotism and self-consciousness in the wake of the struggle for power and prestige. The individual is often torn between pride and his psychological needs as concretized in his commitments to the institutions which command his life. For example, the need for affection and response will necessitate a commitment to the elements of the cultural grouping that can provide them.

Since values, attitudes and goals of the individual are formed under the influence of the elements of individual and group personality, it is fair to assume several things. First, attitudes and goals of an individual member are not expected to match those of any other member nor indeed those of the household as a whole exactly. Consequently, disagreement about what comprises the best means of achieving stated objectives is likely. Second, decisions made by the farmer are likely to be influenced by individual and collective personality of members of the household. Such situations, whenever they occur, would put the household in danger of being in conflict over basic issues, a threat to orderly formulation and execution of survival strategies. Given these considerations, promoting common understanding is likely to be an important preoccupation of the leadership of the household.

7.2.1.2 Leadership in rural households

The farm pursues objectives through allocation of functions and responsibilities among members for the purpose of mobilizing resources to meet its goals. Ideally this would call for a pattern of coordinated, systematic ordering of positions and duties. A chain of command of some sort, which would enable integration of special functions would be an essential characteristic of leadership. This need is fulfilled by the farmer who should more properly be regarded as the entire collegiate leadership of the household.

Even where the leadership is relatively autocratic (e.g., farmers numbered 108 and 104), factors of cohesion and persuasion rather than coercion are likely to be emphasized. Attempts to secure a high degree of monolithic power may well provoke considerable dissension among their charge. In general, manipulation of sentiment in favour of the leadership is pursued through a range of inducements to individuals concerned.

Whenever the balance of dependency shifts in favour of an individual as often happens, there will be an urge to claim a voice in the determination of policy. The principle is that people are systematically co-opted into the leadership structure as a concession for and in recognition of the resources they independently control (e.g., wage income, items of capital equipment, own livestock, etc.). This is the most common way in which structural change in the management of rural households seems to be taking place in eastern Kenya.

A wide range of external and internal events often give rise to upheavals, resulting in a variety of responses which may include changes in composition and style of management. Such changes may involve a redefinition of both goals and strategies, and the identity of the farm may undergo a measure of change.

Decisions are a composite of views and opinions of all senior members of the group who may not be full-time residents. The important point that arises from this is that the 'feelings' of the farmer as represented by such measures as individual utility functions may have limited usefulness in helping explain previous decisions and projecting future decisions that are essentially made by groups whose level of conflict changes over time. Such difficulties would not apply with the same degree of severity in absolutely autocratic type and in perfectly co-operative type households. In the former type, the firm's utility function is that of the farmer, and in the latter, every person has an equal voice.

7.2.1.3 Categories of rural households by managerial structure

Given the complexity in composition and organization, grouping of households by managerial structure is a difficult task. In this section the classification of households in the sample of 94 households was based on simple ratios of adults to children. This method of classification yielded three different categories.

- Relatively young households whose composition is dominated by school age children. Control over resources and income rests with the farmer and spouse exclusively.

- Well established households where membership may span several generations. Usually there will be grown-up members other than the farmer and spouse. In all such cases, the farmer's role as decision maker resembles that of chief executive of a company, but input from others is significant. Where parents are present, they will usually have residual veto power as enjoined by custom but they will not normally expect himself to exercise it routinely. In matters pertaining to changes in strategic assets such as land, his consent would be sought. Within this type of arrangement, it is common for semi-autonomous units with own crop fields and livestock in addition to the common enterprise. In all such cases (e.g., Farmers No. 101, 102, 103, 105[12] and 107), the 'farmer' is really the whole group. This type of grouping represented 56 per cent of the sample of farms and this proportion can be expected to rise.

- A variant of type 1 farm may be represented by households which have 'weaned off' most of their former members. In this category, the farmer would be expected to be in control of resources and income exclusively. Farmers 106 and 104 (both are septuagenarian) represent this class. In general, this is a category of ageing operators with rigidly defined ideas. As a proportion of farms in the region, they are in the minority and this proportion can only be expected to decline.

7.2.2 Values, goals, attitudes and strategies

In the previous section, attention was directed at describing farm-level organizational structures within which adoption decisions develop. The main concern of this section is to clarify some of the concepts which give form, substance and character to the process itself. For a given community the values subscribed to are reflected in goals, coping strategies that evolve, and in the attitudes of individuals and groups in the community.

Aspirations of individuals as well as those of the groups to which they belong can be interpreted in terms of socially accepted goals as well as means of achieving such goals that are considered to be legitimate. Here legitimacy and social sanction are no more than values that have overriding significance for the community as a whole. Group values consist of rules and injunctions which coalesce into an ethical code of universal acceptance. Such a code may be regressive, constructive or adaptive according to how well it is able to accommodate change in the requirements of the economic and technological environments of the community in question. Like any other mechanisms for coping with persistent areas of uncertainty, values may have varying degrees of rationality. As social groups become more receptive of mechanistic explanations of phenomena, values they subscribe to become increasingly rational.

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[12]Farmer No. 105 has undergone all these changes over the last ten years (period of contact with NDFRC). The spouse, a retired bus driver, is now permanently at home but does not involve himself in routine matters. All sons have now obtained wage employment and set up families of their own and now have considerable input into farm operation.

In recent times, people in the rural areas in Kenya have had to deal with the dilemma posed by the need to reconcile the requirements of the ethic of progress and the needs of preservation of group identity. The essential ingredients of the ethic of progress are, among others, predominance of acquisitive goals, mechanistic assessments of achievement, distribution of sympathy in favour of achievement rather than need, bias towards individualistic outlooks, and supremacy of contractual arrangements in interpersonal relationships. In general, however, traditional values, such as conferment of respect and seniority on the basis of position, gender and age, rather than achievement and mutual assistance among neighbours and kin, are still significant aspects of rural life.

7.2.3 Goals and strategies in the management of smallholdings

Like any other class of organization, farm households are subject to pressures exerted upon them within their ecological and institutional settings. The main preoccupation of leadership is with the formulation and implementation of appropriate responses. Overall, the leadership of the household will hold notions of what the mission of its membership is. These notions, stemming from subjective dispositions, that is, purposes and motives, coalesce into goals with which to direct the required adjustments. From a larger set of goals emerge specific objectives and performance targets. Innate propensities to expand as modes of response to pressure from within have to be carefully balanced with defensive actions intended to avert threats to welfare and survival. The two tendencies often impose conflicting requirements. Households which concentrate on maintaining internal conditions while ignoring boundary conditions are likely to suffer impaired capacity to exploit new markets, more efficient resources and new technology. Ability to cope with changes induced within the household and those taking place independently will be diminished. In general, the leadership must be willing to break into old integrities or create discontinuity to take advantage of changes in technology and markets. Inability to face up to such demands may threaten the very survival of the farm household.

In most agricultural situations, transformation of inputs into outputs is never instantaneous. Areas of uncertainty that have to be dealt with by management arise due to variation as a characteristic of the meteorological and economic dimensions of the production environment. Smallholders who set out to deal with each variance as it occurs as their sole strategy would at best, make survival for themselves precarious, but such a path could also lead to ruin. Virtually all the farmers have some sort of plan setting out goals to be pursued (ends) and a strategy describing how resources (means) are to be used for the goals to be achieved (technology).

7.2.3.1 Goals

Goals may be viewed as the farm's medium to long-term aspirations. They are indicators or declarations of what the decision making entity's position should be with respect to inputs, outputs and infrastructure at some future date. Where goal setting is inspired by conflicting drives as related earlier, rarely is 100 per cent consensus to be expected. Priority will differ across goals and for different individuals. A weighting mechanism determined according to the perceptual apparatus of the individual or group is required. As specific goals indicate what the farm's position should be at a future date, the intervening time interval may well span several production cycles. Under each goal, specific objectives are set, usually one for each production cycle. Within a given objective, specific targets are set.

In the implausible case of fixed aspirations, goals, objectives and targets would be identical. In reality, however, these all change with time and among individuals within the same organizational unit. The likelihood of full consensus about the weight to be assigned each goal within the group is likely to remain low. For expository convenience, let a set Γ be defined to designate the set of household goals such that $\gamma \in \Gamma$, where γ represents individual goals. Members (γ) of this set, would include security, acquisitive and self esteem related goals. While Γ may well cover a much wider area, the three subsets appear to bear the greatest relevance to adoption decisions.

Preservation and maintenance of the identity and character of the household is often considered to be an overriding concern for farm operators. Security related goals will entail emphasis on pursuit of actions which maximize chances of continued existence. Actions that appear to harbour tendencies which can lead to the destruction of its essential character would be avoided. Assured family subsistence was found to be an important security oriented goal for households in semi-arid Eastern Kenya (Ockwell *et al.* 1991a; Parton 1992). Pursuit of the security of subsistence goal, however, is related to other goals such as maintenance of the productive resources as well as the social and cultural position in the community.

In a situation where demographic, market and production dynamics dictate that change and adaptation have to be part of the goal system, a highly inflexible outlook on the part of the leadership of the household will do little to shield its membership from the vagaries of the environment. Wise household heads would appreciate that the farm has to undergo a certain measure of growth and differentiation. Previous chapters of this thesis cite evidence to support the view that for most farmers in eastern Kenya, this is the case. Based on the requirements for growth and differentiation, acquisitive type goals are now a significant aspect of the goal system of many farms. One such goal is the maximization of household income.

Security and growth oriented goals can only be sought successfully within a social environment that is sufficiently congenial. This is often approached through pursuit of self esteem oriented goals. In so doing, members of given households will be expected to espouse tendencies to help them gain and maintain a reasonable level of prestige both individually and collectively. These tendencies often reinforce the urge to acquire certain consumer items.

7.2.3.2 Strategies

For a given set of goals, there usually are a number of ways or alternatives in which resources can be combined to achieve a predetermined end. This suggests the existence of a number of possible strategies. It is reasonable to suppose that farms will seek to employ least-cost strategies in pursuing goals. To aid in the process of strategy formulation, several conditions should be met. First, the decision making unit will call on some input of information about the farm and its environment. The farmer's experience can be regarded as a synthesis of the signals to which the farmer is already attuned. The farm builds up this experience through some learning process. Associations between clues and subsequent occurrence are gradually incorporated into their cognitive equipment. Their range of anticipations about the future, now governed by clues become limited by the number of alternatives available. These are translated into strategies associated with the pursuit of each goal.

As goal-seeking entities, firms evolve strategies to guide their goal-seeking behaviour. Again, for expository convenience, let the set of all possible strategies S be defined such that $s \in S$ (s is an element of S). Given a set of goals Γ, each member of S can be associated with an element in Γ represented as $\{f\colon s \rightarrow \gamma\}$. The responsibility or task of a decision making agency is to obtain and implement the most efficient mapping of $\{f: S \rightarrow \Gamma\}$. Once goals have been set, a measure of performance is then conceived. The next step is to relate the measure of performance to some function of those aspects of the system that are subject to control by management and which affect the outcome, and uncontrolled factors which also affect the outcome. In an idealized situation, values of the control variables which maximize (or minimize) the measure of performance should be found. A set of rules, one for each control variable, which establish the level at which that variable should be set for any possible set or combination of the uncontrolled variables, should be defined. Such rules comprise the organization's strategy. Further refinements in this categorization are often considered useful. Within a given strategy, there are likely to be sub-strategies (operations), and sub-sub-strategies (tactics).

In cases where goal attainment depends upon factors whose values cannot be determined beforehand, it is likely that there will be some general master plan couched in terms of strategies. A given strategy would itself involve one or more operations. The term, operation, as adopted and popularized by theorists of German and Soviet military doctrine, sets out the choice and implementation of a planned series of strategic initiatives against an opponent. In agriculture the notion of operation would serve to classify initiatives taken in response to developments in the production environment as they unfold. Among these responses would be within season tactical adjustments such as additional weed control operations, fertilizer applications and pest control measures.

In pursuing a chosen objective, farms would also be expected to consider selecting strategies which would afford them some ability to change or modify objectives or substitute an objective should they discover mid-point that the objective they are pursuing is not the best. This confers flexibility to the farm in carrying out its mission. Flexibility is measured as the minimal time within which a provisional objective may be replaced with another without stressing the system too much. With complete foresight, flexibility is not of crucial importance.

7.3 Representation of Decision Making in Farm Households

A particular adoption decision results from a series of choice events. Behind such choice events are numerous factors, some of which are easily identified and measured while some are typically unobservable (Parton 1992). The magnitude of the complexity of the factors which influence adoption decisions can cause difficulties of representing choice situations in a formal theory of decision making.

Some analysts have voiced concern about relevance and viability of formal models of decision making. They hold that decision making systems are, effectively, open and cannot be represented by a finite set of cardinal measures. This, they suggest, could especially be true if clarity in procedure and logical precision, and qualitative accuracy, of high standard are required. On the whole, however, the need to undertake decision analysis often asserts itself with such urgency that reasonable compromises are found acceptable.

A decision rule consists of an orderly framework for evaluation of alternative courses of action. Such a decision rule would include:

(a) A selection criterion reflecting the decision makers risk attitudes.

(b) Procedures for describing alternatives.

(c) Computational procedures for evaluating the alternatives.

Altogether, a consistent decision rule should accurately reflect the goals of the decision maker, and the decision choices, while at the same time being easy to understand and apply. Selley (1984) has discussed the concept of decision rules in considerable detail. Various possible uses of decision rules as well as examples of their application in the field of agricultural economics were summarized in that discussion.

The basic structure of a decision problem may be represented as follows. There will be a set of mutually exclusive actions a_j, (j = 1, ..., n); mutually exclusive states of nature, S_i, (i = 1 , ..., m); and probability functions $P(S_i)$ associated with each of the possible states of nature; a consequence, c_{ij}, associated with j actions and i states of nature, and a decision criterion for ordering the actions. Five decision rules namely, the expected utility model; the mean variance model; the mean absolute deviation model; the mean semi-variance model; and safety first models are outlined. These rules are briefly reviewed in Appendix E. Most of the decision rules reviewed have been criticized on the grounds that none of them takes into account the simplifying procedures that people use in real life decision making.

Research in economic anthropology has yielded alternative approaches to the representation of smallholder decision making. Theoretical developments in economic anthropology concern applications of cognitive versus statistical behaviour models in the evaluation of alternatives open to farmers and the role of risk in farmer responses. Gladwin (1984), for example, has proposed a two stage theory of smallholder decision making which uses some of the simplifying procedures people use in every day life that may be represented by a decision tree. In stage one, a wide range of options open to the farmer are narrowed down to a smaller set to be further considered. The choice criteria in stage one involve elimination by aspects. In stage two, each option is considered on the basis of one important aspect, and the best option must pass all the constraints of the decision situation in order to be chosen. While this approach might have provided a richer framework for assessing smallholder adoption decisions, actual implementation would have called for extensive adaptations which are beyond the scope of this study.

7.4 Procedures and Methods

The conduct of attitudinal assessments among small farm operators in developing countries is notoriously difficult. The phenomena to be studied are typically characterized by complex influences which are themselves not directly amenable to assessment. Moreover, elicitation of attitudinal type data is susceptible to biases that are related to attributes of both the assessors and the assessed alike. It is often necessary to make compromises in the interest of obtaining the required information.

The strategy adopted for this study was to attempt to induce heads of households, either individually, or, if appropriate, with the assistance of other members of the household to enumerate what they regarded as essential aspects of the mission of the household. They were then asked to assign orders of precedence by simply assigning ranks. The procedure was repeated for the preferred and actual strategies for goal attainment, order of priority here being the rank assigned to resource use in that strategy.

The proportion of households nominating given goals/strategies indicated the relative prevalence in the community. The proportion of respondents assigning a given rank to a particular goal/strategy taken over the whole community was the indicator of how highly the community held such a goal or strategy.

Significant goals were subsistence, education of children, making purchases off-farm, and homestead and home improvements. Strategies evaluated were non-farm undertakings, crop production, livestock production and wage employment. An attempt to elicit quantitative subjective scaling did not yield useful results. Consequently, these assessments relied entirely on ordinal measures.

7.4.1 Measures of risk preference

Smallholder farmers are, generally, risk averse. As Binswanger (1982) has observed, failure to take sufficient account of risk in farm models can lead to serious specification bias. Risk specification tends to yield results that are in closer agreement with observed behaviour than do optimization models in which risk is disregarded altogether. Specification of risk averse behaviour in turn requires estimates of risk preference measures. Methods of doing this include: observed economic behaviour, interval measures and experimentation. Implementation of any of these would entail specification of a utility function as well as the nature of its argument and algebraic form. The experimentation approach was used in the current study.

In the Observed economic behaviour approach, measures of preference are derived from relationships between actual behaviour and predictions of empirical models. Applications include Moscardi and de Janvry (1977); Brink and McCarl (1978) and Wolgin (1975). While the approach is relatively cheap to use, it has been criticized on the grounds that discrepancy between observed behaviour and that predicted by empirical models is ascribed to risk aversion only. Given the number of influences that result in decisions and actions, the usefulness of this approach in empirical assessments is somewhat diminished.

The second approach is based on the identification of a confidence interval for the Arrow-Pratt measure of absolute risk aversion through the ordering of density functions for the prospect in question. This potentially low-cost approach allows the analyst flexibility in the specification of risk aversion intervals and avoids many of the problems inherent in the other approaches. The main disadvantage, however, is that if the interval is not properly specified, a preferred choice may be left out of the efficient set (King and Robison 1981).

Utility functions (the third approach) are usually elicited by asking series of hypothetical questions or by simulating gambling situations with realistic pay-offs. Numerous studies have been carried out based on this approach. An example of an early application of this method in agriculture was Officer and Halter (1968). The hypothetical gamble version of the experimental approach has been criticized on the grounds that subjects lack incentive to give hypothetical gambles adequate consideration, leading to results that do not reflect the true preferences. In the Binswanger (1981) and Grisley and Kellogg (1987) studies, gambling situations with lotteries set at realistic levels were simulated, after the former approaches had failed to yield consistent results. An approach based on Binswanger (1981) was adopted in the current study.

7.4.1.1 Implementation of the ELCE method

The equally likely certainty equivalent method (Anderson *et al.* 1977) was used to elicit utility functions of small farm operators in the semi-arid Eastern Kenya. The purpose of elicitation was to obtain an indication of the distribution of risk preferences of typical farmers within the community. Because ELCE is based on the 50/50 gamble, it is relatively simple to use. It is easy to explain and to be understood by farmers. Many of the problems associated with probability weighting in the tails are greatly reduced.

From the 94 farm households of the larger sample, 37 were selected randomly, 15 in Mwanyani and 22 in Kyawango administrative sub-locations. In addition, all eight households that had been selected from the case-study program were also included. Each of the 45 farms was visited on average, four times, once to make the necessary introductions, once to explain the procedure and finally twice to carry out the elicitations. This aspect of the fieldwork commenced in January 1990 and concluded in May 1990. As an aid to the elicitation procedure, attempts were made to simulate gambling situations with realistic payoffs. Lotteries were defined in terms of lots of farm inputs as levels of gains and losses. The elicitation procedure yielded between five and eleven points on the utility function of each farmer. The functions were plotted after consistency checking for each point. The data points for each household head were fitted to the negative exponential utility function of equation 7.1.

$$U(x) = 1-e^{-\lambda x} \tag{7.1}$$

Equation 7.1 is everywhere monotonic in x, it is twice differentiable and it implies constant risk aversion for gains and losses for all x. There are a number of other algebraic forms, but few of these possess desirable properties over the entire range of $U(x)$.[13] The Arrow-Pratt coefficient of absolute risk aversion, r, was calculated via equation 7.2.

$$r = \frac{-U''(x)}{U'(x)} \tag{7.2}$$

where

$U'(x) = dU/dx = -\lambda e^{-\lambda x}$

and

$U''(x) = d^2U/dx^2$

and, in terms of equation 7.2,

$$r = \frac{(-\lambda)(-\lambda)-e^{-\lambda x}}{-\lambda(--e^{-\lambda x})} = \lambda \tag{7.3}$$

Thus, for each of the 45 household heads for whom utility functions were obtained, a measure of absolute risk aversion r (equation 7.3) was estimated using nonlinear least squares regression.

7.5 Results and Discussion

In Ockwell *et al.*, (1991a,b) a hierarchy of household goals espoused by participating households were identified and described. The top priority goal was household subsistence needs, followed by the necessity to be able to meet expenditure for education of children. Third and fourth in the hierarchy were acquisition of non-farm consumer goods and investment in farm improvement including acquisition of livestock. A number of farms also had investment in non-farm activities as important goals. Given the nature of the environment, the second, third and fourth goals in the hierarchy could also be interpreted as coping strategies. All could if viewed as survival mechanisms support a variety

[13] A number of algebraic forms of utility functions as with desirable economic properties exist.

of survival, growth, acquisitive and prestige goals in particular households. Another set of goals, that is, preservation and enhancement of the productive resource base, namely, land, was implied though not stated. Subdivision of land among children also featured prominently as a coping strategy.

7.5.1 Goals

In this section, growth and development, security and self-esteem related goals that had been postulated to have bearing on adoption decisions are discussed. Note, however, that there is considerable overlap among goal categories and between goals and strategies. For example, preservation of the productive capacity of land objective may be viewed as a risk management strategy as well as representing the households' desire to achieve growth.

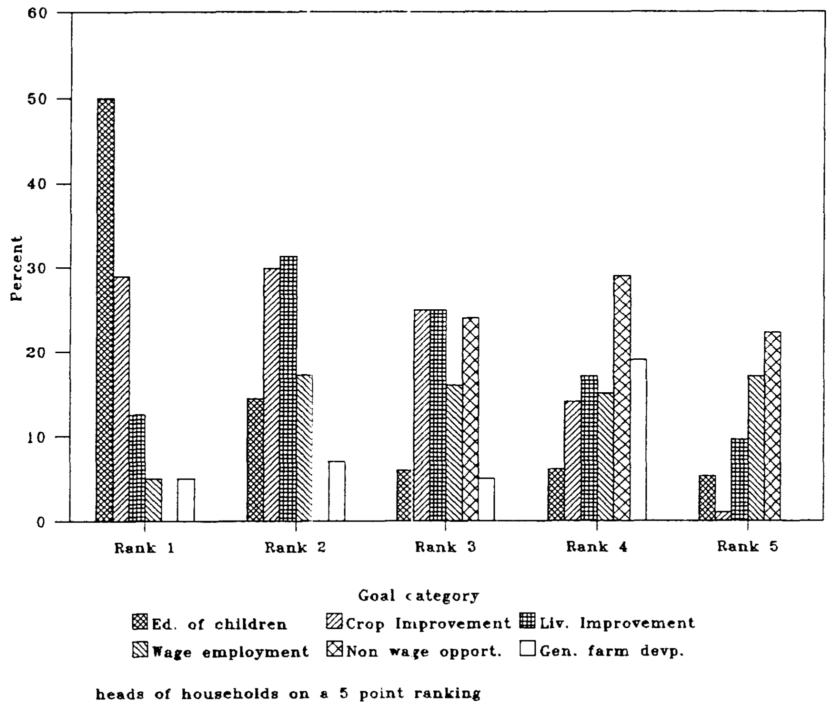

Fig. 7.1: Household goals and relative importance in the community

7.5.1.1 Growth and development oriented goals

Education of children represents the area of overlap among several goals and strategies. Growth and development-oriented goals were pursued through construction and maintenance of buildings, water resources and general farm development. The objective is to improve the minimum standards of shelter in support of growth, security and prestige considerations. Pursuit of these goals entailed expenditure of a substantial proportion of the household budget.

A persistent theme in the development literature for Eastern Kenya is that of shrinking farm size brought about by subdivision of land among children when they attain a certain age. This practice is thought to reduce the capacity to support the rapidly growing population. As a phenomenon that is relevant to crop management decisions, and hence, adoption of innovations, it was included in the study as a variable. The majority of households expressed the belief that ideally, grown up children should strike out on their own, to set up independent households. In the majority of households (59 per cent), rather than subdivide the land into units that may not be economically viable, this land was operated communally by all members of the household. This may account for the fact that the drop in mean holding size between 1980 and 1990 was only 0.3 hectares (from 7.5 ha in 1980 down to 7.2 ha in 1990).

Nearly all farmers had soil conservation as an important goal in the 1980 and 1990 surveys. As far as crop management is concerned, pursuit of this goal can bring about improvements in crop performance, while at the same time drawing on resources which are needed to support adoption of innovations, notably, cash and labour.

7.5.1.2 Goals related to security considerations

This category includes goals that are oriented towards ensuring a reasonable level of welfare for members of the household. Concern with attainment of minimum subsistence targets and dietary preference were rated highest by most households (first choice for 29 per cent and second choice for a further 29 per cent). Subsistence needs could also be met from sources other than crops raised on the farm. Livestock, for instance, contributed to the household's diet directly through provision of milk, meat and eggs. Through sales of livestock, grain could be purchased from the local market. Income from other sources could also be used for this purpose. It is clear that most if not all of the goals assessed (as shown in Figure 7.2) also contributed to the security goal.

7.5.1.3 Education of children

Education of children may be viewed as a goal as well as a strategy. As a strategy, it represents the farmer's desire to improve on the stock of skills which may be needed for the operation of farm and non-farm enterprises. Farmers who regard non-farm activities to be more stable may well invest in education of children as a matter of risk management. The majority of farmers though appeared to be pursuing the education goal for its intrinsic good. Figure 7.2 shows that the education goal was by far the most highly rated objective. The majority (50 per cent) placed it first while a smaller proportion (14.4 per cent) placed it second, ahead of goals related to an improved subsistence base. Taken at face value, this result may seem to contradict findings of other studies. Given that the elicitation was undertaken during one of the best seasons (preceded by a run of better than average seasons), the fact that subsistence had temporarily ceased to cause farmers so much anxiety could have led to the position that education attained. This suggests that goal formation may not be rigidly, set but could be influenced by the turn of events.

7.5.2 Consumption of non-farm goods and services

This category of activities covers the household's desire to acquire a variety of consumer items. Among the essential consumer items are food, clothing, travel, health and repairs and maintenance. In addition to this, there is a desire to achieve an acceptable measure of recreation and to enable the household to enjoy a degree of self-esteem that is consistent with their station in the community. The latter set of goals are revealed by the household's desire to participate in various cultural events and community functions. The results presented in Figure 7.1 suggest that most farmers would be content to attend to this class of goal after the previously discussed goals have been attended to. A few farmers (five per cent) assigned top priority to this type of goal, while some (seven per cent) placed it second. These results may well understate the significance of this goal set. Average recurrent expenditure for the household is split almost equally among school fees, other school related expenditure, clothing and other expenditure.

7.5.3 Strategies for goal attainment

Three broad classes of strategy for goal attainment were assessed. These were crop and livestock production and non-farm enterprises. The results of these assessments are presented via Figure 7.2.

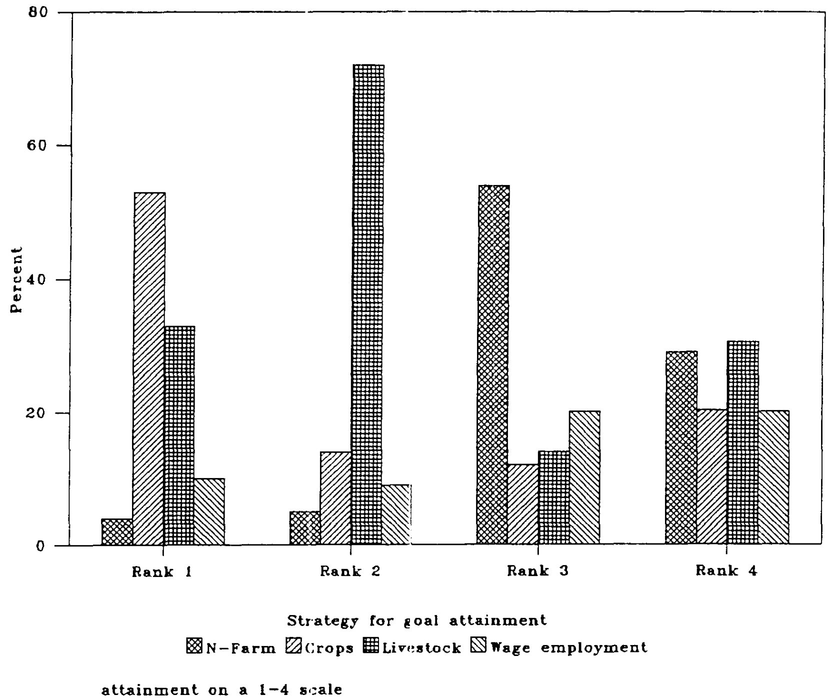

Fig. 7.2: Relative importance of strategies for household goal attainment

For the community (as represented by the sample) as a whole, crop production was ranked first (54 per cent) followed by livestock production (33 per cent) as strategies for goal attainment. The proportion that assigned first position to wage employment and non-farm enterprises were 10 per cent and 4 per cent, respectively. For the larger proportion of the households, non-farm undertakings and wage employment were rated third and fourth. This implies that although wage employment and non-farm enterprises are not strategies of first choice, they are still a significant aspect of the overall strategy.

7.5.4 Crop production strategy

Having established the importance of crop production relative to other enterprises in the farm household, the next step was to attempt to elicit the farmer's assessment of the crop production strategy in more detail. Farmers were asked to rate the relative importance of improvement of soil fertility and plant nutrition, hire of supplementary labour, draft and equipment, and purchase of pesticides and commercial seed. Results of these assessments are presented in Figure 7.3.

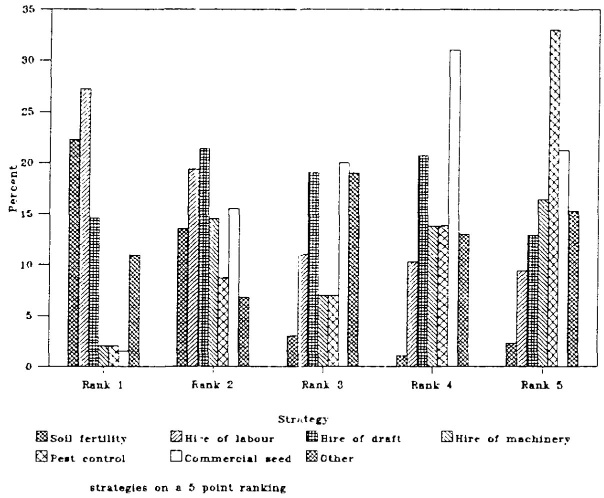

Fig. 7.3: Relative importance of crop production strategies

Basically, labour application was rated highest (27.2 per cent), followed by plant nutrient supply (22 per cent). Hire of additional draft and equipment were assigned the first rank by 14.6 per cent and 10.8 per cent of the sample, respectively. A rather modest proportion of farmers gave purchase of pesticides and commercial seeds high ranking. Purchase of pesticides was assigned first position by 2 per cent of the households, while for commercial seed, the proportion was 1.5 per cent. The favourable position occupied by plant nutrition and soil fertility is interesting. While this appears to convey the farmers' concern about the plant nutrition problem, adoption of chemical fertilizers has lagged behind expectation, despite a massive promotional effort by the extension and education services division of the Agriculture Department. It seems that farmers had organic sources of plant nutrient in mind when considering crop production strategies.

7.5.5 Measures of risk preference

Preference functions were elicited from a total of 45 heads of rural households in the semi-arid eastern Kenya. To facilitate interpersonal comparisons of attitudes to risk, the Arrow-Pratt coefficients of absolute risk aversion (*racs*) were computed from the utility functions. This procedure yielded values that varied greatly from a low 0.00007 to a high 0.1041.

These results indicate that all farmers for whom risk aversion parameters were assessed in this study are risk averse. Out of the 45 utility functions that were successfully processed, 25 yielded *racs* of 0.023 or more. This suggested that most farmers are severely risk averse, but a significant proportion of them are mildly risk averse. For reasons that were offered earlier in this chapter, among them the collegiate nature of decision making, no further use in this study of parameters obtained in this way was contemplated.

7.6 Summary and Concluding Remarks

The main objective of this chapter, was to describe the household decision making system and characteristics of leadership. Relationships between household membership, and values which influence development and legitimization of goals and strategies were outlined. Following the discussion of relationships between goals and strategies, elements of decision theory that have relevance for adoption decisions were outlined.

Methods for assessing farmers' goals and strategies and measures of risk preference were presented, evaluated and applied. In the case of the former, farmers were invited to enumerate and assign, subjectively, orders of precedence to goals and strategies. An assumption made in the interpretation of these data was that for individual farmers the ranking represented their own feelings about relative significance of the various classes of goals and strategies. For the farming community (as represented by the survey sample), proportions of farmers assigning a specified rank gave the relative importance of the goal/strategy within the community. Although this approach is subjective and lacks a sound axiomatic foundation, it seemed to be the only practical way of obtaining the required information.

EUM and extensions were briefly assessed in terms of strengths and weaknesses and suitability for assessing risk preference indices. The outcome of this evaluation was that despite many shortcomings, EUM is the only feasible approach for assessing indices of risk preference and was applied to the elicitation of 45 utility functions for heads of households in the semi-arid Eastern Kenya. These utility functions were intended to indicate the extent of risk aversion within the farming community.

Results of these analyses were varied. Three main categories of goals were considered. These were (a) security, (b) growth and development, and (c) self esteem and recreation oriented goals. Security oriented goals were found to assume a relatively high profile. Growth oriented goals especially education of children was also found to be high in the hierarchy.

Strategies for goal attainment were classified as (a) crops and (b) livestock production, and (c) non-farm undertakings. The highest rated strategy was crop production followed closely by livestock. A significant number of households also ranked non-farm undertakings as a strategy for goal attainment of first choice. Within crop production as a strategy, food crops were ranked above cash crops and increased labour input into field operations and plant nutrition (presumably, organic fertilizers application) were ranked highest while commercial seed and pesticides were assigned top rank by only 2 per cent and 1.5 per cent of the sample respectively.

Assessment of risk aversion measures yielded a varied result. A wide range of the Arrow-Pratt risk aversion parameter, (0.00007 - 0.1041), was observed. The 45 household heads who participated, were found to be risk averse. The majority, (25) had Arrow-Pratt coefficients of 0.0245 and higher, indicating that they were severely risk averse. On the whole, the decision making system is a co-operative system whose principal decision makers are mildly to extremely risk averse. The system is characterized by hierarchical goal (security, growth and development, and prestige and recreation) and strategy (crop and livestock production, and non-farm undertakings) structures. For crop production, labour input into various field operations was considered by the majority of operators to be the preferred strategy followed by plant nutrition. The implications for these findings are taken up further in Chapters 8 and 9. From the point of view of adoption of innovations, these results point to critical areas of household organization which could be targeted by research and institutional development policy instruments. From the technology development angle, dietary preferences as determinants of adoption could be incorporated into the crop improvement program at NDFRC, for example.

Chapter 8

SMALLHOLDER ADOPTION DECISIONS

8.1 Introduction

Smallholders in Kenya operate complex farming systems. This complexity can be ascribed to the multiplicity of wants that characterize individual households. Although subsistence needs are largely met from farm production, there is evidence of shifts in consumer habits among the rural population. In consequence, rural households tend to operate multiple objective strategies as they strive to meet these wants. In chapters 3 and 7, a number of demographic and socio-economic characteristics of households were shown to be associated with the adoption of innovations. Analysis of the attributes of the innovations indicated that the strategies with innovations gave higher expected yields than those without. Such increases in average production could only be achieved at the expense of higher coefficients of variation. As livestock and non-farm enterprises are also known to contribute to the realization of household goals, these were analyzed in chapters 5 and 6. The intent in this chapter is to integrate the findings of these previous chapters to analyze adoption behaviour of smallholders in the semi-arid region of Kenya.

8.1.1 Objectives of the chapter

The main objective is to assess resource values to households arising from implementation of the various strategies (which may or may not be based on new innovations). This should enable the progressive examination of the effects of continuous and systematic changes on the objective function coefficients and on the parameters of the resource or constraint vector. Such examination is across farm plans which also satisfy the minimum subsistence and income requirements at acceptable levels of risk:

(a) with strategies which rely entirely on traditional technology, and

(b) with strategies which utilize innovations as alternatives.

Even if it is assumed that the potential impact of innovations upon resource use efficiency is positive, a variety of demographic and socio-economic factors may still constrain adoption. This study was designed to assess technology adoption potential for selected innovations by farmers facing different resource, ecological and socio-economic constraints. In this chapter, it is sought to assess the impact of:

(a) variation in household and demographic structure on demand for consumption and investment resources (in relation to resource endowments and goal structure);

(b) determinants of variation in the willingness to innovate;

(c) how risk may be influencing implementation and performance of farm plans; and

(d) determination of adoption categories.

8.1.2 Models of smallholder farming under uncertainty

A major characteristic of small farms is that part of the farm's production is consumed by the farm family. This dependency, it is postulated, affects the composition of the farm enterprise and indirectly, technology use. In a pure subsistence situation without trade in goods and labour, subjective equilibrium is where the levels of production, leisure and consumption are simultaneously determined (Nakajima 1969). Separation between the farm and household is inappropriate.

With the existence of perfectly elastic wage employment and other markets for other commodities, consumption, leisure and production can be regarded as separate (Barnum and Squire 1979). The farm household equilibrium can be solved in two stages. First, the farm's production is solved for maximum income. Then, given income and the market wage, the household's consumption of goods and leisure is determined (Barnum and Squire 1979, p. 39). Barnum and Squire have suggested that if risk is introduced through an expected utility framework, then, separation of production and consumption decisions does not necessarily hold. If separation holds, then the production problem should only involve maximization of expected utility of income.

Problems of application of such models arise in relation to estimation of parameters of the utility function. Furthermore, estimation of production and consumption systems simultaneously may not be easily accomplished especially as these are likely to be non-linear and inadequately identified. In the context of semi-arid farming, risk is significant and accounting for risk is not easy to achieve.

In practice, however, many farm households including those in Kenya, are not isolated from trading possibilities in goods, labour and services. Evidence of exchange relationships in non-farm goods and services was provided in chapter 6. Hence, consumption and production decisions may not necessarily be interdependent in all situations.

Furthermore, to make such analyses feasible, detailed production and consumption data are required. Instead, these issues were given recognition in a mathematical programming framework by including labour, leisure, consumption requirements and expected income at specified levels as constraints on the expected income objective function.

8.1.2.1 Risk in smallholder farming

In assessing an innovation, farmers would be expected to consider the extent to which the proposed innovation is risky. Even if the innovation is considered to be more risky, with respect to net returns, the significance of this will depend on the farmer's degree of risk aversion. This suggests that indications as to the levels of farmer aversion would be useful in technology assessment. To approach this question, an assumption of what the farmers hold to be risk has to be made. Farmer perception of risk is usually interpreted in terms of subjective probability. While some writers have cast doubt upon the supposition that farmers can assess outcomes in terms of probability distributions, some evidence that they do has emerged from empirical studies. In a study of Indian smallholders, for example, the general finding was that farmers think in terms of 'so many years out of so many', a well defined probability concept (Binswanger 1979, 1980).

Risk should receive explicit recognition in farm analyses for various reasons. Given the level of risk observed in the experiments reported in chapter 7, adoption of profitable but risky innovations may be impeded. From the point of view of society, risk-induced differences in adoption behaviour can have adverse distributional consequences. Where a trade-off between stability and productivity is inevitable, development of improved practices can have implications for the agricultural research strategy.
Because of these reasons, a number of issues pertaining to risk in farming need to be addressed.

(a) What is the nature of risk? Is it adequately described by the variance of a performance measure, or could it be better represented by other moments of the distribution of the performance measure?

(b) In what ways does uncertainty influence decision processes of farmers?

(c) As there are several players in the adoption process, (e.g., policy makers, researchers and farmers), the issue of whose risk aversion matters should be clarified.

(d) What is the nature of the impact of risk? Are farmers sufficiently risk averse for the risk to adversely affect decision making performance?

(e) If risk aversion influences choice adversely, how might policy change be made to help alleviate its adverse consequences?

Models of decision making under uncertainty can be used as normative, predictive or analytical tools (Anderson 1979). Although normative applications in developing countries are likely to be confined to the appraisal of large projects rather than tools for the analysis of individual smallholdings, they could be used in the description of actions of groups of individual households. Such models are also used in analytical undertakings aimed at improving some aspect of theory or influencing policy. In this study the ultimate objective underlying the use of this type of model is both analytical and descriptive. The analysis aims at bringing about improvements in decision making at the NDFRC.

Although many models of decision making under uncertainty are now available, these fall into one of two main types. These are:

(a) Models based on the Bernoullian/Bayesian framework.

(b) Models that make use of safety-first criteria.

The two classes of models have many similarities. Reliance on some optimizing algorithm forms the basis of most of the variants of these models. According to Binswanger (1979), both types of model yield similar predictions, and both face similar problems of implementation. In either approach, implementation is data-intensive, and specification of behavioral characteristics of the farmers who are to be modelled is required.

Type (a) models call for specification of utility functions. To implement type (b) models, knowledge about farmers' disaster levels, focus losses, flexibility constraints or safety zones, etc. is needed. Specification of either set of behavioral characteristics cannot be accomplished without difficulty. Both approaches could take better account of farmers' learning behaviour.

8.2 Farmer Preferences: Modelling Constraints on the Pursuit of Household Goals

If consumption of food by households can be related to income through some function, these concerns can be incorporated in a programming model by adding lower bound constraints on production of food crops (a basic minimum must be satisfied before maximization of other goals is attempted). Balance rows and transfer activities are included to allow sales of production that may be surplus to subsistence requirements and vice versa. Moreover, it is reasonable to expect that households will seek to attain a minimum amount of (target) income to meet standing obligations such as school and health care expenditure. Farmers may also want to ensure that other items of expenditure can be sustained with minimum disruption to the running of the farm-household. These include transportation; replacement, repairs and maintenance of farm equipment; and purchase of items of subsistence which cannot be produced on the farm.

It is clear that household 'wants' profiles may be associated with both farm (resource endowments) and household (demographic and human capital) characteristics. It is probable that each farm in the community is unique on the basis of these characterizations. However, if key elements of the farm and household characteristics can be judiciously identified, these can aid in the classification of groups of farms (on the basis of maximum similarity and dissimilarity within and between groups respectively). Such groups can then be targeted by specific research and development policy initiatives.

8.3 Procedures and Methods

A number of reviews of approaches to the analysis of farm problems under scrutiny have appeared. Hardaker (1979), for example, discusses a wide range of techniques and their applications laying emphasis on smallholder agriculture. A subjective rating of some whole-farm modelling techniques is presented in Ghodake and Hardaker (1981). Others (e.g., Anderson *et al.* 1977; Hardaker, Pandey and Patten 1991) have identified and reviewed strengths and weaknesses of a variety of mathematical programming and stochastic efficiency schemes.

These reviews were biased in favour of optimization techniques in general, and, in particular, mathematical programming. Within mathematical programming, classifications are usually based on whether the problem is essentially linear in the objective function and in the constraint set (linear programming) or assumed to be quadratic in the objective function and otherwise linear in the constraint set (quadratic programming and its approximations); single period or multi-period (dynamic linear programming or multi-period linear programming); static or dynamic (dynamic programming); single goal or multiple goal objective function (goal programming and its principal variants); whether stochasticity is embedded in the objective function as well as in the constraint set (stochastic programming and approximations). Implementation of these methods can be hampered or facilitated in varying degrees by the (non)availability of a suitable algorithm, computer hardware resources, data availability and analytical resource limitations. In recent years, spectacular advances have been made in all these areas. Developments in availability of computing power and improvements in communications technology hold out great promise for the ability to solve large models.

An adequate theory of decision making should take explicit account of interactions between the stochastic environment and the actions of the various actors in it. Optimizing approaches offer the most effective analytical framework. An optimizing technique is normative if the purpose is to prescribe a new production plan that is better than the existing one. If on the other hand, it is assumed that the decision maker, in this case, the farmer, is rational, such a device can be used as an aid to the understanding of behaviour. Following Schultz (1964), many authors (e.g., Chennareddy 1967; Hopper 1965; Yotopoulos 1983; Hardaker, Anderson and Dillon 1984) have taken the view that within the constraints they face, smallholders allocate their resources efficiently. While there are a number of dissenting views, these are in the minority. Smallholders in Kenya, under conditions of uncertainty, were found to behave as efficient, risk averse entrepreneurs (Wolgin 1975).

8.3.1 Desirable attributes of models of decision making under uncertainty

It is desirable that a theory of choice under uncertainty should not exclude patterns of choice which frequently occur in real life (Quiggin 1988). A theory of choice should not permit or require choice patterns which violate basic tenets of rationality, particularly, transitivity and dominance.

A theory which violates dominance would be of questionable value. This is because, an individual whose preference orderings include violations of dominance can be made to operate a money pump. Suppose that such an individual faces a prospect *A*, but prefers a prospect *B* such that *A*FSD*B*, then, the individual will be willing to pay a positive price to participate in a lottery of the form *B-A* for which all outcomes are negative. Assuming pervasive violations of dominance, this process can be repeated indefinitely or until the individual is bankrupt. Second, in a model with violations of dominance, voluntary exchanges should make both parties worse off with probability one. Similar arguments apply to the case of intransitivities. Representation of choice under uncertainty should include assumptions of transitivity of preferences and preservation of dominance. It seems likely that some sort of continuity is also necessary or at least desirable.

At least two methods for specifying a programming model so as to conform with some of the requirements just outlined in this section exist. These are, the Utility Efficient Programming and the Target-MOTAD methods. The utility efficient programming formulation can, if properly structured, generate greatly reduced efficient sets (Hardaker *et al.* 1991). The objective function could be specified as a negative exponential utility function of the form:

$$U = \exp[-\{(1-\beta)g + \beta h\}z], \qquad \beta \ \textit{parametric} \tag{8.1}$$

This utility function implies decreasing risk aversion as z increases. With bounds set on the absolute risk aversion of g and h, Utility Efficient Programming structured in this way can generate solutions that are similar to if not identical with the corresponding Generalized Stochastic Dominance *(GSD)* efficient sets. This programming formulation, however, requires a utility function. Data requirements are high, and availability of a suitable algorithm and efficient code can be a problem. In the co-operative nature of decision making that was described in Chapter 7, the decision making unit is the household, whose membership is constantly changing. Utility functions of such decision making units were not elicited. The cost would have been too high. Therefore, the Utility Efficient Programming method could not be implemented for this study. Target-MOTAD was used instead.

8.4 Target-MOTAD

A two-attribute risk and return model, Target-MOTAD (Tauer 1983), was chosen to analyze decision making for farmers who must manage both subsistence and income risk simultaneously. The appropriate utility function for farmers who are concerned about survival thresholds on expected returns (or losses) below target is:

$$U(x) = c + aR + b \quad Min\,(R-T, 0) \tag{8.2}$$

Where R is return and T is target return and *Min* is the minimum operator and a , $b > 0$. $U(x)$ is increasing and concave over R. It is therefore consistent with the requirement of First Degree Stochastic Dominance (*FSD*) and Second Degree Stochastic Dominance (*SSD*) assumptions (Tauer 1983). Thus plans that are in the Target-MOTAD efficient set are also *SSD* efficient. The relevant theorems and proofs can be found in Tauer (1983, p. 607).

> ... The proof that Target-MOTAD is second degree stochastic efficient is by *modus tollens*. If plan $F \prec$[14] G by *SSD*, (the antecedent), then $F \succ G$ by Target-MOTAD (denying the consequent). Then it will be assumed that F does not dominate G by Target-MOTAD (denying the consequent). This allows the conclusion that F does not dominate G by *SSD* (denying the antecedent).
>
> The theorem is that every plan that is efficient by Target-MOTAD is also efficient by *SSD*, except for plans with equal means and deviations.
>
> ... The proof states that portfolios on the Target- MOTAD frontier are all *SSD* efficient, since plans that are inefficient by *SSD* will not be part of the Target-MOTAD solution set. The proof does not state that all *SSD* efficient portfolios will be on the Target MOTAD efficient frontier. ... there may be portfolios not derived by Target-MOTAD that are acceptable under *SSD*.

For a given value of T, the (E,D)-efficient set (for risk averse decision makers) can be generated within this framework. In applying this scheme, three facts should be borne in mind. First, both T and D have to be specified. Secondly, Target-MOTAD generates only a sub-set of the *SSD* efficient set for risk averse decision makers and, thirdly, no means is provided within the framework for discriminating among the large range of stochastically efficient solutions that are typically generated (Hardaker, Pandey and Patten 1991).

Return was measured as the probability weighted sum of activity returns while risk was represented as the sum of negative deviations of the solution from a target level. Equations 8.3-8.11 represent the basic structure of the programming model.

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[14]The relational operators $\prec$ (is preferred to) and $\succ$ (the converse) are adopted by convention.

Maximize

$$E(x) = \sum_{j=1} c_j x_j \qquad j=1,2,...,n \tag{8.3}$$

subject to

$$\sum_{j=1}^{n} a_{ij} x_j \le b_i \qquad i=1,2,...,m \tag{8.4}$$

$$\sum_{j=1}^{k} f_{fj} x_j \ge b_f \qquad f=1,2,...,k \tag{8.5}$$

$$\sum_{j=1}^{z} q_{qj} x_j \ge b_q \qquad q=1,2,...,z \tag{8.6}$$

$$\sum_{j=1}^{r} l_{lj} x_j \ge b_l \qquad l=1,2,...,r \tag{8.7}$$

$$\sum_{j=1}^{n} c_{tj} x_j - y_t \ge T_t \qquad j=1,2,...,n \tag{8.8}$$

$$\sum_{t=1}^{s} P_t y_t = G \qquad t=1,2,...,s \tag{8.9}$$

$$G = M \rightarrow 0 \tag{8.10}$$

$$\forall x_j \text{ and } y_t \ge 0 \tag{8.11}$$

By convention, *E(x)* in equation 8.3 is expected net return for the farm plan, c_j and x_j are expected return and level of the *j*th activity respectively. Unit requirement of the *i*th resource by the *j*th activity is represented as a_{ij}, and b_i is a vector of resource levels. *T* is the target level of return, c_{tj} is net return for the *j*th activity in the *t*th state of the environment, y_t is the deviation below *T* for that state and P_t is the probability of occurrence. In addition, subsistence (*k*), soil and water management (*z*) and land management activity sets (*r*) were defined as linear constraints on the objective function. The input-output coefficients are *f*, *q* and *l*. *G* is a number to be parametrized from *M* to 0. Descriptions of these equations are as follows:

(8.3) Maximizes expected return of the solution set.

(8.4) Represents the feasibility constraints on (8.3).

(8.5) Represents subsistence requirements as constraints on (8.3).

(8.6) Represents soil and water management requirements as constraints on (8.3).

(8.7) Represents land management (e.g., harvesting, transportation and application of organic fertilizer on crop fields) requirements as constraints on (8.3).

(8.8) Measures revenue of solution under state *r* and if that revenue is less than the target *T*, the difference is transferred to (8.9) via the variable y_t and x.

(8.9) Sums negative deviations after weighting them by probability of occurrence P_t.

The structure of the programming matrix[15] for the farm household model described via equations 8.3-8.11 is as shown in Table 8.1.

The basic structure of the activity set includes

- Production activities (MZ = maize, BN = beans, CT = cotton, CW = cow, OX = oxen).
- Labour activities (INW = labour hiring, OFW = off-farm work, LES = leisure).
- General farm activities (SWM = soil and water conservation structures, ORG = management of *boma* manure).
- Buying and selling activities (SMZ, SBN, SMK and SLV = sales of maize, beans, milk and livestock respectively; BMZ, BBN and BMK = buying maize, beans and milk respectively).
- Risk activities (RK).

Rows:

- Row names (LAND1-3 = short rains, long rains seasons and grazing land; LAB1-24 = labour in periods 1-24; ATH1-6 = animal traction in periods 1-6; CASH1-12 = cash in periods 1-12; LIV, MZ, BN, TER, MZCON, MNR, TRG and TRSK are subsidence, land management, target income and risk rows).

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[15]The full programming matrix showing all rows and columns was not included here because of lack of space. However, programming matrices for each of the eight farms may be obtained from the Department of Agricultural and Resource Economics, University of New England, Armidale, N.S.W., Australia.

Table 8.1 The target - MOTAD matrix

Row	Column names																			
	MZ1	BN	CT	CW	OX	INW	OFW	LES	SWM	ORG	SMZ	SBN	SMK	BMZ	BBN	BMK	SLV	RKI	SG	RHS
Unit	ha	ha	ha	ha	ha	hr	hr	hr	metre	kg	Sh	Sh	Sh	Sh	Sh	Sh	Sh	Sh		Levl
Obj	-580.0	-338.0	-339.0	-189.0	-90.0	-14.0	8.0	-0.0	7.0	-0.0	2.3	4.2	5.5	-2.7	-4.9	-6.0	0.0	0.0	N	Max
LAND1	1	1	1	1															≤	+
LAND2				1	1.0	7.0		6.0	8.0		1								≤	+
LAB1	+		+	+	+	-1	+	+	+	+									≤	+
ATH	+	+	+																≤	+
CASH	+	+	+	+	+	+	-1	+	+	+	-1	-1	-1	+	+				≤	+
LIV LAND3				-1 1	-1 1												+		≥ ≤	+ +
MZ	-1										+								≥	+
BN	-1											+							≥	+
TER																			≤	+
MZCON	+																		≥	+
MNR										-1									≤	+
TRGT																	-1		≥	+
TRSK	+	+	+	+	+												+		≥	+
RTN	-2849	-1131	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	=	0

8.4.1 Data

The locations shown in Figure 8.2 represent variation in the growing conditions to be found in the parts of the semi-arid region where reasonable crops of maize are grown. According to Jaetzold and Schmidt (1983), Mwala, where farms 101 and 108 are located, is on the fringe of upper midland zone 4. The soil type on these two farms is light clay. Farms numbered 103 and 104 are located at Miondoni in Wamunyu Location, which falls within the lower midland zone 4. There is a great difference in soil type at the two farms. The predominant soil type over much of farm 103 is shallow light sandy soil. Farm 104, by contrast, is covered with a light brown soil. Farm 102 is in a relatively favourable location (upper midland zone 4) with fertile soils. Although most of the Mutomo area where Farm 106 is located is classified under the lower midland zone 5, the farm is located on a special land form and hence, enjoys more favourable ecological conditions.

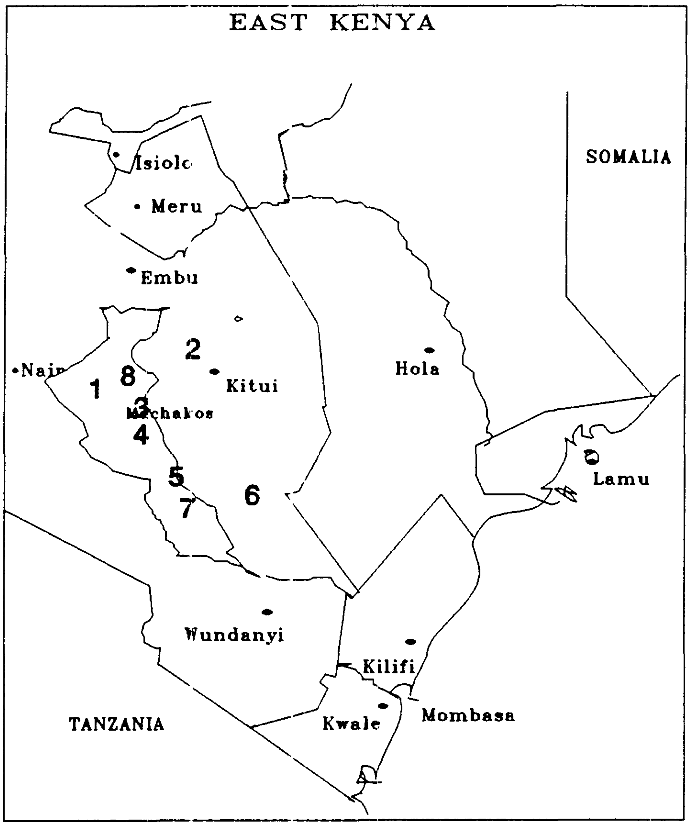

Fig. 8.1 Location of Case Study Farms

Farms numbered 105 and 107 are sited at Mbumbuni in Kisau and at Kilili in Nzaui Locations respectively. Both locations are in upper midland zone 4. Again, the farm 105 soil type contrasts sharply from 107. The former has relatively well drained fertile clay soil whereas the latter has relatively infertile light sandy soils.

8.4.1.2 Planning coefficients

The data used were from five sources. These were: the survey carried out by Rukandema *et al.* (1981); the survey carried out in 1990 as part of this study, the on-farm research and direct observations. Enterprise partial budgets which generated the planning coefficients that were used in the programming models for each of the eight farms were based on chapters 4, 5 and 7. Labour use coefficients for crop enterprises were obtained by field observations and measurements. Some of the crop husbandry data were supplied by farmers.

The laying out and construction of physical soil conservation structures like *Fanya juu* terraces requires specialized knowledge. Appropriate tools and implements may need to be purchased. Moreover, the rate of work in construction of soil conservation structures depends on factors such as soil type, terrain, and the condition of the tools. For the purpose of this study, a simplifying assumption, that labour is the only input into the soil and water management activity had to be made. Similarly, the harvesting, transportation and application of organic fertilizer was assumed to use no resources other than labour. These data are presented in Table 8.2.

Table 8.2: Labour coefficients for land management

Activity		Labour	Rate of work
Manure collection			
Low density	20kg/wb		
Heaping	2 men	1.64 mins	
Digging up	3 men	1.75 mins	
Loading	1 man	8.0 mins	
Carrying	1 man	6 mins	285 meters
Total(20kgs)			18 hrs/ton
Medium			30 kg/wb
22.59 hrs/ton			12.55 hrs/ton
Heavy 60 (kg/wb)			6.75 hrs/ton
Cut off drain			
94 sq. m or 3.5m/md	2.7md	9.69m for 2.7md	0.28 meter/md
Waterway			
260 sq. m/2.7md	16.13m/2.7md	5.59m/md	
Digging terraces			
189 sqm/2.7md	13.75m/2.7md	0.19m/md or 5.09m/md	
189 sqm/2.7md	13.75m/2.7md	0.19m/md or 5.59m/md	
Planting grass			
1050sq m	50md/ha	0.005md/sqm	
Tree planting			
1 hr/tree			
Banana planting	3trees/hr		

As neither agronomic nor soil and water management research has reached the stage where benefits of these activities to the farmer can be quantified, zero values appear in their objective function coefficients. Labour coefficients for soil and water management and organic fertilizer application were elicited from farmers. These data were recorded on the resource use record of schedule A and section G of schedule B (Table 3.1). Yield data obtained from on-farm research results were supplemented with field observations and measurements. Daily local market price data for farm produce were used in the calculations of net returns.

8.5 Results and Discussion

Household requirements were determined following discussions with farmers. Results that were obtained from these discussions are reported in Tables 8.3 (per household) and 8.4 (per person).

Table 8.3: Subsistence and financial requirements

Farm	Maize (kg)	Beans (kg)	P.peas (kg)	C.peas (Kg)	Cash (KShs.)	Cloth (KShs.)	School (KShs.)
101	540.00	180.00	180 00	180.00	4000.00	2000.00	11700.00
102	450.00	450.00	270 00	n.a	n.a	10000.00	n.a
103	1800.00	450.00	540 00	540.00	1000.00	2000.00	4070.00
104	900.00	180.00	450 00	450.00	2000.00	5000.00	13570.00
105	720.00	450.00	90.00	n.a	900.00	1500.00	5900.00
106	450.00	225.00	90.00	90.00	3000.00	n.a	10000.00
107	450.00	135.00	90.00	90.00	600.00	1000.00	1000.00
108	2160.00	450.00	180 00	180.00	2320.00	2400.00	11060.00
Mean	933.75	315.00	236 25	191.25	1727.50	2987.50	7162.50

Table 8.4: Subsistence and financial requirements (per person)

Farm	Maize (kg)	Beans (kg)	P.peas (kg)	C.peas (Kg)	Cash (KShs.)	Cloth (KShs.)	School (KShs.)
101	50.00	16.00	16.00	16.00	365.00	182.00	1064.00
102	54.00	27.00	27.00	n.a	n.a	1000.00	n.a
103	42.00	21.00	21.00	21.00	76.90	153.80	313.08
104	128.00	39.00	39.00	39.00	143.00	357.00	969.00
105	120.00	75.00	15.00	22.50	150.00	250.00	983.33
106	112.50	45.00	45.00	45.00	750.00	n.a	2500.00
107	75.00	22.50	15.00	15.00	100.00	166.70	166.70
108	108.00	54.00	18.00	18.00	232.00	240.00	110.00
Mean	86.19	37.44	24.50	22.06	227.11	293.69	763.26

Note on mean consumption of maize and pulses per person per day

- Maize - 0.32 kg/person per day
- Pulses - 0.26 kg/person per day
- Cereal/pulse ratio - 1.23

In Table 8.3, the subsistence requirements ranged from 450 to 2160 kg/household for maize (the mean was 916.20 kg/household). The range for the three items of direct financial expenditure was even greater. School expenditure dominates the other two items of financial expenditure by a substantial margin. School expenditure ranged from KShs. 1 000.00 to 13 570.00 per household. Expenditure on clothing was the largest item of non-school related expenditure (KShs. 1 000.00 to 5 000.00). Farmer number 102 was not able to distinguish between clothing and general household expenditure and hence, the figure of KShs. 10 000.00 is for the combined items. Financial requirements for general household expenditure ranged from KShs. 600.00 to 4 000.00 per household.

To enable between-household comparisons, data from Table 8.3 were divided by household size (Table 8.4). Subsistence requirements for maize ranged from 42-128 kg/person. The national average is 164 kg/per person (CIMMYT 1984). Moreover, although 'per person consumption' figures indicate that only 50 and 54 kg/person for farms 101 and 102, dietary compositions include large non-farm components.

Figures for farms 103 and 107 indicate that food intake in these households was below average. On a per person basis, figures for financial expenditure show the same pattern as in Table 8.3.

The preferred farm plan should meet household requirements in good years through direct production of the subsistence items and sales of produce. Surplus production is usually sold to realize financial resources with which to increase the farm's inventory of assets and cash reserves. During average years plans should enable the household to meet subsistence requirements as well as essential expenditure like purchases of certain food items, travel, health-care and school fees. During poor seasons, a substantial proportion of subsistence requirements would be acquired from sources that are external to the farm. It was assumed that households set their production target in relation to these considerations. Strategies for pursuing such targets were evidently different at each of the farms. Not all the farms pursued strategies that included the innovations described in chapter 4.

8.5.1 Risk programming: empirical results

A variety of security, acquisitive and prestige related goals were described in chapter 7. Analysis of adoption decisions was pursued through examination of how such goals interact with farm and household characteristics to give rise to preferred strategies. These assessments sought to establish enterprise choice patterns for typical households in the region. A risk programming framework (Target-MOTAD) was used to simulate the household's enterprise choice patterns which maximize expected net return subject to resource, subsistence and risk constraints. The results of these assessments are discussed in the remainder of this section.

8.5.1.1 Resource use

The programming models were designed to assess the effect of farm level resource constraints on adoption decisions. Farm resources were classified as crop land (short rains and long rains season), grazing land, farm labour (24 labour periods, equally spread over the year), working capital (12 cash periods) and animal traction. The 'base' Target-MOTAD models were designed to simulate existing resource and technology structures of individual farms as they were in July 1990. Activities incorporating the innovations set at GSD efficient levels were then introduced.

In the 'base' models, all farm plans included maize, beans and pigeon peas. The cowpeas activity entered the Target-MOTAD efficient farm plans for three out of eight farms. The cotton activity entered the farm plans for two households only. The most limiting constraint on crop area was land in both seasons. Marginal values of crop land were highest on farm 102 (KShs. 5027) and farm 1048 (KShs. 5481). The lowest marginal values for land were for farms 104 (KShs. 814) and farm 107 (KShs. 385 per hectare).

Labour shortages occurred in all but one farm (103). These labour shortages were acute in labour periods 4, 5, and 6. These periods would coincide with planting and weeding time. Harvesting can also be labour intensive, but it is spread over eight weeks, as each crop attains maturity. Surprisingly, there was no binding animal traction constraint on any of the farms. As already noted, all farms except two (103 and 104) supplemented 'own labour' with hired labour. Farm 103 had surplus labour while farm 104 was just self sufficient. The cash constraint was active in all farms in periods 4 and 9.

Production activities incorporating one or more of the innovations entered in Target-MOTAD efficient farm plans at very low levels. Medium planting density appeared in optimal plans for all the eight farms. Modest amounts of fertilizers (at the rates of 10-20 kg/ha) entered optimal plans for farms 108, 104, 105 and 103. The new farm plans had reduced areas planted to crops. The net result was that more labour in periods other than periods 4, 5 and 6 went into slack. Reduction in total crop land appears to have come about because the subsistence constraint was now fully relaxed.

The most critical constraints on the expansion of the medium planting and fertilizer innovations appear to have been labour shortage in periods 4, 5 and 6 and cash constraints in cash periods 4 and 9. Marginal values for labour in these periods ranged from KShs. 8.00 per SALE (farm 102) to KShs. 135.00 per SALE (farm 108). Marginal value for cash ranged from KShs. 0 to KShs. 1.7 per Kenya Shilling (KShs.).

8.5.1.2 Expected net returns and farm produce for subsistence

Subsistence requirements were only partially met from own production on farms 103 and 107 in the without-innovation farm plans. In the with-innovation plans for all farms, maize production could meet subsistence needs, while production of beans, cowpeas and pigeonpeas was consistently below subsistence requirements. Thus, buying activities for pulses entered the solution on introduction of the maize 'planting density' and fertilizer innovations, as maize production was emphasized relative to other crops.

Expected net return for plans which were based on traditional technology ranged from KShs. 6 300.00 (Farm 103) to KShs. 27 617.00 (Farm 104). Whereas the expected net return for farm 104 is sufficient to cover the financial needs of the household, expected return for farm 103 would be KShs. 670.00 less than the amount required to cover financial expenditure. The 'medium planting density' innovation for maize was the only innovation to be included in optimal plans for all eight farms. The optimal plan for farm 105 included 0.51 ha. of the 'medium planting density' and 0.13 ha of the 'high planting density' innovations.

When maize activities based on the innovations were included as options, expected net returns for the plans increased for all farms. For farm plans incorporating innovations, incremental benefits ranged from KShs. 960.00 (Farm 101) to KShs. 26 894.00 (Farm 103), representing 5.5-81 per cent improvements in farm performance. Modest improvements were observed in the overall performance of farms 102 (16 per cent), 104 (12.3 per cent), 108 (14.3 per cent) and 105 (17.5 per cent). Substantial progress would have been achieved at farms 106 (39.1 per cent) and 107 (38.2 per cent). The overall indication was that farms with relatively low management standards are likely to achieve higher incremental benefits from the adoption of the 'planting density' innovation than the farms where performance is already relatively high.

Some examination of the differences in performance of the with-innovation and the without-innovation optimal plans for farm 103 is revealing. The without-innovation optimal plan included food crops produced under traditional management and livestock. This plan, however, does not produce enough maize and grain legumes to meet subsistence needs in both seasons. Buying activities for these items enter the solution set, as do off-farm work activities in each of the 24 labour periods. The with-innovation plan did not include any crop activities under traditional management except 0.08 ha. of pigeonpeas. According to this plan, there was labour released from crop activities to enter off-farm work activities in all 24 labour periods.

A range of farm plans for which net farm revenue ranged from KShs. 11 000.00 to 28 000.00 were obtained. As expected, if the without-the-innovation results are compared with each other, raising the levels of target income resulted in more negative deviations for a given level of expected income with each other. A similar effect is observed when comparing the with-the-innovation frontiers. At a given target level (KShs. 21 000), the with-the-innovation frontier dominates the without-the-innovation frontier. As the risk constraints are increased (movement down the expected target negative deviation (E-tND) curve), livestock activities expand up to the point where all the grazing land is used up.

Table 8.5 shows the Expected Value-target Negative Deviation (E-tND) efficient farm plans for traditional, medium (early planting and medium planting density) and high (early planting, medium planting density and fertilizer application) levels of management. The results were presented in Table 8.5 in terms of the net revenue per person and per hectare. This was to facilitate comparison of the performance of farms with different household characteristics in different agro-ecological zones (AEZs). Farmers in AEZ 3 and 4 sites (farms 101, 102, 105 and 107) had partially adopted seed, plant density and fertilizer innovations. Farms in the more arid ecologies (farms 103 and 106) had adopted the early planting recommendation only. Farm number 104 had adopted the early planting and the seed innovations only. Under traditional management, expected income per person ranged from KShs. 365.00 (farm 102) to KShs. 7 261.00 (farm 104). There was no apparent association between net revenue per person and site. For example, while farm 102 is located in agro-ecological zone (AEZ) U/LM4, expected net revenue per person was only KShs. 365. For farm 106, expected net revenue was KShs. 3 129 despite its location in AEZ U/LM5. This is because the former has 10 members of the household most of whom are school children, while the latter has only 5 members in the household.

Table 8.5: Expected net returns (Kshs.) of E-tND efficient farm plans

Farm no.	PCI1	PCI2	PCI3	PCL1	PCL2	PCL3	ADOPTION
101	1166.5	1592.4	7264.8	1458.1	1990.5	9081.0	Fertilizer, seed and plant density
102	365.6	1752.5	4634.9	114.25	547.7	1448.4	Fertilizer, seed and plant density
103	2119.1	3906.64	5036.7	40[illegible]8.97	7409.14	9552.4	Early planting
104	7261.7	3157.0	7264.7	4538.6	1973.1	4540.4	Early planting and seed
105	1798.5	4596.5	10791.5	1660.2	4242.9	9961.8	Fertilizer, seed and plant density
106	3129.4	3252.2	5644.6	1664.6	1729.9	3002.5	Early planting and seed
107	4954.0	9559.5	13332.5	1501.2	2896.8	4040.2	Early planting
108	2052.3	3180.8	7626.0	2638.7	4089.7	9804.9	Seed and fertilizer

Note:

- PCI1 - Net revenue per person (traditional)
- PCI2 - Net revenue per person (medium level management)
- PCI3 - Net revenue per person (input applications at the optimum)
- PCL1 - Net revenue per hectare (traditional)
- PCL2 - Net revenue per hectare (medium level management)
- PCL3 - Net revenue per hectare (input applications at the optimum)

8.6 Summary and Concluding Remarks

Risk programming models of eight farm households in the semi-arid region of Eastern Kenya were constructed for the purpose of analyzing technology adoption decisions. These models provided a framework within which results from previous chapters could be integrated to assess the goal structure for these households. For each of the eight case-study farms, simulation of activity selection was implemented in two stages. In the first stage, only traditional management practices were considered.

In the second stage the activity set from which to select was expanded to include the 'planting density,' time of planting and inorganic fertilizers innovations.

The impact on household goals was assessed in both stages. Farm plans based on traditional management showed that such plans could satisfy the subsistence needs of all households except one. Out of five innovations that were designed to help farmers attain higher levels of productivity, only one (medium planting density) was included in the optimal plans for all households. Inclusion of this innovation in the farm plan was associated with reduction in the area sown to other crops. This tended to result in greater need to purchase grain legumes from other sources. In households in which family labour was not limiting, a significant impact on the organization of production was that participation in wage employment increased. In all cases farm plans with the innovation yielded higher expected returns than those based entirely on traditional methods of farming. At any given target level, (e.g. KShs. 21 000.00), the with-innovation E-tND frontier dominated the without-innovation frontier.

Although the assessments of all innovations in chapter 4 showed that adoption of inorganic fertilizers could lead to substantial gains, the fertilizer-based innovations were included in the E-tND efficient sets for only a few farms, indicating that the fertilizer based strategies were dominated in the second degree stochastic dominance sense. In chapter 4, it was established that although farmers responses to questions concerning the use of other aspects of the maize technology package were generally consistent with extension recommendations, those pertaining to fertilizer use were markedly different from recommended practices. Here, farmers' apparent lack of the urge to acquire effective knowledge for fertilizer use could be interpreted in terms of risk aversion.

The 'medium planting density' innovation was included in the E-tND set for all farms. On the face of it, this suggests that this particular innovation is superior to the inorganic fertilizer using strategies as well as some of the without-innovations strategies. Secondly, resulting farm plans tended to show large increases in the farms' expected net revenue over the without-the-innovations farm plans. This difference in net revenue tended to derive from greater participation in wage employment. This suggests that widespread adoption of this innovation could call for far reaching changes in the local wage and grain markets. Adoption of this innovation may also result in changes in land use patterns on adopting farms. The question of why the innovation has not been adopted on a large scale still remains to be answered. Lack of awareness on the part of farmers may be one of the reasons. Another reason may be that the analysis did not capture significant aspects of the innovation. It has to be borne in mind that the data points which generated these results were too few. Moreover, it was the rate of fertilizer application for these trials was not included with the source of the data (Nadar 1984b). In computing the partial budgets for these strategies, it was assumed that standard recommendations (40 kg N and 40 kg P_2O_5/ha) had been used. Also, in the absence of guidance as to the availability of wage employment, the model assumed that all who seek wage employment may obtain it.

From the stand point of agronomic research, these analyses have indicated a clear need to base experimentation on methods which can yield results which generate more reliable information along the lines suggested in this chapter. It seems that performance data should cover a sufficient number of seasons and locations. Extension recommendations based on such data can have a better chance of being adopted. From the point of view of the social science research, it seems that the non-farm enterprise is poorly understood. Given that it is likely to assume increasing importance, better focused studies of the functioning of this enterprise are needed.

Chapter 9

SUMMARY, ISSUES ARISING FROM THE STUDY AND CONCLUSIONS

9.1 Introduction

On attainment of statehood, many third world governments saw their mission as embracing three trends. These were, consolidation of political independence, preservation of territorial integrity and promotion of rapid socio-economic development. In relation to the third objective, technical change in smallholder farming was pursued in order to raise productivity and improve the living conditions of rural people. In pursuit of this objective, agricultural research and extension services in Kenya have been receiving an increasing share of budgetary resources in recent years. The government of Kenya, for example, expects that much of the projected 5.6 per cent per annum growth in GDP for the period 1984-2000 will be achieved through a more efficient agriculture industry (Government of Kenya 1990). As people level impacts can only come about as a result of adoption of the innovations, by the majority of producers, this study was about elucidation of the factors that may be acting to constrain this adoption.

In the preceding chapters of this thesis, various aspects of the adoption of innovations for semi-subsistence farmers in the semi-arid region of Kenya were examined. Following a summary of the objectives, hypotheses, methods and the main findings, issues arising from the assessment of earlier sections of this thesis are presented in this chapter. The chapter concludes by outlining further agronomic and socio-economic research that is required in order to improve adoption.

9.2 Summary

The environmental and institutional context in which smallholder adoption decisions are made was described chapter 1. To recapitulate, smallholder farming in the semi-arid region is undertaken by a large number of individual holdings. Average farm size was 7.2 hectares. A variety of crop and livestock enterprises are operated, supplemented with petty commerce, industry and numerous forms of wage employment. Farm production is characterized by high levels of climatic risk. Despite a relatively progressive institutional setting (by African standards), few farmers have adopted improved methods and efficient inputs as recommended by the research and extension services.

A review of technical change in the region showed that farmers have been selectively responsive to agricultural innovations (e.g., the mould board plough and Katumani maize seed), irrespective of cost, risk and socio-cultural considerations. On the other hand, the innovations that were considered in this study are likely to offer farmers the greatest return, are relatively simple and most farmers in the region are aware of them. Previous research has invariably attempted to account for lack of adoption solely on the basis of three 'explanations,' namely, shortage of labour and working capital and socio-cultural constraints. The research problem in this study was that there is a gap in the understanding of the mechanisms through which adoption of proven innovations is impeded.

9.2.1 Objectives

The objectives of the study were to identify, evaluate and extend appropriate concepts and analytical tools and apply these in the acquisition of additional information that was needed in the identification and analysis of factors which impede adoption; determine possible consequences of alternative research and extension strategies; and, identify areas in agronomic and farm household issues requiring research.

9.2.2 Hypotheses

The objectives set out in the previous paragraph were pursued through the examination of a five-point thesis. Specific postulates to be tested were that non-economic elements: lack of 'real advantage', high adoption costs (of information, installation and operation); lack of information and risk impeded the adoption of innovations.

9.2.3 Methods

Existing procedures and methods (with suitable adaptations to local conditions) were identified and applied to the examination of observed farmer behaviour in relation to adoption of innovations. Broad descriptions of farming in the region were facilitated through information gained from the results of a survey of 94 farm households. As a first step, these data were scanned for causality relationships between adoption and a variety of household characteristics with the aid of a Qualitative Dependent Variables Model (QDVM). Implementation of QDVM was achieved through the fitting of farm survey data to the Logit function. Microeconomic theory of production was applied to NDFRC data with the goal of revealing cost, profitability and risk attributes of the technology upon which the three innovations were based. Data from agronomic field trials (Nadar 1984a,b; Nadar and Faught 1984a,b) were found to be not adequate to represent production risk that may have been entailed in the innovations. Additional data sets were generated through application of maize yield simulation using a crop growth model, CM-KEN. Stochastic Dominance Theory was used to assess the extent to which these innovations may be risk efficient. To make explicit allowance for the possibility that farmers are expected to compare advantages of the proposed innovations with the benefits from existing enterprises, realistic measures of the performance of the livestock and non-farm enterprises were sought. The lack of ready-to-use procedures prompted the development of a method for use in the assessment of livestock performance which combined climatic data with the performance parameters developed at NDFRC. Household survey procedures were used to obtain goal and strategy profiles for individual households for the sample. Elements of the Binswanger (1981) and the Equally Likely Certainty Equivalent method, ELCE (Anderson *et al.* 1977) methods were combined into a modified procedure and used to elicit utility functions for 45 households in the region. Household information, attributes of innovations and performance measures of the crop and livestock and non-farm enterprises were combined to aid in the assessment of adoption decisions in relation to risk, household characteristics and goals and resource endowments for eight case-study farms. This was undertaken within a mathematical risk programming framework (Target-MOTAD).

9.2.4 The main findings

The farm survey was designed to capture data on variables that are generally associated with adoption decisions of smallholders. These included innovator characteristics, attributes of the innovations and the socio-economic environment in which adoption is constrained to take place.

Survey results showed that between 1980 and 1990, the adoption of improved farm practices had risen from 68 to 83 per cent (organic fertilizers); 8 to 18 per cent (inorganic fertilizers); and 14.7 to 17 per cent (pesticides). There was an apparent decline in the proportion of farmers using seed of the recommended maize variety from 31 to 30 per cent. Most of the farm households operated non-farm enterprises and participated in wage employment. The most important source of farming information was the 'neighbour', but various extension agencies were also significant.

Assessments of association between farm and household and adoption from within the QDVM (Logit) framework yielded interesting results. The Maximum Likelihood Ratio (MLR) test statistics for all coefficients were significant. On the basis of these test results, the hypotheses of 'no relationship between innovation and household characteristics' were rejected. However, relationships between the estimated coefficients of individual household characteristics were insignificant except the constants and the gender variables. This suggested that it was worth pursuing the assessment of the influence of other factors which might have been significant constraints on adoption. Accordingly, relative advantage of the innovations, profitability of the livestock and the non-farm enterprises were assessed in chapters four, five and six respectively.

The main components of the technology on which the innovations are based were appraised for relative advantage. The analyses showed that the strategies incorporating innovations gave higher expected yield and net return than the traditional production strategies. However, the gains in expected yield and net return were attained at the expense of increased risk (increases in coefficients of variation). Appreciable productivity gains were recorded for sites in AEZs in LH2/3 and L/UM4 ecologies only while they represented little advantage in L/UM5 and 6 ecologies. This suggested that risk aversion as an influence on adoption should be considered, and that in so doing, agro-ecological zone specific recommendations should be developed.

Most farmers had diversified their activity portfolios so as to include livestock and a variety of non-farm activities as investment options. Labour and financial requirements per unit of the livestock enterprise were evenly distributed over the year. Net returns per hour and also per shilling were higher in the livestock than in crop enterprises. Performance measures for the livestock enterprise such as milk and manure production as well as gross margins per livestock unit were found to be subject to a high degree of variation about their expected values. This was contrary to the common belief among livestock researchers at the NDFRC, that the enterprise is not subject to production risk. Also, there was little evidence to support the commonly held view that the enterprise provides most of the farmers cash requirements.

Self employment and wage employment were considered explicitly in this study. Nearly all households had at least one member employed in non-farm employment. Out of 94 farm households, 23 had at least one permanent employee. More than 80 per cent of the households had at least one person in wage employment. A further 125 persons were engaged in self employment type activity. Average incomes were KShs. 24 175.00 and KShs. 17 320.00 per year in services and commerce respectively. Average earnings were KShs. 2 400.00 per year for those engaged in farm related employment.

Characteristics of household leadership and decision making systems were assessed. A 'co-operative' decision making system was described. Production and consumption decisions are made by the leadership (all senior members) of the household. Usually, members of a household would be co-opted into its leadership structure in recognition of the resources they independently control (e.g., wage income, own livestock, items of capital equipment, etc.). It was found that farmers subscribe to a variety of security, growth and development and self esteem and recreation oriented goals. The main strategies for goal attainment were: crops and livestock production, and a number of non-farm enterprises. To obtain indications of the levels of farmer risk aversion, utility functions for 45 household heads were elicited. Of these, 25 were severely risk averse (Arrow-Pratt coefficient ≥ 0.0245). The remainder were mildly risk averse (Arrow-Pratt coefficient ≤ 0.00007).

Results of the assessments of the non-economic factors, attributes of the innovations, the livestock and non-farm enterprises and household goals and strategies were integrated within a risk programming framework with a view to analyzing smallholder adoption decisions for each of the eight case-study farms. Farm plans which were based on traditional management were found to satisfy subsistence needs for each of the seven out of eight households. Increased maize production following inclusion of innovations resulted in more labour being released. This surplus labour was used in the non-farm enterprise. The inorganic fertilizer innovations were included in the optimal plans for five farms (only at the rates of 10-20 kg/ha). The 'medium plant density' innovation, entered the optimal plans for all farms. Incorporation of these innovations in the farm plan tended to be associated with sharp reductions in the levels of beans, cowpeas and pigeon peas, a decrease in area cultivated and an increase in participation in non-farm employment. Activities which included these innovations entered the optimal farm plans in small acreages. Entry of activities incorporating the two innovations into the optimal farm plans was constrained by labour (periods 4, 5 and 6) and cash (periods 4 and 9) shortages.

9.3 Issues Arising from the Study

Assessment of possible causality relationships among personal and demographic characteristics such as age, level of formal education and the nature of non-farm occupation showed that these had little influence on adoption decisions. In chapter 3, coefficients of the gender variable were significant for the adoption of both time of planting and organic fertilizers innovations. Female headed households were shown to complete planting operations earlier than their male counterpart. However, male headed households were shown to be more likely to adopt the inorganic fertilizers innovation.

Farm inputs and produce marketing did not seem to represent a severe handicap for the group of farmers in the sample. Discussions with the management of local stores indicated that existing capacity is not fully utilized. The extension services seemed to have covered a significant proportion of farmers through public meetings, direct visits and radio broadcasts. The survey showed however, that farmer response to the extension message was selective. Farmer understanding of the timing of planting and plant spacing recommendations were generally consistent with current extension recommendations. There were, however, noticeable divergences between farmers' stated understanding on the one hand and practice on the other. Although most of the farmers had used fertilizers before, their responses as to methods of use were generally different from extension recommendations. Subsequent analyses indicated that although use of fertilizers gave higher average yields, the coefficient of variation tended to increase with increasing rates of application. Hence, riskiness seems to be an important consideration, especially given the high levels of risk aversion observed in the elicitation of utility functions.

9.4 Conclusions

The objectives of the thesis were to identify, evaluate and extend appropriate concepts and analytical tools and apply these in the acquisition of additional information that was needed in the identification and analysis of factors which impede adoption; determine possible consequences of alternative research and extension strategies; and, identify areas in agronomic and farm household issues requiring research. The intention in the previous sections of this chapter was to show the extent to which the objectives of the thesis were addressed. In the remainder of this chapter, conclusions about factors which impede adoption of the three innovations are drawn, and areas requiring agronomic and farm household research are proposed.

The greatest constraint on the adoption of the plant density innovation was the risk of loss of seed should soil moisture be inadequate. It was shown that this innovation is based on recommendations which are suitable for farms in the wetter areas. GSD risk efficient planting densities were 2.2-4.4 plants per m^2.

It was shown in chapters 4, 5, 7 and 8 that livestock is an important aspect of the farming systems in the region. Livestock always entered the target MOTAD (SSD) efficient farm plans. In chapter 5, it was shown that the livestock enterprise is also subject to risk. Both carrying capacity and animal performance in terms of milk production, live weight gains and manure production depend on availability of feeds and water. Production risk is mainly due to unstable feed and water supply. Farms tend to be over stocked in average seasons. Reductions in stock numbers usually occur in seasons in which insufficient rainfall is received. An area where animal feed research might invest profitably is the development of efficient methods of harvesting and preserving feed material whenever supply exceeds livestock needs.

Yield as well as quality of manure is also expected to follow the same pattern as described for feed production. Yet as noted earlier, organic fertilizer in form of manure is used by the majority of smallholders to improve productivity of crop land. A wide range of interesting questions concerning the production and use of manure in smallholder farming in the semi-arid lands of Kenya need to be addressed by agronomic as well as livestock production research. Some of the issues that should be addressed through research include the determination of the rates of transfer of nutrients from grazing land to crop lands; the possibility of recycling nutrients through feeding crop residues and efficient harvesting methods. These issues have considerable significance for sustainable increases in crop production, given the reduction in average farm size, depletion of plant nutrients and increased crop and livestock interactions (McIntire, Pingali and Bourzart 1992).

Per unit financial returns to resources was found to be consistently higher for the non-farm than for farm activities. For this reason, farmers would be expected to adopt innovations which would enable them to earn a reasonable return on additional resource outlays that innovation requires. Expected gains from investment should compensate the farmer to the extent of foregone opportunities in alternative non-farm activities. This suggests that a better understanding of the factor and product markets for the non-farm enterprises is essential.

9.4.1 Research needs

If, as the findings of this study have indicated, other than the soil moisture availability constraint, low soil fertility is the most limiting factor in maize production, then, as long as this constraint is binding, potential benefits from innovations such as improved varieties, time of sowing and plant densities are not likely to be realized. In consequence, adoption of these 'dependent innovations' is likely to remain low. The highest gains from investment into agronomic research are likely to come from soil fertility and plant nutrition research. Farmers are already using organic fertilizers. There is a need to shift the focus of research away from demonstrating the usefulness of organic fertilizers. The farmers' priority concern is that low cost ways of preserving, harvesting and applying manure should be sought. In the longer term, consideration needs to be given to the development of plant types with better nutrient use efficiency.

The focus of socio-economics research should be pursuit of a better understanding of goal-strategy systems of smallholder households. A good understanding of producer goal-strategy and preference-constraint complexes can aid in the design, development and promotion of innovations that have a high likelihood of being adopted. Representative farm household models designed to describe relationships among goals, resources, strategies and constraints need to be constructed. Such models would be used to estimate potential levels of uptake and to project possible consequences of widespread adoption of a given innovation. Success with which such projections can be achieved will depend on how well farmer categories are defined. The current practice of equating adoption categories with agro-ecological zones has merit in determining the production potential for particular innovation. However, it fails to take account of farm to farm differences in the ecological as well as socio-economic factors which may affect adoption. A categorization of farm households based on agro-ecological as well as socio-economic variables was implemented in chapters 7 and 8. Following this classification three adoption categories were defined for each agro-ecological zone.

A number of research areas that have bearing on smallholder adoption of innovations were not explicitly addressed in this study. For example, research designed to relax institutional constraints to adoption can result in substantial productivity gains. The non-farm sector was treated superficially in chapter 6, mainly because of lack of a suitable theoretical framework. There is a need for a better understanding of the rural farm and non-farm factor markets. Research would address lack of knowledge about the rural land, labour, and capital markets.