Farming Systems of the Semi-Arid Tropics of Eastern Kenya and Adoption of Innovations by Smallholder Farmers: A Case-Study of 16 Farms

Anthony P. Ockwell[1], Kevin A. Parton[2], Simon Nguluu[3] and Lutta Muhammad[2]

1. Bureau of Transport and Communications Economics, Canberra, ACT.
2. Department of Agricultural Economics and Business Management, University of New England, Armidale, NSW 2351.
3. Ministry of Agriculture, National Dryland Farming Research Station, P O Box 340, Machakos, Kenya.

The authors wish to acknowledge the assistance provided by the Australian Centre for International Agricultural Research and the Government of Kenya. Thanks are offered to Gunnar Harland, Bob McCown and Roger Jones who provided comments on various drafts of the paper, and to Jeff Gow for his editorial improvements.

Paper presented at the Australian Agricultural Economics Society Annual Conference, University of Queensland, Brisbane, 13-15 February, 1990.

1. INTRODUCTION

Increased population pressure on land in the semi-arid tropics (SAT) of Eastern Kenya has placed greater demands on research organisations to generate technologies for intensifying small-holder 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 for 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.

The returns to investments in research on improving technology for these farmers will remain low with adoption 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.

Achievement of this understanding requires intensive study of farms at various points along the adoption process. In this paper, the results deriving from the case studies of 16 such farms are reported. These case studies incorporate analysis of the complex mix of social and economic factors which influence the decision-making processes of farmers. Although the case-study approach requires substantial inputs of time, manpower and other resources, it was felt that it was the only reasonable way to gain the knowledge of the farming system which would assist the technical researchers in setting their research priorities. This should avoid generating technologies which are not in tune with the real needs of the farmer and which therefore have little chance of being adopted.

The current paper is restricted to providing a description of farms in a particular environment. This description highlights the farming-household system and its relationship with adoption of new technology. It emphasises the socio-economic component. A related paper (Ockwell, Muhammad, Nguluu and Parton 1990) concentrates on the technological component by examining current farming practices and the ways in which new technologies impinge on them.

2. BACKGROUND

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-November) and the long-rains (March-April). As shown in Ockwell et al (1990) the pattern of farm activities, as well as demands on farm labour, closely follow the seasonal rainfall pattern.

Diagnostic surveys were conducted by the Farming Systems Section of the National Dryland Farmland Research Station (NDFRS) in the districts of Machakos, Kitui and Embu during the period of 1980 to 1985 (Rukandema, Mavua and Audi 1981, Rukandema, Muhammad and Jeza 1983a, Rukandema, Muhhamad and Jeza 1983b, and Audi and Jeza 1986). The surveys sampled 690 farmers from the seven locations shown in Table 1. Also contained in the table is a summary of the principal characteristics of farms in each of those locations as revealed by the surveys. Households were often extended families with a range in average size across locations of 3.83 to 13.50 persons. The farms were generally mixed crops and livestock enterprises. Between regions, oxplough ownership levels differed markedly. This was despite the small variation in preferred activities between regions.

The stated objective of conducting the farm surveys was the provision of detailed background infonnation for scientists, so that they may better tailor their research programs to finding solutions to identified problems facing small farmers (Rukandema 1984). Evidence of the need for the diagnostic surveys was the lack of adoption of several of the technologies (e.g. a multi-purpose toolbar implement) and only partial adoption of others (e.g. improved crop varieties) that had previously been tested in on-farm Pre-Extension Trials over the period from 1980-82. These technologies had emerged from the technical research programs of the NDFRS, Katumani (Baktri, Gavotti, Odhiambo and Nguluu, undated). Their poor record of adoption suggested that the technical researchers needed to understand more clearly the decision-making processes of farmers if they were to develop and promote technologies which would be widely adopted.

Table 1

Summary of Principal Farm and Household Characteristics of the NDFRS Surveyed Farms

	Unit	Mwala (1980)	Mutomo Kawelu (1982)	Mutomo Kibiuni (1982)	Lower Kamarandi (1982)	Embu Kathera (1982)	Northern Kaivirya (1985)	Kitui Kimangao (1985)
Sample Size	no	100	100	100	145	145	40	60
A. Farmland								
Total farm size	ha	7.47	NA	NA	8.65	2.10	NA	NA
Cropland	ha	1.95	1.90	3.38	1.01	0.76	3.34	3.50
B. Oxplough p/ship	%	78	32	34	16	0	58	38
C. Cropping patterns								
planting after onset of rains	%	28	58	32	99	100	80	87
planting at onset of rains	%	65	42	68	1	0	65	38
planting before onset of rains	%	7	-	-	-	-	-	-
inter-cropping	%	91			90	94	100	100
D. Major crops grown								
Maize	%	100	100	100	23	90	95	45
Sorghum	%	11	84	87	92	56	98	100
Millet	%	1	32	84	94	70	100	100
Beans	%	64	62	39	1	31	43	10
Pigeon pea	%	100	97	98	2	39	58	30
Cowpea	%	91	100	100	85	83	98	98
Cotton	%	75	25	12	6	34	15	55
Sunflower	%	9	8	3	-	-	70	15
Green gram	%	5	69	66	85	85	85	90
Castor	%	1	68	86	-	-	86	87
Cassava	%	74	80	42	1	30	15	18
Sweet potato	%	37	47	13	0	24	5	3
E. Livestock								
Cattle	no	7	11	12	4	4	8.3	6.6
Goat	no	3	7	[illegible]	2	1	4.6	6.7
Sheep	no	10	11	10	9	8	17.9	14.4
Donkey p/ship	%	-	19	28		-	-	-
F. Household composition								
0-10 yrs	no	3.35	2.72	2.33	3.0[illegible]	3.40	1.07	1.28
11-15 yrs	no	1.16	0.91	1.23	1.[illegible]	1.56	0.54	0.59
16-60 yrs	no	3.63	3.40	3.60	4.[illegible]4	3.99	1.32	2.01
>60 yrs	no	0.61	0.12	0.53	0.53	0.50	0.90	0.17

Source: Rukandema et al 1981; Rukandema et al 1983a; Rukandema et al 1983b, Audi and Jezi 1986.

A quantitative description of farms was provided by the diagnostic surveys. This included: (a) resource endowments across farms (e.g farm size, implements, labour force); (b) current farming practices (e.g. crops grown, crop areas, livestock numbers, methods of cultivation); and (c) major production constraints as perceived by farmers (e.g. erosion, soil fertility, dry season livestock feeding problems). However, these surveys tended to yield information which was too general to achieve the detailed understanding of adoption that was required.

The present study was designed to complement the diagnostic surveys by giving essential information on: (a) farmers' responses to the technologies to which they were exposed; (b) those factors which influence the decision making processes of farmers in the context of adoption; and (c) the risk-management behaviour of farmers.

3. METHOD

A case-study approach was adopted to examine farming systems of the Machakos, Kitui, Embu and Meru Districts. Sixteen farms were used to provide a coverage of factors which characterise farms in the selected region. The locations of these farms are shown in Figure 1. They all had participated in the on-farm Pre-Extension Trials (PETs) from 1980 to the end of 1982 (Baktri et al. undated). There had been no further contact with those farmers until the present study was commenced at the end of 1985. Selection criteria for the PET program required that farmers should be representative of the farming population in terms of resources, constraints, and mixed farming practice. Representativeness was achieved by local extension officers and district agricultural officers assisting with farmer selection (Baktri et al. undated).

The method of interview was a combination of formal and informal techniques. The approach was similar to that used by Maxwell (1986) and Binswanger and Ryan (1980), as it attempted to explore factors influencing the decision-making processes of farmers, and hence, the evolution of current farming practices. A formal questionnaire was used as a checklist for the researchers in obtaining basic data on farm and household variables, e.g. farm size, livestock numbers, crops grown, crop area, household composition, workforce. However, informal discussions were found to be the best way of obtaining an insight into a farmer's behaviour in relation to cropping practice, livestock retention, constraints to the

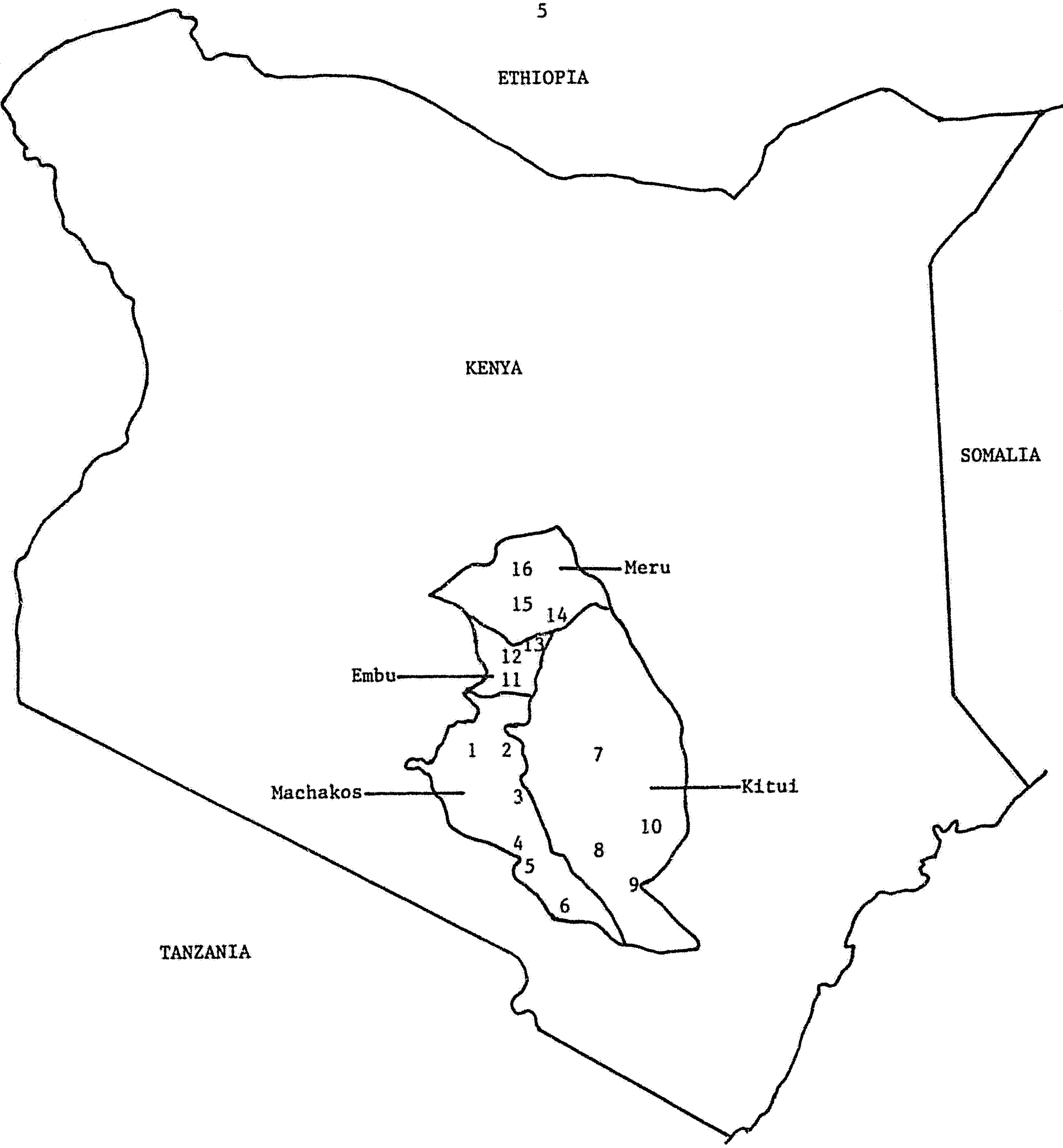

Figure 1 Location of case-study farms in the Semi-Arid Tropics of Eastern Kenya.

improvement of farm producti ity, risk management, and seasonal expectations. The informal approach also proved to be a useful means of exploring interactions between the production and household activities of farms.

At each visit, farmers were asked about their intended levels of crop and livestock activities for the forthcoming six-week period. On the next visit, farmers were asked to discuss their actual activities over the period between visits, and if they had changed their plans, to explain their reasons for departing from their earlier intentions. The recursive nature of this approach allowed the field team to explore in detail the relative importance of factors influencing farmers' decisions.

Farm visits were conducted at about six-weekly intervals to coincide with farm activities as dictated by the bimodal rainfall distribution. The monitoring of farms continued for 15 months, and provided inclusive coverage of the five seasons from the short-dry of January-March 1986, through the long-rains (March-July), the long-dry (July-October), the short-rains (October-December) to the short-dry of January-March 1987. On average, each farm was visited on 9 occasions. The field team normally comprised an agronomist and an economist. However, on occasions, another agronomist or another economist was included to improve the linkage between on-farm and on-station research, and to provide a base for conducting on-farm experiments at a later stage in the project's development.

4. THE TECHNOLOGIES

Nineteen technologies were delineated for study. There were ten high-yielding crop varieties, improved grasses, early land preparation, terracing, dry planting, farmyard manure, chemical fertilisers, pesticides, crop storage using chemicals, and oxen weeding. Improved crop varieties included Katumani Composite B maize (KCB), Mwezi moja bean (MMB), cowpea varieties Katumani 80 (K80) and Machakos 66 (M66), single-season pigeon pea, green gram line 26 (L26), sorghum varieties IS76, 8595 and Serena, and millet variety Katumani PM-1. The principal livestock technology disseminated to farmers involved the establishment of improved fodder banks. In part, this was also seen as a means of stabilising terraces against erosion by planting improved grasses such as napier (Pennisetum purpareum) and bajera (Pennisetum typhoides) along the terrace banks. Leucaena leucocoephala (cultivar unknown) was distributed to a sub-set of farmers for on-farm grazing trials with goats. The Pre-Extension Trials of the pesticides and storage using chemical technologies were based on providing recommendations on the use of chemicals (DDT, Aldrin, Malathion, Thiodana and Diazinon) against selected pests, such as maize stalk borer (Busseola fusca), aphids (Aphis fabae), pod sucking insects (Acanthomia horrida), aprion weevil and pod borers (Maruca testulatis).

Based on the diagnostic surveys, our a priori expectations were that adoption of these technologies would be patchy. For example, the use of pesticides had rarely been observed. Moreover, even where a techniques like distribution of farmyard manure was adopted more widely, it was seldom applied adequately on any farm.

Previous studies also support these general expectations. Ruthenberg (1980, p.135), when discussing permanent upland systems in the tropics, observed that farmers attempt to adapt their cropping system to the risk of drought. They would not capture maximum yields by dry planting, but would plant after they are sure that the rains had arrived, thereby losing plant nutrients through leaching. Drought resistant crops would often be perferred even though they have lower yields. Furthermore, low-income farmers are placed in a far more critical position when drought occurs, and hence they continue to avoid use of intensive techniques like mineral fertilisers. Indeed, integrated agricultural development programs (see Ghai, Godfrey and Lisk 1979, p.112), involving co-ordinated provision of improved varieties, modern inputs like fertiliser, credit and training, which were promoted widely in Kenya in the late 1970s, seem to have had a limited impact (Onyango 1987).

With respect to terracing, Ruthenberg (1980, p.137) suggested that it would rarely be maintained in regions like those of the present study. This was because the short-term returns to such investment were low. Consequently soil erosion would be widespread, despite the fact that terracing techniques are traditionally known.

While hand hoe-cultivation remains predominant across the semi-arid regions of Kenya, oxen ploughing and weeding is becoming more widespread. In western Kenya, Oluoch-Kosura (1987) has shown the substantial returns that are associated with timeliness of operations when oxen ploughing replaces the hand hoe. Our a priori expectation was that the use of oxen would be a technology in the stage of more rapid adoption by the case-study farmers.

5. RESULTS

The results presented here commence with our general observations on the farming system, farm-household characteristics and types of farm production. This is followed by a more detailed analysis of the case farms that shows (a) the innovations which have been adopted, and (b) some relationships between household characteristics and adoption. Throughout, farmers' views on the various improved practices are reported.

5.1 The Farming Systems

The farming systems observed in the 16 case-study farms in the SAT of Eastern Kenya are the end result of complex interactions involving livestock production activities, crop production activities and household considerations. A conceptual model of the farming systems which was developed during the farm survey work is presented in Figure 2. The use of a framework of this type enabled attention to be directed to the critical aspects of each farm during farm visits and in the analysis of the results. By describing the various components of this figure, the typical farming system can be reviewed.

5.2 The Farm Household

Starting from the centre of Figure 2, the farm-household decision-making unit provides the organisational structure. The main household characteristics of the case-study farms are summarised in Table 2. 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 most often the male head of the household, but not always. There were two 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 16 farm households were 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

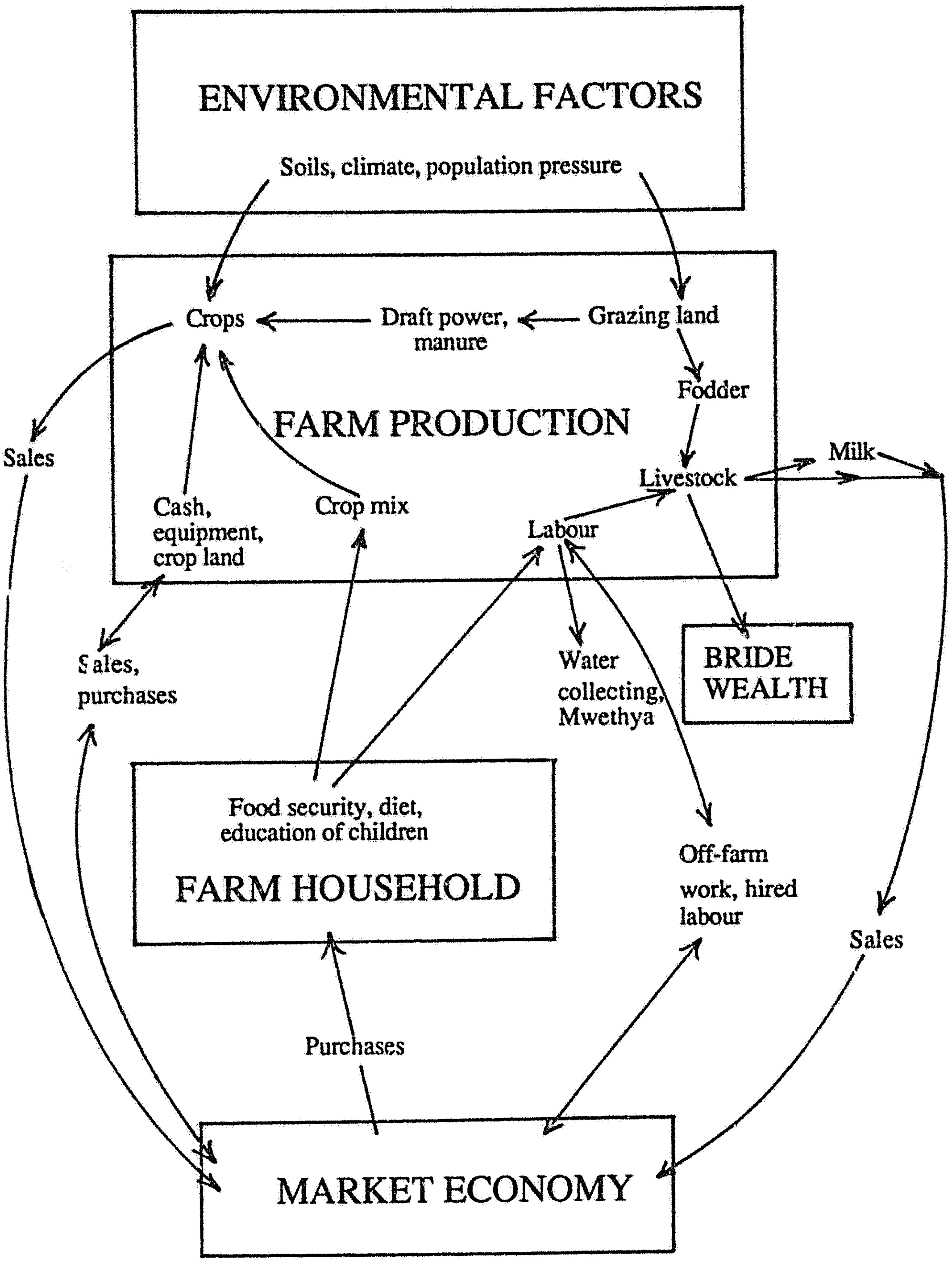

Figure 2 The farm/household system

Table 2

Household Characteristics of Case-Study Farms

Farm No.	Household Composition												Annual School Fees (KShs) (b)
	Children					Adult Workforce							
	Not at School	Prim. Sch.	Sec. Sch.	Coll. Univ.	Total	M	F	Hired Cas	Hired Perm	Other Adults	Total Adults	D-M (a)	
1	1	5	1	0	7	1	1	0	1	0	3	H	4500
2	0	2	1	1	4	0	1	2	0	0	3	W	2700
3	4	2	2	0	6	0	3	0	0	2	5	H	6000
4	0	0	0	1	1	0	1	0	1	1	3	W	0
5	3	4	1	0	8	2	2	0	0	0	4	H	2400
6	3	4	1	0	8	0	4	0	0	0	4	W	1000
7	1	3	1	0	5	1	2	0	0	2	5	H-W	5600
8	0	0	2	1	3	1	1	0	1	0	3	H-W	4600
9	0	0	0	1	1	1	1	0	2	0	4	H	200
10	2	4	0	1	7	0	2	0	0	1	3	W	200
11	3	5	0	0	8	1	2	0	0	1	4	H	250
12	0	4	2	1	7	0	1	0	0	0	1	W	11100
13	0	1	0	0	1	2	3	0	1	0	6	H	1050
14	5	6	0	0	11	1	2	0	0	0	3	H	200
15	3	6	0	0	9	1	2	0	0	0	3	H	200
16	2	5	1	0	8	1	2	0	1	0	4	H	5825

(a) The principal decision-maker (D-M) was taken to be the household member who was responsible for making decisions on the management of the farm. The decision-maker was usually the male head of the household (H), but in cases where the male head was absent from the farm, the decision-maker was either the wife (W), or the parent (P) of the absentee male.

(b) School fees were taken to include contributions to building funds for primary schools and formal fees for secondary schools. Exchange rate Kshs16.5:$US1.

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 food crops in order of planting, application of farmyard manure, weeding and in terms of their being grown on the best land. Cash crops (e.g. cotton, tobacco, sunflower, green gram) were planted after the food crops, and were grown to provide the cash needs of households (e.g. 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 short-fall 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 14 of the 16 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 ground form or in a soup (O'Leary 1984).

The related 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).

Some of the case-study farmers increased the area planted to cash crops during the short-rain season of 1986 in an attempt to meet the cash demand for school fees in the following January. The alternative for most farmers is to sell livestock; hence there is regularly a marked slump in livestock prices in January. From discussions with the case-study farmers, it was rare for a cash surplus generated through the sale of cash crops or livestock to find its way into re-investment on the farm. The order for the use of cash proceeds appeared to be immediate household needs, education, and then farm needs.

Hence, attainment of the education goal competed directly with longer-term farm investments in their respective demands for cash and labour resources.

Bride price was still held as an important part of the marriage contract in the more traditional areas of the case-study region, such as Kitui, Lower Embu and Lower Meru, and could be a substantial drain on the capital resources of those farmers who had predominantly male children. The price was generally considered to be about 70 goats or an equivalent combination of goats and cattle. However, girls who had been educated in secondary school commanded a higher price (O'Leary 1984). The price was usually paid out over a number of years, and there was a mutual understanding that the bride's father would not make demands for payment during times of crisis (e.g. drought). The bride-price was not upheld in the Machakos district in the traditional manner of the other areas, but was interpreted more as a recognition that the bride's parents needed and required continual support through time.

5.3 Farm Production

5.3.1 General considerations

As indicated in Figure 2, farm production is influenced by the goals of the household and 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 emerged as the preferred cereal grain, finger millet and bullrush 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 non-terraced grazing land of several of the case-study farms.

The farms are all multi-enterprise crop and livestock production units. Their principal production characteristics are summarised in Table 3. Their size ranged from 1.2 ha to 32.0 ha, whereas the variation in crop area per farm was much lower, ranging from 1.2 ha to 10.0 ha. There was considerable variation in the number of livestock on each farm and in stocking rate per hectare of grazing land. A comparison between the last two columns of the table reveals that on most farms the technical carrying capacity of the land was exceeded; sometimes excessively. While there is some use of common grazing land that is not recorded in the table, pressure on grazing land remains a critical problem.

Table 3

Principal Farm Characteristics of Case-Study Farms

Farm No.	Loc (a)	Farm Size Ha	Crop Area Ha	Graz Area Ha	Livestock						Technical Capacity (LSU/ha) (c)
					Oxen	Cattle	Goat	Sheep	LSU (b)	LSU/ Graz ha	
1	MWA	7.2	4.0	3.2	2	15	8	0	13.4	4.2	0.25 - 0.40
2	MWA	8.0	3.5	4.5	3	6	3	2	7.2	1.6	0.25 - 0.40
3	WAM	16.0	3.5	12.5	2	6	10	0	7.3	0.6	0.20 - 0.35
4	MAK	6.4	3.2	3.2	2	10	6	2	9.8	3.1	0.50 - 1.00
5	MAK	8.4	2.4	6.0	4	6	6	0	8.1	1.4	0.50 - 1.00
6	MAK	6.0	4.0	2.0	2	9	10	0	9.4	4.7	0.20 - 0.35
7	KIT	32.0	6.5	25.5	4	8	20	5	12.5	0.5	0.50 - 1.00
8	MUT	8.9	4.9	4.0	4	1	10	2	5.5	1.4	0.25 - 0.50
9	MUT	25.0	10.0	15.0	3	8	25	0	11.8	0.8	0.25 - 0.50
10	MUT	3.0	3.0	0.0	0	0	0	0	0	-	0.18 - 0.30
11	EMB	3.0	1.0	2.0	0	0	6	0	1.0	0.5	0.67 - 1.25
12	EMB	1.2	1.2	0.0	0	2	0	0	1.4	-	0.67 - 1.25
13	EMB	18.6	3.3	15.3	0	15	72	32	27.2	1.7	<0.33
14	MER	11.7	2.7	9.0	2	2	30	13	9.7	1.1	<0.33
15	MER	5.0	3.0	2.0	1	7	46	2	13.3	6.7	0.33 - 0.83
16	MER	15.6	5.8	9.8	3	7	4	0	7.8	1.2	0.33 - 0.38

(a) Locations (Loc) are Mwala (MWA), Wamunyu (WAM), Makueni (MAK), Kitui (KIT), Mutomo (MUT), Embu (EMB) and Meru (MER).

(b) Estimates of livestock units (LSU) were derived from conversion factors used by Tessema et al. (1985).

(c) Estimates of technical carrying capacity are derived from Jaetzold and Schmidt (1983).

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" for their particular farm or sub-location very firmly in their minds. Their land preparation and planting activities were performed in relation to this date. Farmers were also very much aware of the crop yield penalties of late planting, so that they had a "cut-off date" related to their "onset date" in mind, by which time they will have attempted to plant all the land they intended to crop in that season. Several farmers emphasized that they would not have land prepared before onset on those occasions when actual onset was early. If onset was late, the type of adjustment that farmers made was to adjust a maize/bean intercropping plan to 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 draft power and manure to benefit the cropping activities, as well as being a relatively liquid asset which could be mobilised in times of crisis. Despite these similarities, 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. (1990) discuss these issues in more detail.

5.3.2 Livestock activities

Livestock were kept by farmers for a variety of reasons. First, all categories of livestock provided farmers with a source of capital in the event of crop failure. In fact, farmers often invested any cash which was surplus to farm and household needs in livestock. The category of livestock subsequently sold to meet household needs depended on the order of need. For example, cattle were often sold in January, April/May and August/September to meet secondary school fees for the coming term. Other household needs included clothing, the purchase of non-farm food items and the purchase of household items. Farmers often argued that investment in livestock enabled them to store money from season to season, and this was seen as a preferred option to the capital market. Evidence from discussions with farmers about their drought management strategies of 1982-83 suggested that, even with diminishing feed reserves for livestock, farmers would only sell livestock in order to buy grain for the farm household. Otherwise, farmers would attempt to retain livestock for as long as possible in the expectation that rains would occur. This is a finding which contrasts strongly with the observations of Jodha and Mascarenhas (1983, p.15) for the semi-arid tropics of India. They found that a prominent drought strategy was asset depletion, with livestock having the largest relative decline.

Second, the ownership of livestock represented an important status symbol for many of the case-study farmers, with cattle being highly regarded as a sign of wealth. This was related to the traditional practice of bride-wealth discussed above.

Third, the link between livestock and cropping activities shown in Figure 2 represents the provision of manure and draft power and, in reverse, the availability of crop residue for feed. Oxen were used as draft power, and had a work rate of about one acre per day for ploughing. The work rate was constrained by the relatively poor condition of animals coming out of the dry seasons and the need to water and feed animals. The livestock management practice entailed the use of compounds (bomas) for yarding, and a high demand for labour during herding and watering activities. Many farmers cleared manure from the bomas for application to the short-rain season crops. Several farmers argued that, with a ready supply of manure available from livestock, the option of selling livestock to purchase fertiliser was too risky. Overall, the application rate of manure was far below that required to maintain soil fertility.

Fourth, livestock also contributed directly to the food needs of farm households through the provision of milk and occasionally meat. Several farmers expressed interest in upgrading fodder resources with a view to investing in an improved cow for milk production. Two of the case-study farmers had already proceeded down that investment path, and the sale of surplus milk provided them with a significant link to the market economy. Usually only on festive occasions would a goat be slaughtered for household meat consumption.

5.3.3 Labour

It became apparent from our discussions with farmers that labour is the relatively scarce factor of production. This scarcity has been exacerbated in recent years by their desire to have their children educated. The critical period for labour was in February and March, between the two rainy seasons. The demand for labour to harvest the short-rain 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 at Makueni. So there is little time available between the harvesting of the short-rain season crops and the plough-planting of the long-rain season crops. Then, during the long-rains season there was a continuing significant 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-rain season crops. The high demand for labour continued throughout December to January 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 a farmer made use of the mwethya group, he had to provide the suppliers of services with food, and in the case of male contributors, local brew (beer). In return, the recipient also had to repay the suppliers with work at some future point in time. Among the case-study farmers, mwethya was used for ploughing and weeding activities by two farmers. Two other farmers participated in a mwethya based activity for the construction of community water supplies.

Involvement in more formal off-farm work was widespread and provided the most significant link with the market economy shown in Figure 2. Five of the participating farmers had invested surplus resources in the ownership or management of a shop in a nearby town. In two other cases, the male head of the farm household had permanent off-farm work. In a further six cases, other members of the farm household had permanent off-farm work, and contributed either to the maintenance of the farm household or to re-investment in the farm. Such family members 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. On one farm, off-farm earnings were used for establishing citrus on disused terraces and the hiring of tractors to re-develop old terraces for cropping.

Several 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 observed on the case-study farms 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 on cottage industries were undertaken mainly by those households which had fewer resources, and which had problems in ensuring continuity of food supplies.

5.4 Adoption of Improved Technologies

Table 4 provides a summary of the extent of adoption by the 16 case-study farms. The three levels of adoption shown in the this table have the following specific meanings. Non-use (N) of improved techniques of production referred to those cases where even trial use is not observed. In contrast, the use of technology (A) was taken to indicate full commitment and regular application. Partial-use (P) was a "grey area" to assess, but included the (limited) adoption of technology either on a trial basis or in conjunction with a traditional technology.

In order to assess the adoption pattern of the various improved techniques, the farms were classified into four groups on the basis of the number of innovations adopted. The outcome of this grouping is shown in Table 5. In general it seemed that there was a progression in the manner in which innovations were adopted.

Farms 2, 6, 10, 11 and 15 comprise the first category. They were all close to being non-adopters of any of the improved techniques. Of the techniques under consideration, farmyard manure and terracing were used by three of the five, while improved fodder had been adopted by two and partially adopted by another. In addition, all except farm 11 had grown various improved crops on a trial basis.

A group we have classified as partial adopters consists of farms 3, 5, 9, 13 and 14. The distinguishing feature of the partial adopters over the previous category is the fact that there are identifiable techniques in addition to farmyard manure, terracing and improved fodder that they have taken up. All five had adopted dry planting, four had improved maize

Table 4

Levels of Technology Adoption

Farm No.	Type of Technology															
	Soil + Water Management							Improved Crop Varieties								
	ELP	EPT	FYM	FTZ	TER	OXW	KCB	MMB	CWP	SOR	MLT	PIP	GRG	FLD CHM	STO CHM	L/S FOD
1	P	N	A	A	A	A	A	A	A	N	N	N	-	A	A	A
2	N	N	A	A	A	A	N	P	P	N	-	N	-	N	N	P
3	N	A	A	N	A	A	P	A	N	-	-	N	-	N	P	P
4	P	P	A	N	A	A	A	P	N	-	-	P	-	N	A	A
5	P	A	A	N	A	N	N	A	N	-	-	P	-	N	N	A
6	N	N	A	N	A	N	N	P	N	A	-	P	-	P	N	A
7	A	A	A	P	A	A	A	A	A	A	-	A	A	A	A	A
8	A	A	A	N	A	A	A	A	P	-	A	P	A	N	A	P
9	A	A	N	N	A	A	A	-	P	P	-	N	N	N	A	A
10	N	N	N	N	A	N	P	-	P	P	P	N	-	N	N	N
11	N	A	N	N	N	N	N	N	N	N	N	-	-	N	N	N
12	A	A	A	A	A	N	A	P	P	A	N	N	-	N	A	A
13	P	A	A	N	A	N	A	A	P	N	P	N	N	N	N	N
14	P	A	A	N	N	N	A	-	A	P	N	P	A	A	N	N
15	P	A	A	N	N	N	P	N	N	P	P	P	N	N	N	A
16	A	A	A	N	A	A	A	N	A	A	A	A	P	P	A	A

A - Adoption, P - Partial Adoption, N - Non Adoption, (-) not grown.
ELP - Early land preparation, EPT - early planting, KYM - farmyard manure,
FTZ - fertiliser, TER - terraces, OXW - oxen weeding, KCB - Katumani composite B maize,
MMB - Mezi Moja bean, CWP - cowpea, SOR - sorghum, MLT - millet, PIP - pigeon pea,
GRG - green gram, FLD CHM - crop protection (field) chemical, STO CHM - crop storage chemical,

Table 5

Adoption Pattern

Group	Farms	Technologies adopted (a)
1	2, 6, 10, 11, 15	Farmyard manure, terraces, improved fodder.
2	3, 5, 9, 13, 14	Early planting, terraces, maize, farmyard manure, beans, improved fodder.
3	1, 4, 8, 12	Farmyard manure, terraces, oxen weeding, maize, chemicals in crop storage, improved fodder, early land preparation, beans, early planting.
4	7, 16	Early land preparation, early planting, farmyard manure, terraces, oxen weeding, maize, cowpeas, sorghum, chemicals in crop storage, improved fodder, green grams, chemical protection in the field.

(a) The order within each group represents the intensity of use.

and three had improved beans. All except farm 3 had at least partially adopted early land preparation. Once again a variety of other improved crops were grown on a trial basis.

Farms 1, 4, 8 and 12 had made significant progress in using some improved techniques from all areas of innovation. Except for dry planting which was not employed on farm 1, these farms were more intensive users of the innovations adopted by the previous group. In addition, oxen weeding and chemicals in crop storage were fully adopted by all four farms. Chemical fertilisers were used by two of the group, and improved cowpeas had been planted in conjunction with traditional varieties by three farmers.

The final group, which we consider to be innovators, consists of farms 7 and 16. Both had fully adopted early land preparation, dry planting, farmyard manure, terracing, oxen weeding, and the use of chemicals in storage, together with improved varieties of maize, cowpeas, sorghum and fodder. In addition, farm 7 grew only new varieties of beans and green grams, and applied chemicals to protect crops in the field. Farm 16 grew traditional and improved varieties of green grams, and grew only improved varieties of millet and pigeon pea. The technology which was not prominent was the use of chemical fertilisers. Only one of the two had partly adopted it.

Overall it was observed that some improved technologies were in use by the majority of the farmers. However, only two from 16 had close to a complete package, 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 next group used these together with dry planting and improved varieties of maize and beans, and some early land preparation. The third group used the techniques just mentioned more intensively, and added oxen weeding and the use of chemicals in crop storage. The final group of two farms had adopted a wide range of techniques, but the use of fertiliser was not prominent.

5.5 Relationships between Household Characteristics and Adoption

In order to examine the relationships between household characteristics and patterns of adoption, the four PET farm groups defined in Section 5.4 were analysed further. The key results are shown in Table 6.

Table 6

<u>Household Characteristics and Patterns of Adoption of Different Groups (Mean Values per Farm)</u>

Group	Farm size(ha) (c)	Crop area(ha)	Grazing area(ha)	Crop/ grazing	Lsu/ grazing	School fees per dep. (Kshs)	Off-farm income (a)	Maleness (b)	Agedness
1	5.0	2.9	2.1	1.4	2.9	124	0.4	0.4	0.6
2	15.9	4.4	11.5	0.4	1.1	340	1.0	1.0	0.2
3	6.2	3.3	2.9	1.1	2.2	1262	1.5	0.4	0.0
4	23.8	6.5	17.3	0.4	0.6	1758	1.5	0.7	0.0

(a) Because of the difficulty of obtaining money values of earnings off the farm, the number of individuals working off the farm is recorded.

(b) A farm with a male decision maker is recorded as 1.0, a husband and wife team as 0.5 and a female decision maker as 0.0.

(c) A farm with a decision maker 60 years of age or less is recored as 0.0, and more than 60 is recorded as 1.0.

First, a direct relationship was observed between the intensity of adoption and (a) expenditure on school fees per dependent, and (b) off-farm income. An inverse relationship seems to exist between age of the decision maker and intensity of adoption. With respect to the school fees per dependent, 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. Alternatively, it could be a one-way relationship in which the income generated from innovations and off-farm employment enables 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. For example, all three farmers who applied di-ammonium phosphate to their maize crops during the short-rain growing season of 1986 had sources of off-farm income. One (farm 12) also was able to borrow against expected tobacco returns from the British and American Tobacco Company.

The age variable was rather crude, having only the two categories older and younger than 60 years. However, three of the four decision makers who were over 60 were in the lowest adoption category, and the fourth was in the second lowest.

Turning to the other variables shown in Table 6, it can be seen that, except for the relationships just mentioned, adoption groups 2 and 4 are similar. They both have a high proportion of female decision makers and similar levels of cropping and livestock activities. They both seem constrained by land availability, which group 2 tends to counteract by off-farm employment. This again supports the notion that cash availability may be a determinant of the level of adoption.

A rank correlation analysis was completed to assess the degree of association between level of adoption and the other variables of the data set. A part of the correlation matrix which shows those variables having the highest correlation with adoption level is shown in Table 7. The innovations which are most strongly associated with overall adoption are crop storage using chemicals, Katumani composite B maize, oxen weeding, improved cowpeas and early land preparation. Other variables directly associated with adoption are off-farm income opportunities and school fees per dependant.

Table 7

Spearman Rank Correlations Among Techniques Adopted, Off-Farm Income and School Fees per Dependent

	No. techniques adopted	STO CHEM	KCB	OXW	CWP	ELP	Off-farm income	School Fees per dependant (Kshs)
No. techniques adopted	1.000							
STO CHEM	0.884	1.000						
KCB	0.777	0.677	1.000					
OXW	0.769	0.835	0.411[b]	1.000				
CWP	0.741	0.560[a]	0.788	0.481[a]	1.000			
ELP	0.713	0.707	0.783	0.393[b]	0.597	1.000		
Off-farm income	0.707	0.711	0.650	0.678	0.546	0.574	1.000	
School fees per dependant (Kshs)	0.706	0.550[a]	0.374[b]	0.619	0.285[b]	0.367[b]	0.599	1.000

1. Significant at the one per cent level unless otherwise indicated by a superscript.

a. Significant at the five per cent.

b. Not significant.

The table also shows some of the practices that are likely to be adopted in conjunction with a particular innovation. For example, farmers who have adopted Katumani composite B maize also have tended to adopt crop storage using chemicals, improved beans (rank correlation of 0.513 not shown in the table), improved cowpeas, and early land preparation. They are also likely to have off-farm income opportunities and to be hiring permanent labour (rank correlation of 0.689).

6. SUMMARY AND CONCLUSIONS

By interviewing farmers over a 15-month period, a description of the farming systems of the Machakos, Kitui, Embu and Meru Districts of Kenya was obtained. Analysis of the results revealed a number of aspects of farms and households which would need to be considered in developing appropriate innovations and in effectively directing extension activities. First, the farm-household system is complex with a deal of interdependency between the household and the farm decision-making processes. This is evidenced in a partly hierarchical goal system in which the objective of food security dominates dietary-preference and education-of-children objectives. Knowledge of the goal system is of significance to the innovation process in that it is the basis of observed behaviour such as farmers stubbornly persisting with low yield/low risk traditional crop varieties.

Livestock were important to the farm-household system. Besides being a source of food, they were a store of wealth available in times of stress such as crop failure, a status symbol and a source of draft power. When drought occurred farmers would retain livestock as long as possible, despite the devastating effect on pasture.

There was widespread involvement in off-farm work, particularly by the more innovative farmers. The results indicate that income earned from such work seems to facilitate adoption of some new techniques. However, further research could be preformed to provide a more thorough understanding of the nexus between the goal system of farmers, cash income and adoption.

Next, it was observed that there was a distinct order in which innovations were adopted. For example, there was more intensive use of improved varieties of maize and beans as one moved from the less to the more innovative groups. While some improved technologies were in use by the majority of farmers, yields remained low as few farmers adopted complete packages of technologies. This raises the issue of whether extension efforts should be concentrated on fewer farmers with the objective of their attaining reasonable yields by accelerating them through the innovation process.

With respect to household and demographic characteristics, younger farmers tended to be the more innovative, off-farm income tended to facilitate adoption and the attainment of higher-level goals like children attending secondary and tertiary education.

7. REFERENCES

Audi, P. and Jeza, A. (1986) "The farming systems of semi-arid Northern Kitui, Eastern Kenya", Project Field Document No. 7, Ministry of Agriculture and Livestock Development, UNDP/FAO, Nairobi.

Bakhtri, M.N., Gavotti, S., Odhiambo, S. and Nguluu, S. (undated), "Farming systems research at the NDFRS Katumani", Project Field Document No. 2, FAO/Ministry of Agriculture, Nairobi.

Binswanger, H. and Ryan, J.G. (1980), "Village level studies as a locus for research and technology adoption", in Proceedings of the International Symposium on Development and Transfer of Technology for Rainfed Agriculture and the SAT Farmer, 28 August - 1 September 1979, ICRISAT, Patancheru, A.P., India.

Ghai, D., Godfrey, M. and Lisk, F. (1979), Planning For Basic Needs in Kenya, International Labour Office, Geneva.

Jodha, N.S. and Mascarenhos, A.C. (1983), "Adjustment to climate variability in self provisioning societies: some evidence from India and Tanzania" Economics Program Progress Report 48, ICRISAT, Patancheru, A.P., India.

Maxwell, S. (1986), "The role of case studies in farming systems research" Agricultural Administration and Extension 21(3):147-80.

Mbithi, P. (1974), "Rural sociology and rural development: Its application in Kenya", Kenya Literature Bureau, Nairobi.

Neunhauser, P., Bayrether, H., Engel, A., Friesceneggar, M., Magelassa, A., Neves, A.M., Renneke, V. and Salzer, W. (1983), "Appropriate land use systems for smallholder farms - A survey of ecological and socio-economic conditions in the Machakos District", Centre for Advanced Training in Agricultural Development, Berlin.

Ockwell, A.P., Muhammad, L., Nguluu, S., and Parton, K.A. (1990), "The farming systems of semi-arid Eastern Kenya", mimeograph paper, ACIAR/CSIRO Dryland Project, Nairobi.

O'Leary, M. (1984), The Kitui Akamba - Economic and Social Change in Semi-Arid Kenya, Heinemann, Nairobi.

Oluoch-Kosura, W. (1987), "Mechanizing land preparation for maize production in Kenya", in Bellamy, M., and Greenshields, B. Agriculture and Economic Instability, International Association of Agricultural Economists Occasional Paper No. 4, Gower, Aldershot.

Onyango, C.A. (1987), "Making extension effective in Kenya : the district focus for rural development", Chapter 10 in Rivera, W.M. and Schram, S.G. Agricultural Extension Worldwide, Croom Helm, London.

Rukandema, M., Mavua, J.K. and Audi, P. (1981), "The farming systems of lowland Machakos District, Kenya", Technical Report No.1, Ministry of Agriculture / FAO, Nairobi.

Rukandema, M., Muhammad, L. and Jezza, A. (1983a), "The farming systems of semi-arid Southern Kitui, Eastern Kenya", Project Field Document No. 3, Ministry of Agriculture / FAO, Nairobi.

Rukandema, M., Muhammad, L. and Jezza A. (1983b), "Farming systems of semi-arid Lower Embu, Eastern Kenya", Project Field Document No. 4, Ministry of Agriculture / FAO, Nairobi.

Rukandema, M., (1984), "Farming systems of semi-arid Eastern Kenya", Proceedings of the Symposium of Dryland Farming Research in Kenya, East African Agriculture and Farming Journal 44(4),422-435.

Ruthenberg, H., (1980), Farming Systems in the Tropics, 3rd edition, Clarendon, Oxford.

Stewart, J.I. and Faught, W.A. (1984), "Response farming of maize and beans at Katumani" in Proceedings of the Symposium of Dryland Farming Research in Kenya, East African Agriculture and FarmingJournal, 44(1),29-51.