Household Goals and Technology Adoption of Smallholders in Eastern Kenya

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The farm-household system of smallholders in semi-arid eastern Kenya is described. This is followed by a review of the extent of adoption of a set of new practices. A lexicographic utility framework is then developed to analyse the interaction between household goals and technology adoption. The results highlight the importance of closely considering goals of individual farmers when designing technologies and disseminating information on new practices.

1. Introduction

Increased population pressure on land in the semi-arid tropics of eastern Kenya has placed greater demands on research organisations to generate technologies for intensifying smallholder agriculture. Diagnostic surveys have provided general quantitative descriptions of some farm characteristics, and have identified problems for technical research. A disturbing finding of these surveys is that the adoption rate of improved technologies is low. This is despite the fact that many farmers are aware of these improved technologies following various extension activities, including on-farm trials.

For these farmers, the returns to investments in research on improving technology will remain low while adoption is at such restricted levels. A preliminary step to increasing returns to agricultural research is to gain a better understanding of the way farmers arrive at decisions about which farming practices to employ, and of the constraints under which they operate. The work reported in this paper is part of a project designed to establish farm-household models that can be applied to the evaluation of smallholder decision making in relation to adoption of improved farm practices. An overview of this project is described in Muhammad and Parton (1992). In the current paper attention is focused on the use of a lexicographic goal system to analyse technology adoption. The discussion relates to 93 farm families involved in a broad survey, and 18 additional farms that were studied more intensively over a 15-month period. They are located in the Embu, Machakos, Kitui and Meru districts. The technologies at the centre of attention are new varieties of maize. However, a total of 16 associated technologies were delineated for study.

The four remaining sections of the paper are a description of the farming systems that were observed, a review of the extent of adoption of new technology, an outline of a hierarchical preference theory and its use in an analysis of the adoption of maize technology, and a discussion of the lessons learned.

2. Farming Systems

Farming systems in the region have evolved largely in response to economic and environmental factors of which effective rainfall is considered to be the single most important (Stewart and Faught 1984). The distribution of rainfall is bimodal, allowing two cropping seasons per year under average seasonal conditions. These seasons are known locally as the short rains (October-December) and the long rains (March-July). As shown in Ockwell, Muhammad, Nguluu, Parton, Jones and McCown (1991) the pattern of farm activities, as well as demands on farm labour, closely follow the seasonal rainfall pattern.

2.1 Household Goals

While there were significant variations between different groups of surveyed farmers (see Ockwell *et al.* 1991), it is still possible to make some general remarks about the goals of these households. Starting from the centre of Figure 1, the farm-household decision-making unit provides the organisational

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structure. In most cases, the household unit was an extended family. Commonly, the families of sons who either worked on the farm or were employed in permanent off-farm work were part of the household unit. On other farms, the families of daughters and the parent(s) of farmers who managed and worked the farm were included also. The principal decision maker was often the male head of the household, but not always. There were clear instances where the management decisions were made by a husband and wife team, and a number of others where the wife was in charge, given that the male head was absent from the farm on a long-term basis.

The principal goals of the farm households were observed to be food security, dietary preference and the education of children. Farmers' attempts to attain the food security goal were evidenced by their cropping practices, their retention of livestock and their participation in the market economy through such activities as off-farm work and the ownership/management of a shop. The importance of the food security goal was revealed by the priority given to subsistence food crops in order of planting, application of farmyard manure to them, and in terms of them being grown on the best land. Cash crops (e.g. cotton, tobacco and sunflower) were planted after the food crops, and the cash generated was used to purchase non-farm food items, clothing and other household items, and education. In seasons of poor crop performance, farmers often sold livestock to meet the subsistence and cash needs of their families. However, most farmers attempted to store enough grain for one season so that they did not have to sell livestock when a one-season shortfall in crop production occurred.

Dietary preferences of the households included both crops and meat. However, crops formed the staple diet, with the preferred food mix being a cereal and a legume. A combination of maize and beans was the stated preference of a majority of the farmers. After maize, preferred cereals were the millets and sorghum, although the order of preference for those two cereals varied across farmers. After beans, the preferred grain legumes were cowpeas, then pigeon peas, but all farmers included both crops in their cropping mixtures. Cowpea was favoured because it produced edible vegetable matter early in the growing season, and the grain could be used either in a cracked form or in a soup (O'Leary 1984).

The goal of education of children was regarded by farmers as a longer-term risk-management strategy. Education increases the likelihood of children being able to obtain permanent off-farm work and thereby reduces their dependency on the farm (Mbithi 1974). Off-farm employment is of increasing importance in the region because the traditional practice of sub-dividing land among sons is resulting in decreasing farm sizes and the emergence of an increasing landless class (Mbithi 1974, O'Leary 1984).

2.2 Farm Production

The farms are all multi-enterprise crop and livestock production units. They range in size from just over 1 ha to almost 40 ha, but most are between 3 ha and 6 ha in area. While there was considerable variation in the number of livestock on each farm, pressure on grazing land remains a critical problem for all farms in the study.

As indicated in Figure 1, farm production is influenced by the goals of the household and by environmental factors. For example, dietary preferences of households have an important influence on the types of crops grown by farmers, but climatic conditions may restrict the impact of such preferences. Although maize was found to be the preferred cereal grain, finger millet and bulrush millet are regarded as being better adapted, particularly to the drier areas of the region (Neunhauser *et al.* 1983). In addition, the relationship between population pressure and the semi-arid environment was manifest in the badly eroded condition of the soils on the generally non-terraced grazing land of many of the farms.

Cropping practices reflected the risky environment in which farmers attempted to manage their resources to realise the food security goal. A significant feature of the production cycle is that farmers have an 'expected date of onset' of rains firmly in their minds for their particular farm or sub-location. Their land preparation and planting activities were performed in relation to this date. Farmers

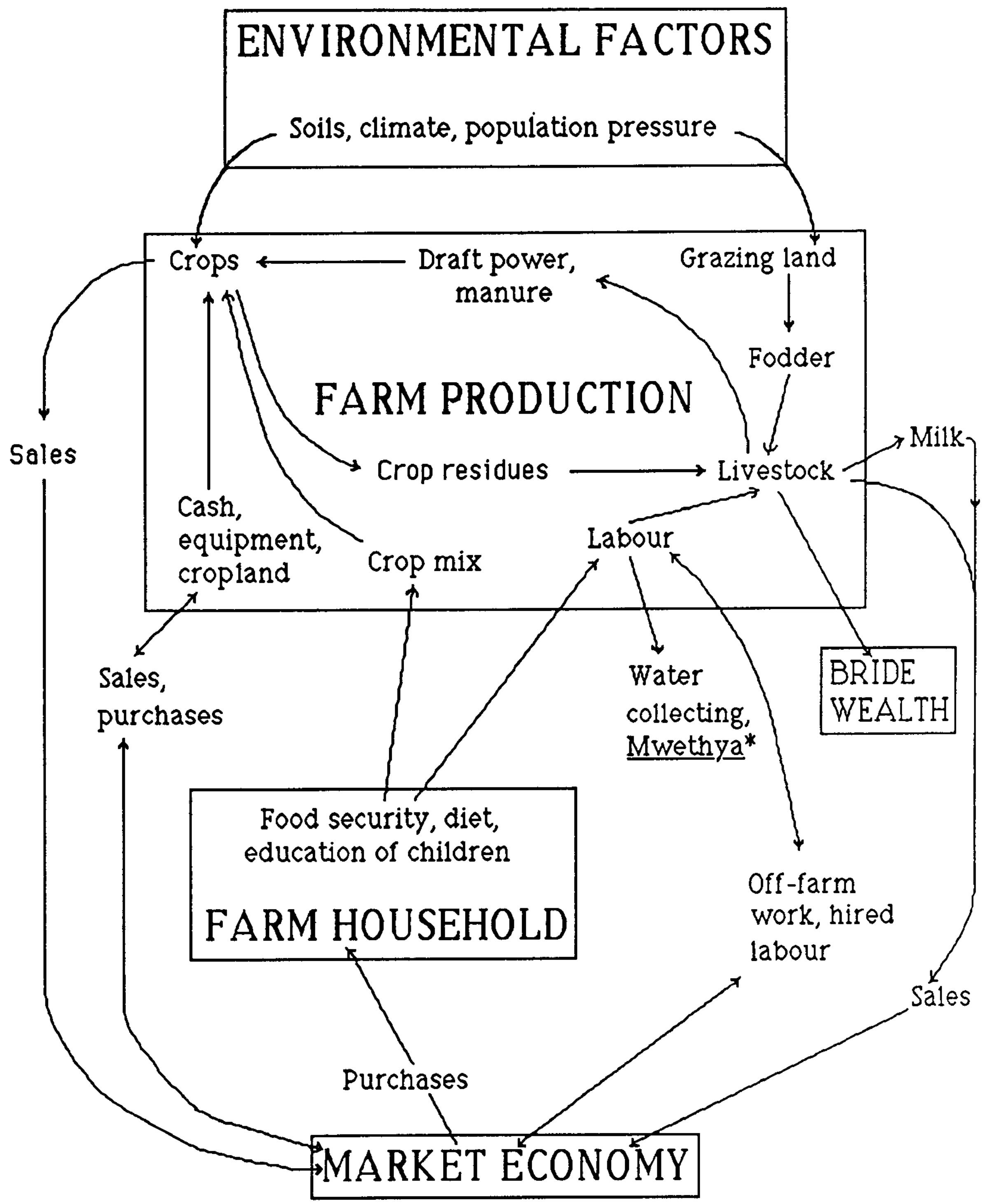

Figure 1 The farm-household system

* Mwethya is a combining together of labour from a number of farms at a critical time of the production year. The labour may be utilised on a particular farm or on a community project.

Source: Ockwell, Parton, Nguluu and Muhammad (1993) were also very much aware of the crop yield penalties of late planting, so that they had defined a cut-off date, related to their onset date, by which time they will have attempted to plant all the land they intended to crop in that season. Several farmers emphasised that they would not have land prepared before onset on those occasions when actual onset was early. If onset was late, some farmers adjusted their maize/bean intercropping plan by planting a sole crop of maize. With increasing pressure being placed on natural grazing lands, crop residues formed an important source of fodder for livestock during the two dry seasons. In return, livestock contributed draught power and manure to benefit the cropping activities, as well as being a relatively liquid asset which could be mobilised in times of crisis.

Livestock were kept by farmers for a variety of reasons. First, all categories of livestock were a store of wealth providing farmers with a source of cash either for general consumption needs or in the event of crop failure. Typically, livestock would be sold to meet secondary school fees for the coming term, or to purchase clothing, non-farm food items or household items. Second, the ownership of livestock represented an important status symbol for many farmers, with cattle being highly regarded as a sign of wealth. This was also related to the traditional practice of bride-wealth. Third, as mentioned above, the link between livestock and cropping activities shown in Figure 1 represents the provision of manure and draught power and, in reverse, the availability of crop residue for feed. The average work rate of oxen was about 0.4 ha per day for ploughing and was constrained by the relatively poor condition of animals coming out of the dry seasons, and the need to water and feed animals each day. Many farmers cleared manure from the bomas (compounds) for application to the short-rain season crops. However, overall, the application rate of manure was far below that required to maintain soil fertility (Ikombo 1984). Fourth, livestock also contributed directly to the food needs of farm households through the provision of milk and occasionally meat.

It became apparent from discussions with farmers that there is a seasonal shortage of labour in February and March, between the two rainy seasons. The demand for labour to harvest the short-rains crops commenced about mid-January with beans and proceeded until early March for maize. This was about a week before the expected date of onset of the long rains. So there was little time available between the harvesting of the short-rains crops and the plough-planting of the long-rains crops. During the long-rains season there was a continuing labour input to weeding. A second peak in the demand for labour on the case-study farms occurred in October when plough-planting activities commenced for the short-rains crops. A lower demand continued throughout November to December with the weeding of those crops taking place.

Another aspect of labour management was that of the *mwethya* activity, which represented both a supply of and a demand for household labour (Neunhauser *et al.* 1983, O'Leary 1984). This cooperative activity provided or required labour assistance during critical phases of the cropping cycle, such as ploughing, planting and weeding. It was also used by farmers for the construction or maintenance of terraces on their farms and for community works, such as the construction of water storage facilities. When farmers made use of the *mwethya* group, they had to provide the suppliers of services with food, and in the case of male contributors, local brew (beer). In return, recipients also had to repay the suppliers with work at some future point in time.

Involvement in more formal off-farm work was widespread and provided the most significant link with the market economy shown in Figure 1. Family members involved in off-farm work included sons or sons-in-law, and contributions to the farm household usually involved payment of school fees and assistance with food purchases. In some cases, sons who had received higher education and were employed in well-paid positions (e.g. teachers, Government employees) re-invested capital in their parents' farms and met the costs of hired labour, thereby effectively replacing their own previous labour input to the farm.

Other farmers or members of their household engaged in casual off-farm work which was generally confined to the local area and was often associated with 'food-for-work' programs. Another dimension of the casual-work activity was that of cottage industries, e.g. rope making, basket weaving, wood carving, charcoal production and the preparation of honey. Casual off-farm work and work in cottage industries were undertaken mainly by those households which had fewer resources, and which had problems in ensuring continuity of food supplies.

Notwithstanding the above general observations, there was still substantial variation across farms within the region as evidenced by differences in resource endowments, livestock numbers and environmental favourability. Such variability is relevant to the design, generation and dissemination of crop and livestock production technologies. Ockwell *et al.* (1992) discuss these issues in more detail.

3. Technology Adoption

The improved techniques were categorised into 16 types, and in Table 1 the 18 farms from the more intensive case study are ranked according to the number of techniques adopted. The various techniques can be classified as (a) non-cash using, (b) low-risk cash using, and (c) high-risk cash using. In the first category are early land preparation, dry planting, terracing and farmyard manure. Although the last two techniques in this category are labour-using, they have the potential to result in a more efficient use of labour. The second category includes livestock fodder, crop storage using chemicals and oxplough weeding. Then the high-risk cash using group is composed of fertiliser, improved crop varieties and field protection chemicals.

As shown in Table 1, the techniques with the highest level of use by farmers were terracing and farmyard manure, followed by dry-planting of crops. Terracing and farmyard manure are complementary techniques for improved soil and water management, which place high demands on available labour but do not necessarily require cash for their implementation.

The next most used techniques were Katumani Composite B maize, livestock fodder, oxplough weeding, improved bean varieties and early land preparation. Where farmers owned oxen and tillage equipment, oxplough weeding, early land preparation and dry planting placed no demands on the cash resources of the farm. The benefit that flowed from their use was the potential to smooth out the peak demand for labour at planting and weeding, and to improve the timeliness of cropping activities.

Those techniques that had a low level of use by farmers included fertilisers and field protection chemicals. Both of these techniques were cash-using in their implementation, and were characterised by a high degree of risk. Fertiliser, particularly di-ammonium phosphate, was regarded by farmers as a seasonal item of cash expenditure which was characterised by a low probability of return in a high-risk production environment.

Overall, farmer behaviour is risk averse and constrained by the cash requirements. A ranking of the techniques from highest to lowest use reveals that, except for maize and beans, the non-cash using techniques have been adopted by many farmers, while the low-risk cash using techniques have an intermediate level of adoption and the high-risk cash using techniques are hardly used. The significant departures from this trend were the wide adoption of Katumani Composite B maize and to a lesser extent improved bean varieties. Two reasons are advanced for this. First there was a complementary relationship between dry planting of maize and the use of 'fresh' Katumani maize seed because of the chemical treatment of maize which allowed it to remain in the soil for longer periods of time without risking deterioration before germination. Second, there was a dietary preference for maize which may have stimulated early interest in a higher-yielding variety. Improved bean varieties also realised a high rate of use among farmers, perhaps for a similar reason.

Hence it was observed that some improved technologies were in use by the majority of the farmers. Few farmers had progressed far towards what agronomists regarded as complete technology packages, and even these farmers seemed not to employ fertiliser effectively. Furthermore, there was a progression in the adoption of new technologies. The least innovative group tended to use farmyard manure, terracing and improved fodder crops. The

Table 1: Levels of Technology Adoption

Farm No. (a)	Type of Technology															
	Non-cash using				Low-risk cash using			High-risk cash using								
	FYM	TER	EPT	ELP	L/S FOD	OXW	STO CHM	KCB	MMB	CWP	SOR	PIP	FLD CHM	FTZ	MLT	GRG
7	A	A	A	A	A	A	A	A	A	A	A	A	A			A
16	A	A	A	A	A	A	A	A		A	A	A			A	
1	A	A			A	A	A	A	A	A			A	A		
8	A	A	A	A		A	A	A	A						A	A
12	A	A	A	A	A		A	A			A			A		
4	A	A			A	A	A	A								
9		A	A	A	A	A	A	A								
14	A		A					A		A			A			A
13	A	A	A					A	A							
17	A	A				A	A		A							
3	A	A	A			A			A							
5	A	A	A		A				A							
6	A	A			A						A					
15	A		A		A											
2	A	A				A								A		
10		A														
11			A													
18																

(a) Farms listed in descending order of adoption index.
A - Adoption.
FYM - farmyard manure, TER - terraces, EPT - early planting, ELP - early land preparation,
L/S FOD - improved fodder grasses, OXW - oxplough weeding, STO CHM - crop storage chemical,
KCB - Katumani composite B maize, MMB - Mwezi Moja bean, CWP - cowpea, SOR - sorghum, PIP - pigeon pea,
FLD CHM - crop protection (field) chemical, FTZ - fertilizer, MLT - millet, GRG - green gram.

Source: Ockwell *et al.* (1991)

next group used these together with dry planting and improved varieties of maize and beans, and some early land preparation. A third group used the techniques just mentioned more intensively, and added oxplough weeding and the use of chemicals in crop storage. The final group had adopted a wide range of techniques, but the use of fertiliser was not prominent.

Finally, a direct relationship was observed between the intensity of adoption and (a) expenditure on school fees per dependent, and (b) off-farm income. With respect to the former, the relationship may be an association under which the type of farmers who are adopters are also those who spend most on their children's education. Another explanation is that secondary school children may be change agents. This is supported by the fact that most of the school fees are charged for secondary education. Alternatively, it could be a one-way relationship in which the income generated from innovations and off-farm employment enables increased expenditure on school fees. The relationship between off-farm income and adoption tends to confirm the idea contained in the comment repeated by many farmers that the reason for not adopting was their shortage of cash.

4. A Theoretical Framework

This section describes in outline the development of a model, reported in full in Parton (1991). The method of applying this to resource–poor farmers in the study district is then discussed, highlighting some potential reasons for non–adoption of improved practices.

The notion of representing decision making by poor Kenyan farmers as a lexicographic ranking evolved while attempting to examine their preferences in a multiattribute utility framework (Keeney and Raiffa 1976, Ch 6). On each new farm, the interview designed to elicit utility functions reached a certain point at which the farmer began to express his/her goals in terms of an ordering of attributes (Ockwell *et al.* 1993). From highest to lowest preference, many of the expressed rankings can be interpreted as family/farm survival, dietary preferences, education of children, and then (as a group in which trade-offs were significant) farm development and consumer expenditure. This suggested that a better description of decision making by these farmers could be achieved using a lexicographic model (Georgescu-Roegen 1954), rather than the multiattribute utility model from which the experiment began.

A lexicographic perspective for describing decision making by these resource-poor smallholders is based on the assumptions that (a) there are three levels of goals, viz. survival, diet preference and cash, (b) the first goal is pursued until a survival level of consumption is achieved, after which the diet-preference goal becomes operative, and (c) there is a satisfactory level of the diet-preference goal which, once achieved, allows the objective of generating a cash surplus to operate.

The first level goal is the achievement of survival for the farm-family. Wharton (1971) provided a classification of types of subsistence. The term 'survival' used in this paper is closely allied to his 'minimum subsistence standard of living', and includes not only physiological requirements of the family group, but also socio-cultural requirements.

Prior to the growing season, it is the survival goal that influences planning. It is operationalised by assuming that the farmer sows the combination of crops that he/she considers will maximise the chance of achieving the survival threshold of the farm-family. The farmer's decision making can either be analysed in a situation where there is no market for the crops grown or, more realistically, where the food crops grown can be traded in a local market. The first requires the description of the production possibility set, while the second involves this set augmented by marketing activities.

As food production is dependent on weather, the production possibility set is defined stochastically. The line labelled X in Figure 2 shows the possible combinations of two foods that could be produced with a given combination of inputs and a given technology. Thus a shift from one line to another could be either a change in technology, or a changed input combination within a fixed technology. A movement along the line represents the effect of weather. Lines Y and Z are similarly defined for a different combination of inputs or different tech-

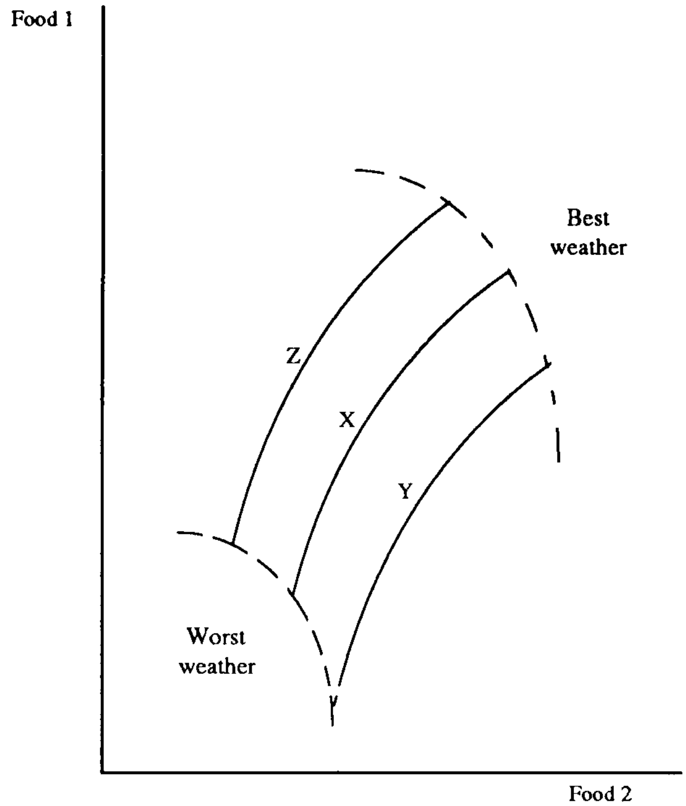

Figure 2: Stochastic production sets.

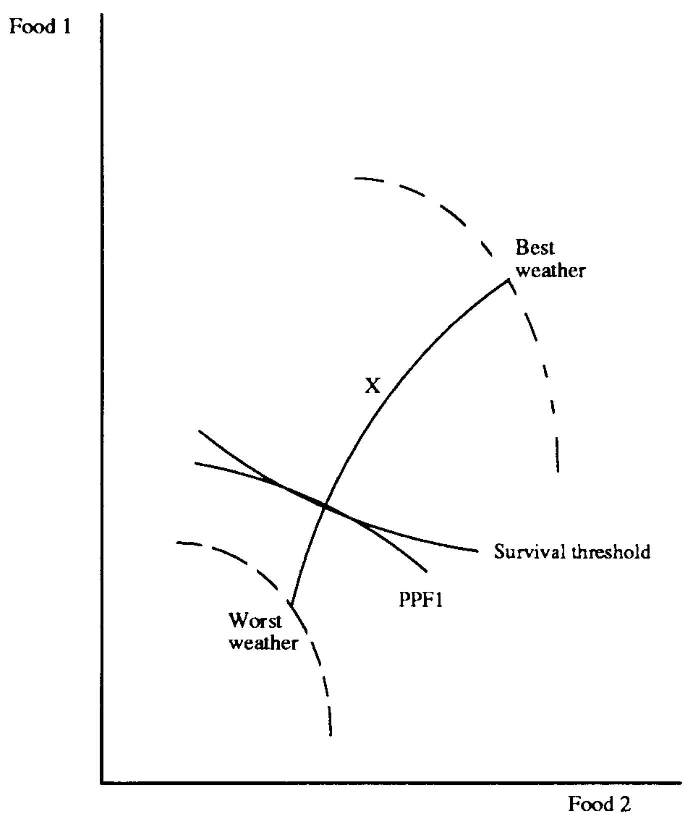

Figure 3: Defining the plan that achieves survival with highest probability.

nology. These three lines can be conceptualised as the planning framework of the farmer prior to the growing season in the situation where there is no market for the foods he/she produces. He/she must select one of the production plans X or Y or Z. (In the innovations context, X and Y might be improved technologies, and Z a traditional one.) Having made a selection, the actual weather that occurs during the season influences farm production and produces an outcome along the selected line. For completeness the boundaries of these production sets are shown as the production possibility curves that apply to the best and worst weather situations, respectively. These are "envelope" production possibility boundaries.

These best and worst production possibility curves are carried forward to Figure 3. Also shown in this figure is a survival threshold. This represents the combination of the two foods which just ensure survival for the farm-family. Given that production is stochastic, the survival goal can be defined in terms of maximising the probability of its achievement. Hence, also shown in the diagram is a third production possibility frontier (PPF1) which has the characteristic that there is a given probability of obtaining outcomes to its north-east. That is, every point along PPF1 represents a different technology, and for each of these points there is a given probability of obtaining outcomes better than it. Then at the point of tangency between the survival line and this final production possibility curve, the production plan that maximises the probability of survival is indicated. In Figure 3 this is plan X.

Extensions to this theoretical framework that include off-farm trading activities and higher level goals are included in Parton (1991). Of more interest in this paper is a practical application to technology adoption by a group of low-income farmers in the study district. Over the seasons 1985 to 1989 this group seemed to be emphasising the survival goal. The technology in question is a new maize variety called Katumani Composite B. From the perspective of the agricultural research scientists the two most significant components of the technology are improved seed and nitrogen fertiliser. This technology package offers farmers a substantial increase in yields and net returns over traditional varieties in all except very dry seasons. The perplexing issue facing researchers is that most farmers have adopted the new seed variety, but few apply fertiliser even though it can be purchased locally. To researchers such partial adoption of the technology package is a considerable loss of potential.

It is revealing to show diagrammatically the production from three alternative technologies, viz., traditional maize, new-maize-without-fertiliser and new-maize-with-fertiliser. Figure 4 indicates the combinations of two food crops produced under these different technologies for five weather patterns. Food 2 is maize, so there is a horizontal shift when moving from one maize technology to another. For example, the movement from A1 to B1 involves a rightward shift from an increased yield from the new variety and a leftward shift because of the cost of purchasing the new seed (where the seed cost is measured in terms of a maize numeraire). Taken together they produce a shift to the right. In a similar manner the movement from A1 to C1 is a net shift to the left, and is produced by a yield increase (to the right) and a cost of seed and fertiliser (to the left).

The comparison that is emphasised in the consciousness of the agricultural researcher is that between the traditional variety (points A1 to A5) and the dominating points of the complete technology package (points C2 to C5). In contrast, the comparison that is in the mind of the farmer whose survival is at risk is between the traditional variety (points A1 to A5), the dominating points with the new maize variety without fertiliser (points B1 to B5), and the inferior point using fertiliser (point C1). In other words, the scientist tends to overlook the downside risk, whereas the farmer sees this of paramount importance when survival of the farm family is at risk. From such a perspective, the adoption of maize without fertiliser is a rational choice.

It must be emphasised that this example is only applicable to those farmers pursuing the survival goal. A different response to the availability of technology can be expected for farmers higher up the want hierarchy. In Figure 5, the same technology effects are shown for a farm-family whose

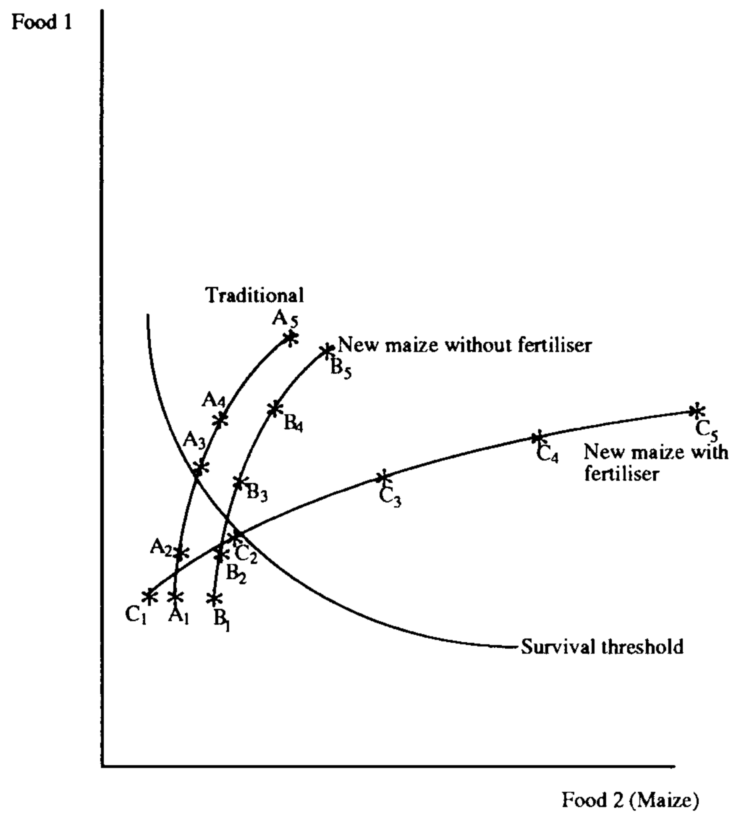

Figure 4: Production relative to the survival threshold using different technologies when survival is at risk.

survival is guaranteed and whose taste preferences have become, for the moment, the dominant goal. The indifference curves portray the observed general preference for maize over the alternative food. In this survival-guaranteed situation, the downside risk of the new-maize-with-fertiliser technology (C1 compared with A1 and B1) is less important than when survival was at risk and, furthermore, there is a demand pull towards higher maize output that makes this fertiliser-using technology more attractive. Hence, there would be a tendency for technology C to be adopted and for fertiliser to be used on farms where survival is guaranteed. The observation made in the farm survey work that cash-surplus farms are associated with the adoption of inorganic fertilizers provides support for this model prediction.

5. Lessons

The objective of the work described in this paper was to gain a better understanding of the way in which farmers make decisions. The rationale for doing this was to suggest ways of improving adoption rates and thereby increasing the returns to the introduction of new technology. The means of achieving the objective was by observing farming communities in the semi-arid tropics of eastern Kenya, and through an analysis of their adoption behaviour.

Extension of the maize technology, the main focus of attention, and of other related technologies, had been widespread and had been carried out over a long period of time. Although farmers were aware of the available technologies, few farms had adopted them fully. Key observations were that there was a general taste preference for maize and that new varieties of maize had been adopted by almost every farmer. However, few farmers had taken up the fertiliser component of the complete technology package recommended by agronomists. By completing a lexicographic analysis, downside risk was observed to be a significant cause of this lack

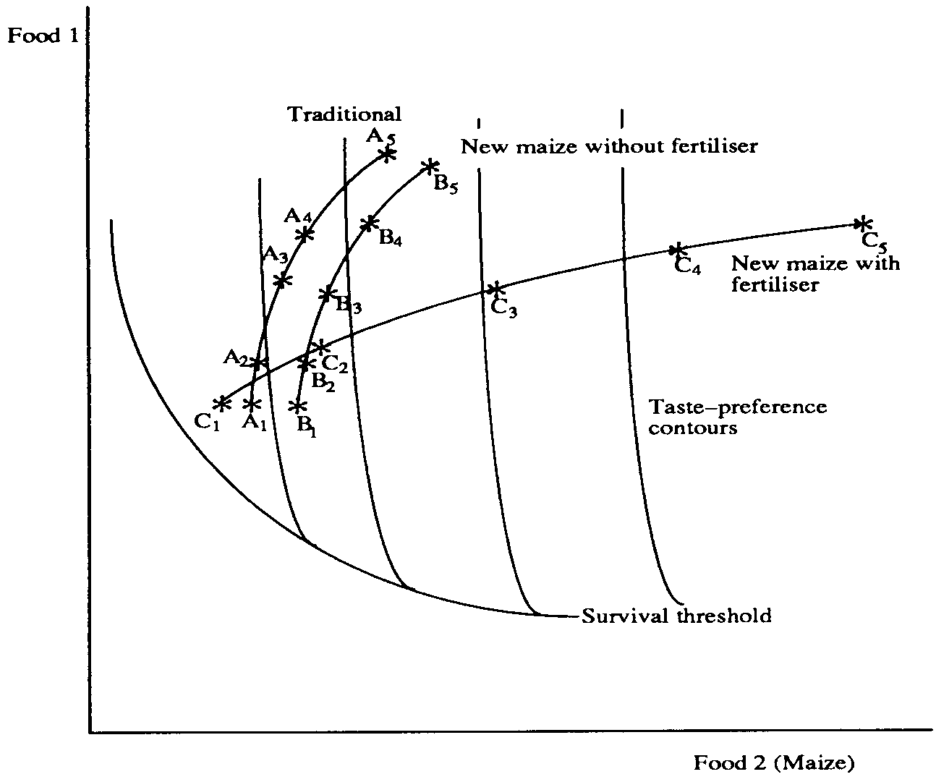

Figure 5: Production relative to the survival threshold using different technologies when survival is not at risk.

of adoption. Moreover, the farms that had adopted fertiliser were observed to be in a situation where survival was not at risk. Hence the fertiliser technology appeared not to be relevant to the goals of those farmers who are at the level of pursuing survival wants. For quite rational reasons, farmers pursuing a survival goal have not adopted cash-using technologies that involve a degree of downside risk.

A policy implication of these results is that the goal system of farmers may need to be considered closely in designing technologies and extension programs. Technologies and extension efforts relevant to one group of farmers may not be suitable for others because they are pursuing different levels of wants. Hence in designing technologies it may be useful to be aware of the proportions of the farm population that are, at a particular time, pursuing the different wants in the hierarchy. Furthermore, an appraisal must be made of the way in which a technology, if adopted, would move a household across a want hierarchy.

Finally, it is worth reflecting on the type of results that could have been produced by applying a more conventional risk analysis to the problem under consideration. In such an analysis, it is possible that use of fertiliser technology and level of risk aversion would have been inversely related. This would suggest that policies that reduce risk, like an input subsidy, would be appropriate. A difficulty with this is that it has not really discovered the prime cause of the lack of adoption because it has observed the behaviour of an individual farmer at too aggregate a level. What is more important, particularly from a policy perspective, is the reason why the individual is risk averse. A closer examination of the want system of individuals in the manner considered in this paper is one step towards an explanation of risk aversion. Such an examination might reveal that a fertiliser subsidy would not induce those farmers at the subsistence want level to adopt fertiliser. Indeed, the subsidy might only provide money transfers to those who have already adopted.

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