Chapter 1

INTRODUCTION

1.1 Background

The performance of agriculture in the traditional sector in the majority of African countries including Kenya has tended to lag behind expectations. Even when country-to-country variations are considered, the trend is that of declining per capita grain production in the wake of an enormous growth in human numbers that is now underway in the continent. Shortfalls in grain production occur from time to time, calling for massive imports. No wonder, then, that although essentially agrarian, few countries have escaped the twin problem of rising grain import bills and mounting foreign debt. Sustainable yield thresholds of the land resources are being systematically breached as soil erosion, loss of soil organic matter and the depletion of plant nutrients set in. Environmental factors, poor incentive systems and lack of appropriate technology are believed to be the root causes of the African agrarian crisis (Eicher 1986). Technical progress, and incentive systems to support participation by farmers are important elements in any strategy to further the development of smallholder agriculture. This study sets out to analyze the adoption of innovations for semi-subsistence farmers. Although specific focus is on innovations for maize production in the semi-arid areas of Kenya, the concepts and procedures that are being developed are of wider applicability.

1.2 Farming in the Semi-arid Tropics

The semi-arid tropics (SAT) account for 13 per cent of the agricultural land of the world and an estimated 700 million people, most of whom rely on rain-fed agriculture for their livelihood (ICRISAT 1980). The farming environment is characterized by low amounts of rainfall, high temperatures and poor soils.

Instability in the climatic variables is the major cause of high levels of risk. Low and highly variable yields, and other problems of resource management such as soil erosion and desertification are rampant. Thus, low living standards and the inability to cope with emergency situations are common features of life in the SAT in developing countries.

1.2.1 The Semi-arid lands of Kenya

Different definitions of the semi-arid lands have been attempted. Climatic variables are usually employed in such classifications (Bailey 1979). In particular, meteorological factors such as precipitation and temperature are commonly used in classifications involving agricultural land use. In Kenya, the semi-arid zone includes areas where annual crops are grown under natural rainfall conditions and where seasonal rainfall is in the 500 - 800 mm range four years in five (ISNAR 1981). Figure 1.1 shows the agro-ecological classification of land in Kenya. On this basis, the semi-arid areas fall within two main areas. Of these the most important is an extensive region which covers parts of the Rift Valley and Eastern provinces. The second region lies in the immediate coastal hinterland. Together they cover over 7.5 million hectares (Table 1.1).

Table 1.1: Area and percentage of total areas receiving selected amounts of rainfall 4 in 5 years

Mean annual rainfall (mm)	Land area (m ha)	Percentage
500	41.95	72
500-750	7.57	13
750-1250	6.99	12
1250	1.75	3
Total	58.26	100

Source: ISNAR (1981)

1.2.1.1 Relief and climate

Jaetzold and Schmidt (1983) have provided a detailed technical description of the relief, climate and soils of the semi-arid lands of Kenya. To put into perspective the ecological setting within which agricultural development takes place, salient features of the agricultural geography are included. Climate is greatly influenced by relief and altitude. Clusters of highlands in Machakos and Kitui districts attain a height of 2100 m above sea level while elevations of about 700 m are common in the lower areas. Eastern Kenya receives rainfall in two distinct seasons, namely the short-rains season (October-December) and the long-rains season (March-May). Each season receives, on average, 250-400 mm (i.e., half the annual amount).

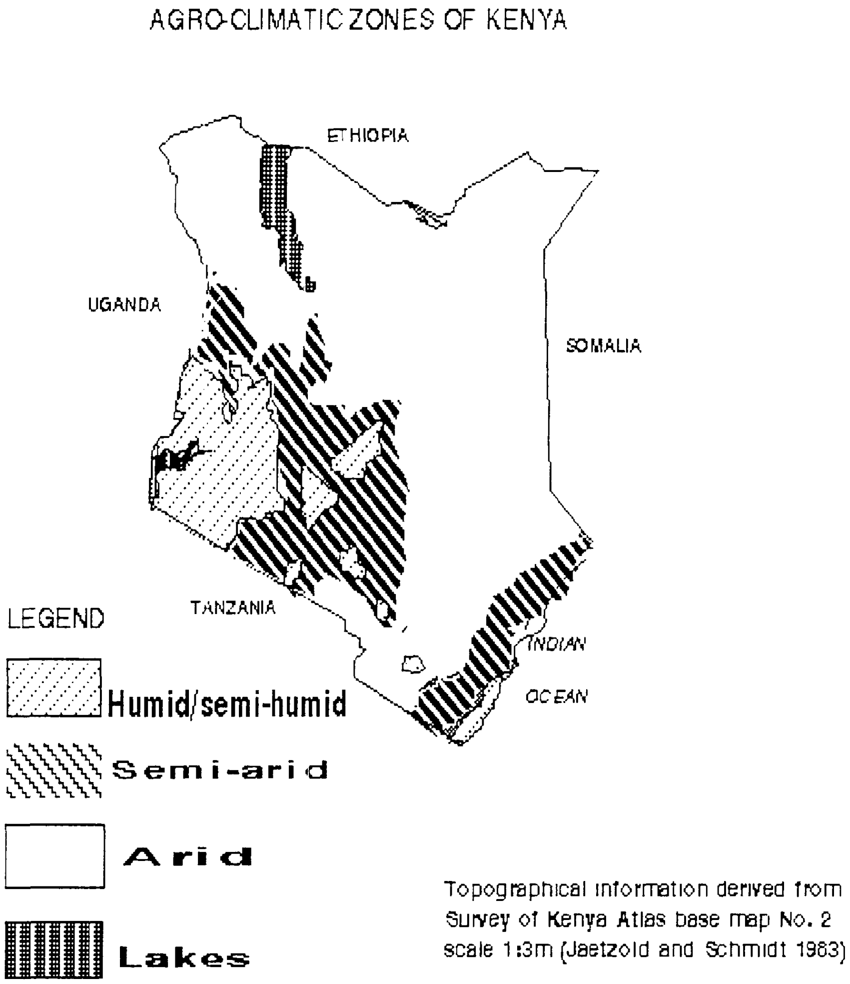

Fig. 1.1 Kenya: Distribution of Agro-climatological Resources

Soils of the area vary greatly in terms of management requirements within individual farms and between different farms. This variability is due to intrinsic properties of their parent materials, local physical and chemical processes which facilitate soil formation, and cultural histories of individual fields. Predominant soil types are luvisols and acrisols. Ferrasols, nitosols and vertisols are to be found in many locations all over the region. In fact, there are numerous other soil types which are without great significance in terms of area of agricultural land they involve. Luvisols and acrisols have poor structural stability, properties that are associated with low infiltration rates and are highly susceptible to erosion. Subsoils of luvisols and acrisols are characterized by low porosities and limited water holding capacities. Pockets of vertisols occur in expansive tracts of low lying areas and in the flat lands to the north and south of Machakos and Kitui districts. Vertisols are moderately deep to very deep clay soils. These soils are relatively more fertile and are of high moisture holding capacity. These attributes are potentially important factors in the management of soil moisture, choice of crops and climatic risk in semi-arid farming. However, there are negative traits of vertisols that should be noted. In general, these soils do not easily drain, are heavy and sticky when wet and extremely hard when dry. Toxicity and salinity often attain levels at which plant growth and development is inhibited. Where subsoils are shallow and gravelly, wear and tear on tillage equipment is usually high. To make the best use of the advantages associated with vertisols, farmers must provide for special adaptations to equipment used. Nevertheless, many farmers produce reasonable food and high value cash crops on them.

1.3 Dryland Farming in Kenyan Agriculture

By all indications, agriculture will continue to dominate the economy of Kenya for the foreseeable future. However, only 12 per cent of the land (Table 1.1 and Figure 1.1) has high agricultural potential. A larger proportion (72 per cent) is either desert or semi-desert and, hence, unsuitable for conventional rainfed arable farming. Another 13 per cent of the land is in the semi-arid category. Mixed farming systems which are now part of the traditional life in the semi-arid environments can be undertaken successfully provided that appropriate management techniques are used.

Population pressure in the high potential areas is intense. Some of this excess population has been moving into the semi-arid areas for several decades. But the region has not fully participated in the socio-economic development that has taken place elsewhere in the country following the attainment of independence. The desire of the government is that the region should be more fully integrated into the mainstream of the economy. The region is also expected to assume an increasing share of agricultural production in Kenya (Government of Kenya 1978, 1983, 1989, 1990).

These considerations have tended to weigh heavily in favour of increased support for agricultural development and against the contention that resources should be committed to areas with higher agricultural potential where returns to investment are more assured. Consequently, there has been increased public investment in agricultural development for the region in recent times.

1.4 The Main Features of Farming

Technical assessments of land use have consistently indicated that much of the SAT of Kenya is suitable for extensive grazing systems. With rapid increases in population due to immigration and intrinsic factors, such a mode of land use has long ceased to be feasible. Farming is now centred around crops and livestock production. Maize, beans, pigeon peas and cowpeas are the main food crops. Cotton and sunflower are commonly grown as cash crops. Cattle, sheep and goats are reared under extensive management systems.

Farm production is highly correlated with amounts of rainfall received, within-season distribution and with appropriate use of the required inputs. On average there is crop failure in two out five seasons (Stewart and Faught 1984). Analyses of the rainfall record based on the concepts of Response Farming[1] have facilitated a classification of the growing seasons into the 3 categories shown in Table 1.2.

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[1]The concepts of Response Farming were developed in eastern Kenya to facilitate the forecasting of season type using rules that are based on the time of season onset and early cumulative rainfall. Tactical agronomic responses such as adjustment in crop densities and amounts of nitrogen fertilizer which determine crop yield ceilings and demands on soil resources are then possible (McCown *et al.* 1991).

Table 1.2: Seasonal rainfall categories and frequency of occurrence

Category	Seasonal precipitation (mm)	Frequency of occurrence (%)
Good (A)	350+	40
Fair (B)	221-349	35
Poor (C)	220-	25

Sources: Stewart and Faught (1984, pp. 33-34)

1.4.1 Household resource endowments

The family provides most of the resources that are used in farming. Family owned land and labour and working capital in the form of seeds, tools and implements, comprise the resource base on most farms. Mean farm size is about seven hectares. Out of the total land area, about 2.5 ha is developed for crop production. The balance is occupied by the homestead and grazing area. Mean household size varies from five to seven persons. In terms of potential labour supply, mean household size works out at about four Standard Adult Labour Equivalents (SALE).

1.4.2 Crop Production

All crops apart from sorghum, pigeon peas and cotton are grown twice yearly, once during the short rains season and once during the long rains season. Yields of these crops are shown in Table 1.3.

Table 1.3: Average yield of some food crops.

	Yield (Kg/ha)				
	Good season	Average season	Poor season		
Crop	h	b	o	b	b
Maize	1279.9	997.0	446.0	627.0	278.0
Beans	495.5	319.0	na	180.0	42.0
Cowpeas	na	329.0	na	269.0	115.0
Pigeon peas	439.9	438.0	na	312.0	186.0

Notes to table 1.3

1. h: Heyer (1967) - data collected over the 1962/63 cropping year from a group of small holdings in Masii location. Above average amounts of rainfall were recorded during those particular seasons.
2. b: Bakhtri *et al.* (1984) - Data from on-farm research studies.
3. o: Ockwell *et al.* (1991) - Summary of crop yields and plant population for case study farms, group 1, Mwala/Wamunyu

Production per unit of land is low and highly variable. A major reason for poor production is non-compliance with recommended practice (Weir 1986). In particular, lower than optimal planting densities, and plant nutrient deficiencies appear to be the major sources of poor performance. Figure 1.2 shows the use of purchased farm inputs. Less than one-third of the farmers in the region use improved seeds and pesticides, even fewer use fertilizers to boost production.

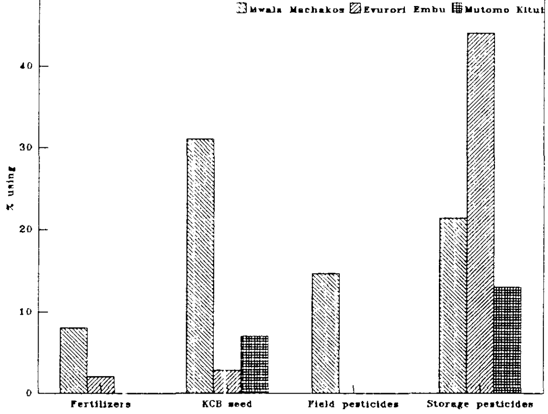


Fig. 1.2 Use of Modern Farm Inputs in Semi-arid Eastern Kenya. Adapted from Rukandema

1.4.3 Livestock Production

Livestock production is based on extensive grazing management systems. Seasonal shortfalls in feed resources, declining productivity of the grazing lands and overstocking are the issues that have received much attention in the livestock production literature. During the November-January and March-July periods, livestock feed resources are in surplus. Farmers experience acute shortages of livestock feed during the August-October and January-March periods. Livestock feed deficits have direct repercussions on the livestock enterprise (low milk yields and liveweight gains) and indirect effects on crop production (inadequate draft and late planting). Overgrazing reduces effective ground cover, and soils become highly susceptible to erosive power cf the elements (Figure 1.3a).

Long run patterns of stocking rates are also strongly influenced by seasonality. Farms are typically over-stocked during average years. In seasons following droughts 'forced destocking' through sales and deaths usually take place (Figure 1.3b).

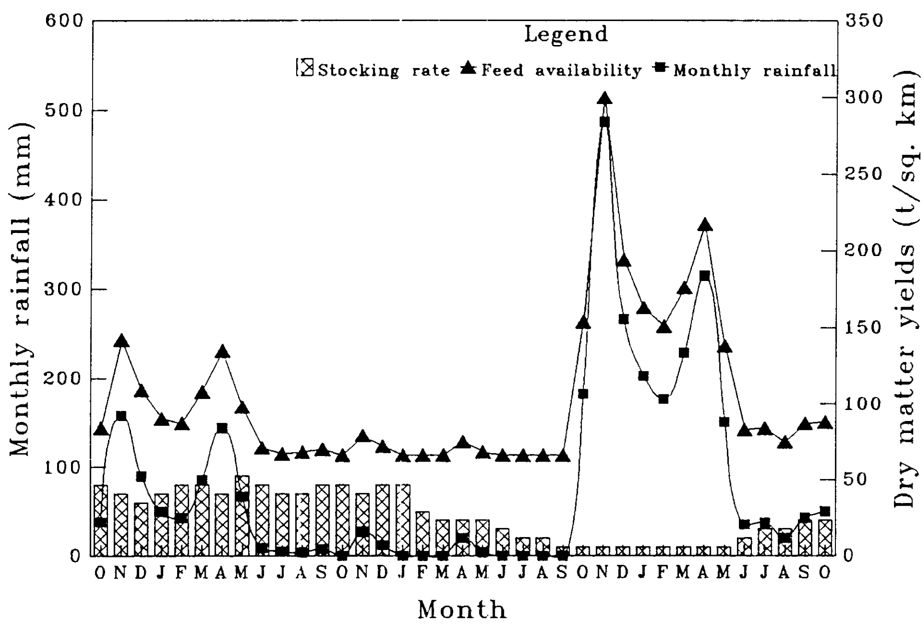


Fig. 1.3a Feed availability vs stocking rates (Unpublished data, NDFRC)

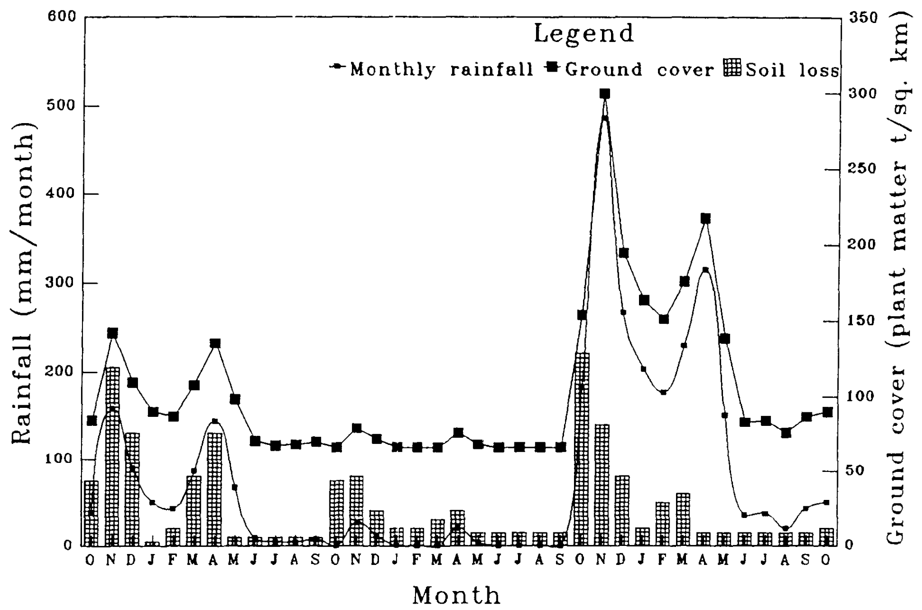
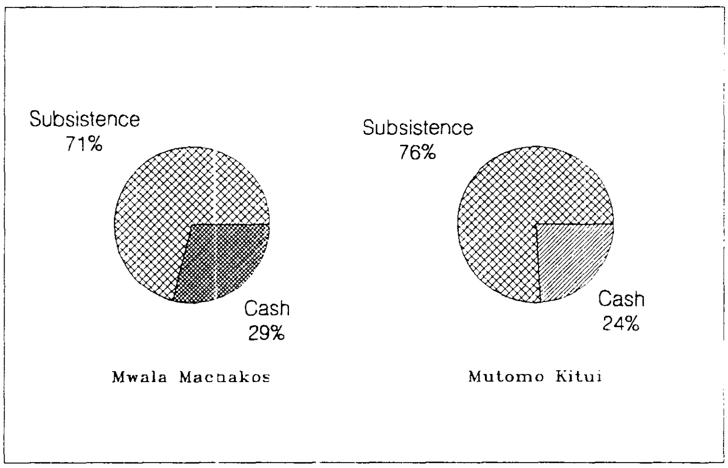


Fig. 1.3b Monthly rainfall, ground cover, and soil loss (Unpublished data, NDFRC)

1.4.4 Farm production

Even during normal seasons, most households are unable to supply year round subsistence requirements. The most important supplementary source of food supplies to the household is the local market (O'Leary 1984; Rukandema 1984; Akong'a and Downing 1985). As Figure 1.4a shows, a larger proportion of production goes towards meeting family subsistence requirements.



Adapted from Rukandema (1984 p. 435)

Fig. 1.4a Composition of Farm Household Production.

1.4.5 Farm output

Apart from the household subsistence needs, there is an increasing demand for goods and services that must be obtained from off-farm sources. As such goods can only be obtained in exchange for money, it is expected that households would seek to undertake cash generating activities with increasing commitment. Frequent crop failures and the need to resort to the market for subsistence requirements would reinforce the motivation to pursue cash generating activities. Hunt (1978), Rukandema (1984) presents evidence in support of this observation. For the three locations that were studied by Rukandema off-farm production was shown to account for a substantial proportion of total household production (Figure 1.4a). Various members of the household commonly engage in non-farming activities.

Large quantities of top soil are washed away during the first showers early in the season. The problem of soil erosion further threatens continued productivity of the land and causes undesirable off-farm effects such as dam siltation and a host of other environmental problems.

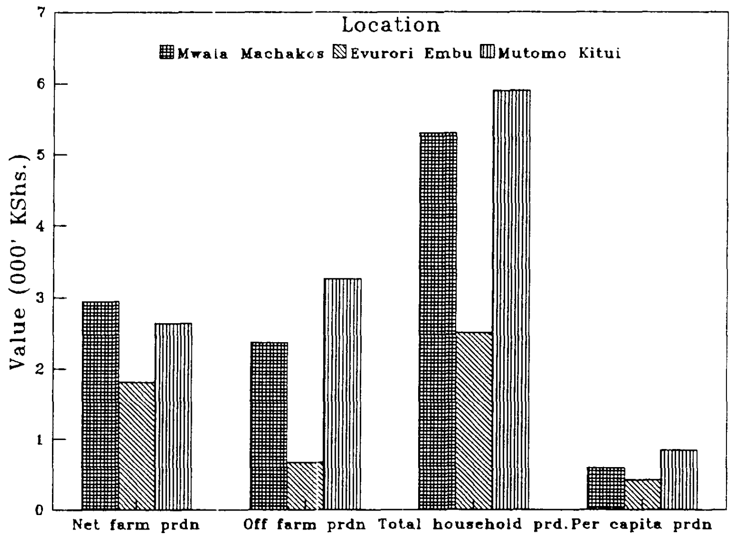


Fig. 1.4b Composition of Farm Household Production. Adapted from Rukandema (1984 p. 435)

1.5 The Institutional Setting

The twentieth century has seen radical change in subsistence farming and in the network of relationships which underpin it over much of Africa. A salient feature of this change has been the adaptation of farming systems to meet the demands created by demographic change accompanied by new aspirations. In the semi-arid areas of Kenya, as elsewhere in the country, new crops, for example, cotton, and new tools, for example the plough, have been gradually incorporated into the village production systems. From the time of the establishment of British rule, the government has had an active role in this process of change and adaptation.

The immediate concerns of the early British administration were to pacify and achieve political control over the indigenous populations and to make the colony economically viable. Specific policies and measures that were taken in pursuit of these concerns and the consequences for the development of national institutions are the subject of a large volume of literature (e.g., Leys 1975; Zwanenberg and King 1975). However, the effects on local-level structures were traumatic. Traditional forces that maintained society were seen as incompatible with the new order and were either systematically dismantled or at least, very seriously undermined. Established norms governing production and distribution and exchange underwent radical change. In particular, institutions within which control over productive resources (land, labour and livestock) and benefits of productive effort at the village and household levels were decided came under increasing challenge.

Commercialization of village life, the advent of migrant wage employment, western-style education and the intrusion on indigenous belief systems by Christianity were the most potent forces behind this revolution. In many places, local ties and parochial perspectives have been rapidly giving way to more universal commitments. As a result of rapid expansion of education in the post-independence era, the proportion of farmers who subscribe to more cosmopolitan attitudes is increasing.

One result of the socio-economic differentiation that was set in motion early in twentieth century was the evolution of institutions through which redistribution of political and economic power among individuals is mediated. This point is particularly relevant to all discussion about rural development strategies which purport to draw strength from participation by the mass of the rural population.

Distribution of economic and political power at the household, village, regional and even the national levels has had significance for the determination of who has access to and control over information, productive resources and income. With regard to adoption of innovations, access to and control over information, productive resources and income is inter-linked with incentive and capacity to innovate. Whilst a full exposition of this subject is beyond the scope of this thesis, it is a topic of such importance to the understanding of the adoption process that an outline must be attempted.

The farm household interacts with a plethora of institutions in the ordinary business of life, not least, the state. As in typical capitalist nations, the state is supposed to function as a relatively neutral advocate and defender of public interest. In reality, however, 'the many groups that exist side by side advance their claims on government, each receiving some of what it wants and no group receiving everything' (Best and Connolly 1976). Stated in simple terms[2], it would seem that 'public interest' entails two objectives. The first objective is the maintenance of social stability, that is, a private profit system that preserves an inequitable distribution of power and wealth. The second objective is promotion of growth and proliferation of private enterprise. With time, dominant class interests emerge.

Exchange relationships involving land, labour, seeds, fertilizers, various consumer items, as well as services, have been effectively brought under the ambit of market forces in varying degrees. Exchange relationships are heavily regulated by the state and at the local level. Various customary and sectarian regulatory influences are also operative.

At the local level, the state is represented by the field arm of the Office of the President under whose supervision are units of technical departments concerned with rural development. The role of the state is complemented by activities of the co-operative movement, the party and local government. The functions of these agencies include arbitration of disputes, trade licensing, provision and maintenance of economic infrastructure, the carrying out of public works and installation of utilities and enforcement of standards inter alia. Several parastatal organizations and the co-operative movement often directly intervene in the local agricultural factor and product markets. Indeed, the former are the principal suppliers of commercial seeds and fertilizers. The agriculture department is responsible for the dissemination of extension advice.

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[2]The national development strategy was to be guided by the principles of democratic African socialism as enunciated in the government sessional paper No. 10 of 1965 entitled *African Socialism and its Application to Planning in Kenya.*

Political and economic power tends to be concentrated in the hands of the various officials and traders. Farm households will have access to information and extra-farm productive resources the more access they have to these centres of power. The major determinant of entry into these services is the level of education. Other factors such as farm size, gender of the farm operator and general standing in the community can influence the bargaining power of given farm.

1.5.1 Brief account of agricultural development in Kenya

Early British administrators appear to have accorded agriculture a high priority. An early commissioner, Sir Charles Eliot, used to write many reports on the agricultural potential of different areas in the country (Swynnerton 1961). An extract from one of his reports for 1901 reads:

··· In the coastal strip, ··· valuable tropical products such as cinnamon, cadamon could be successfully cultivated. ··· The highlands of Ukamba offer favourable conditions for European fruits, cereals and vegetables ··· other promising exports are castor oil, cotton and tobacco. ··· The wide plains seem to offer admirable pasture grounds ··· (Swynnerton 1961).

The first Director of Agriculture for Kenya, Mr. Alexander Whyte arrived in 1902, initially on loan from Uganda. A substantive appointment to the office of Director of Agriculture was made the following year. In response to the need for exploratory research, a number of experimental stations were established. Much of the work at these stations was concerned with economic botany, trying out a range of crops and seeking out those which would thrive (Swinnerton 1961). Nearly all research was directed at servicing the needs of settler agriculture.

In the meantime, conditions in the African sector were deteriorating rapidly. Low yields, soil erosion and frequent famines were common features of life in the reserves. During the post-second world war period, these problems had assumed crisis proportions. Widespread discontent in the country side was becoming as a serious threat to social order. Problems of African agriculture could no longer be ignored.

The Swynnerton (1953) plan was an imaginative response to the agricultural crisis in Kenya. For the first time, the need to base smallholder farming on sound principles of agricultural science was spelt out explicitly as part of the rural development strategy of the government. Foundations for research into the problems of African agriculture were laid. Policy for agricultural education, extension and appropriate land tenure systems was formulated.

In 1956, an experimental farm was set up at Katumani, 12 km east of Machakos town. The farm enjoyed a complementary relationship with the Farmers' Training Centre (FTC) and veterinary farm, both conveniently situated in the same neighbourhood. Initially, responsibility for the farm was limited to the investigation of farm-level production problems for the Machakos and Kitui Districts. Subsequent developments have seen the facility become the National Dryland Farming Research Centre (NDFRC) within the Kenya Agricultural Research Institute (KARI). Sub-centres have been established at Kampi ya Mawe, Ithookwe and Voo to help achieve a reasonable coverage of ecological variation. In addition, the centre has acquired several testing sites. There has been a corresponding increase in the responsibilities of the centre over the years. The mandate of the NDFRC is to contribute to sustainable development in the semi-arid lands of Kenya with special emphasis on development of technology for efficient soil and water management. In carrying out the mandate, close co-operation with local and international organizations which undertake the same type of work is maintained. Some of the results of the research effort at the centre have been highlighted in passing. The following chapters include detailed discussions of the various aspects of technology development at the NDFRC in relation to farming in the semi-arid tropics in Kenya.

1.5.2 Local and National Institutions

Agricultural development in Kenya can be viewed as a result of farmer response to stimuli triggered by interactions among many institutions. These interactions influence the decision making environment of the farmer in many ways. Perhaps the most profound of these influences are those that flow from activities of the state. A brief outline of the structure of the Kenyan state is presented in the rest of this section. In carrying out responsibility of fostering socio-economic development in Kenya, the state acts through two complementary branches of central government. First, there is the political wing of the civil service bureaucracy as represented by the field arm of the Office of the President, the provincial administration. The function of this branch of government is to coordinate and supervise government activities at all levels. Ensuring that development activity takes place within an environment that can offer maximum security and convenience for all concerned is the major business of this branch of the government.

The technical and professional wing of the civil service bureaucracy as represented by the field arm of technical departments comprise the second branch of government. Technical departments are largely concerned with regulatory functions. The departments of Agriculture, Cooperative Development, Water, and Lands and Settlement carry out most of the agricultural development work of the government.

The agriculture department provides extension advice, sets farm produce prices, supervises agriculture related public corporations and carries out a wide range of regulatory functions. Research services which were the responsibility of the Scientific Research Division of the agriculture department are now the responsibility of the newly established Kenya Agricultural Research Institute (KARI). The agriculture department is responsible for ensuring the smooth and efficient functioning of the agriculture industry in Kenya.

The main responsibility of the agricultural research service is to ensure economic efficiency and sustainability of the agriculture industry. Research centres are directly responsible for tackling specific or general farm-level production problems. Most research centres now have Adaptive Research Teams which obtain and pass on information directly from farmers, the extension service, and any other organizations that may be involved in agricultural development. Research and extension workshops at which research findings are discussed and worked out into farmer recommendations are held regularly in each district.

1.5.2.1 The farm inputs delivery system

The Kenya Grain Growers Co-operative Union (KGGCU) supplies most of the physical inputs such as seeds, fertilizers and sprays. The union is a nationwide organization. It operates through a network of branches and subagencies which carry out retail trading activities with the public. Local stockists and the primary co-operative societies also participate in the farm inputs trade. In principle, if not in practice, neither the KGGCU nor any other corporation enjoys monopoly over trade in farm inputs. In 1989, the government decided to do away with price controls in the farm inputs retail trade.

A variety of tools and implements can be purchased at these outlets and maintained and serviced through networks of local artisans. The Kenya Industrial Estates (KIE), a public corporation established for the purpose of assisting small-scale industry also participates in the production and marketing of farm implements. Participation by KIE in the farm implements business is however, not extensive.

Loans for agricultural purposes can be obtained from a number of sources. Official lending is usually arranged through the Agricultural Finance Corporation (AFC). The co-operative movement and commercial banks also undertake lending for agricultural purposes. Farmers' reliance on the formal credit institutions is not the general rule.

1.5.2.2 Produce marketing

The structure of the produce marketing system in Kenya has evolved to cope with and adjust to the demands of the changing economic environment and social conditions. Regulation of farm produce marketing has been an integral part of agricultural policy in Kenya. Three reasons have been put forward as justification for regulation. Agricultural commodities are by nature prone to fluctuations in output. These plus regional differences in production that exist in the country need to be addressed through some regulatory mechanism. Also, it has been suggested that producers and consumers need protection from unscrupulous business interests. Broadly then, regulation of produce marketing is intended to achieve protection of producers from exploitation by unscrupulous people, to ensure stable supplies, to ensure that the incentive to produce is maintained, and to provide an outlet for produce.

The National Cereals and Produce Board (NCPB) has, until recently, enjoyed near monopoly powers in the farm produce market under an act of parliament. The board is responsible for the maintenance of adequate grain supplies through direct intervention in the produce market, purchasing when there are surpluses and selling when there are deficits. The other functions of the board include maintaining the national strategic reserves and regulating the movement of grain across districts. For movement of more than 90 kg of grain across district boundaries, a permit issued by the board is required. A substantial volume of trade in farm produce is handled by the NCPB and KGGCU.

There is considerable local market trade in items of farm produce. At every trading centre, open air markets are held at least once each week. This type of market is largely unregulated. All manner of merchandise can be bought and sold on a willing buyer/willing seller basis and at mutually agreed prices. The local authority exercising jurisdiction over the area where the market centre is located collects a 'gate fee' from vendors with merchandise for sale. The merchandise sold must conform to quality control standards. Clothing, farm produce, tools and implements are among the commodities that are commonly traded at such markets. Livestock marketing activities are subject to additional regulatory control by the Kenya Veterinary Department (KVD).

1.6 Maize in the Local and National Economy

World cereals production is dominated by wheat, maize and rice. In terms of total production, maize ranks second. Annual production now normally exceeds 400 million metric tons. The period 1970-72 to 1981-83 saw production grow at an annual rate of 3.1 per cent. Most of this growth was attained through yield improvement. In developing countries, yields increased by 2.6 per cent while area planted expanded by 1 per cent per year (CIMMYT 1984). The major push behind this upward trend was population growth and income growth. There is still considerable scope for further improvements especially in the third world. However, further improvements will depend on extending the use of currently available improved varieties and superior agronomic practices (CIMMYT 1984).

Maize has almost replaced the indigenous cereals in much of Kenya's peasant farming areas (Harrison 1970). The main reason for this gain in importance is that higher yields can be gained than for any other cereals when growing conditions are favourable. Maize can be handled, stored and processed relatively easily. A much wider range of dishes can be prepared from maize, than from any of the traditional cereals. In 1983 Kenya had 1.72 million hectares or 22.6 per cent of total arable land planted to maize. Annual growth rates for yield and area for the periods 1961-65 to 1981-83 have been 0.9 and 0.4 per cent, and -0.4 and 1.5 per cent for the period 1970-72 to 1981-83 respectively (CIMMYT 1984). These statistics highlight the increasing contribution technology has made to yield improvement. Impressive gains in production appear to have been made without large increases in the land area devoted to maize growing.

Although maize is one of the traditional crops (O'Leary 1984), it only began to gain in importance during the first decade of this century. By 1909 Kenya was already exporting some maize to mainland Tanzania, then German East Africa, and to overseas markets soon after (Republic of Kenya 1966). Maize was the most important commodity in the settler economy during the first three decades of the 20th century. Indigenous people were also growing it, first as a cash crop and eventually as a staple. The place of traditional cereals (sorghum and millets) as the main staple of many communities in Kenya had been taken by maize by 1970. The importance of maize in Kenya is underscored by the fact that it has been a subject of no less than five royal commissions of inquiry and one presidential commission of inquiry.

Selected performance measures of the world maize industry are presented in Table 1.4. In general, the Africa region has not performed as well as the other regions. In spite of a relatively unfavourable ecological setting, performance measures for Kenya compare favourably with all developing country figures. In 1988 and 1989 crop years, for example, Kenya ranked third among African countries as a maize producer (Anon. 1991). The country produced 2.86 and 2.97 million tons, behind Egypt (11.20 and 8.70 million tons) and the Republic of South Africa (4.88 and 4.30 million tons) in 1988 and 1989 respectively.

Within Kenya the semi-arid part which is not ecologically suitable for production of maize has not performed as impressively. Basically, the cause of this situation is that the majority of farmers of this region have tenaciously adhered to low input low output production strategies. A set of technologies have been developed at the NDFRC over the years as part of the strategy to alleviate these problems and help increase household nutrition and income.

Table 1.4: Some measures of maize production for major mass production regions of the world.

Region	Population growth per cent	Production (kg/person)	Utilization (kg/person)	Yield (kg/ha)	Annual growth (ha) per cent	Net imports (kg/person)
Andean	2.7	107.0	56.0	1500.0	-0.7	1613.0
South east Asia	2.1	255.0	28.0	1400.0	1.8	1839.0
Eastern, Central and Southern Africa	2.9	152.0	71.0	1300.0	1.4	618.0
West Africa	2.9	97.0	26.0	800.0	1.5	831.0
Developing countries	2.2	248.0	49.0	2000.0	1.1	17971.0
Developed countries	0.8	707.0	274.0	5800.0	0.8	35986.0
World	1.8	363.0	96.0	3800.0	0.8	69381.0
Kenya	3.9	154.0	123.0	1400.0	0.9	6.0

Source: CIMMYT (1984)

1.7 Maize Production Technology for the Semi-arid Region of Eastern Kenya

A large number of innovations have been developed over the years to meet the specific farm level production problems of the semi-arid region of Kenya. Much of the technology development work was undertaken at the National Dryland Farming Research Centre at Katumani. The adoption record of these innovations has been varied. Most of the innovations have not been uniformly adopted across farms. For instance, the proportion of farmers growing the newly developed drought-resistant maize seeds reached fairly high levels within the first five years of official release whereas the number of farmers practicing various aspects of recommended crop husbandry has remained low for several years. This section is primarily concerned with discussion of the major considerations underlying the crop production policy and strategy for the semi-arid areas. The main features of the principal components of the maize package are now outlined. Detailed description of specific components of the package is to be taken up again in Chapter 2 and in chapter 4. The descriptions undertaken in this section are intended to provide a background to the development of the research problem as well as the theoretical and conceptual framework as presented in Chapter 2.

(a) realizable biological potential
(b) maximum biological potential.

Under farm conditions, parameters of the growth environment such as levels of solar radiation, temperature, humidity and atmospheric carbon dioxide cannot be manipulated at reasonable cost, but must be determined by natural processes. Other variables like availability of soil moisture and plant nutrients and control of pests that contribute to the realization of genetic potential may be subject to manipulation by the farmer to varying degrees. In the semi-arid eastern Kenya, there is little irrigation potential and soil moisture has generally to be supplied by seasonal precipitation. The levels of seasonal precipitation are low and highly variable. Contribution to the extraction of biological potential by other factors will depend on the amount of seasonal precipitation. These considerations have played an important role in the development of crop production technology for the semi-arid region of Kenya.

The stated objectives of technology development at the NDFRC are to achieve increased yields, production stability and wide adaptability, and acceptable food quality. In pursuit of these objectives, two complementary strategies have been adopted. One set of activities is concerned with the search for plant types that fit best within the local SAT environment. The second set of activities is based on economically efficient manipulations of the production environment that would encourage movement towards the plant's biological potential. A brief narrative of some of the innovations that have emerged as a result of these activities now follows.

1.7.1 Seed of high yielding varieties

In pursuit of the stability objective, plant breeders at the NDFRC have sought to develop plants having at least three related attributes. Drought escape/tolerance, early maturity and wide adaptability over the range of growing conditions that obtain in the region have always been important breeding objectives at the centre. To ensure a high probability of adoption, only varieties with acceptable food quality are selected for final evaluation. By 1988, no less than five high yielding varieties of maize had been officially released as commercial seed for adoption by the farming community. Of the five, two are hybrids (H511 and H512), one is a low altitude composite (Coast Composite C), and the other two are dryland composites, Katumani Composite B (KCB) and Dryland Composite C (DLC).

Researchers were faced with the choice between hybrids and composites to form the basis for improved seed development. While hybrids will usually out yield composites often by a substantial margin, hybrid seed must be purchased each season. Researchers decided in favour of a composite led strategy, basing this choice on the presumed inability of farmers to purchase hybrid seed every season.

The established commercial variety, KCB, is well suited to dryland farming conditions. Optimum altitude is between 1000-1500 m ASL. It takes 100-120 days to reach maturity from the date of germination, depending on local relief and altitude. Moisture requirements are in the order of 220-400mm per season. A well managed crop yields 3150-3600 kg/ha. Higher yields have been recorded on good farms (Nadar and Faught 1984a). Demonstrated yield potential is over 8000 kg/ha.

A more drought tolerant variety, DLC also known as Makueni Composite, was developed to cater for the needs of the farmers who have pushed the cultivation margin into the climatically less reliable eco-zones. This variety bears similarity to Katumani in that the two have a shared parentage. It reaches maturity in 90-110 days. Expected yields are in the 2900-3600 kg/ha.

To the extent that the adoption of KCB seed technology reached the 100 per cent mark within a relatively short period following official release, this seed technology may be regarded as a very successful product of agricultural research. However, adoption of agronomically sound recommendations which would enhance the exploitation of genetic potential has lagged far behind expectation. This and other related issues are taken up later in this thesis.

With the release and widespread adoption of high yielding varieties, it was necessary that appropriate agronomic practices be sought that would help ensure maximum extraction of biological potential. The guiding principles involved provision of an environment that would facilitate optimal realization of the genetic potential of the plant. Among the many factors which make up an ideal growth environment for a crop in the SAT, plant nutrients commands the greatest significance. Another factor to be considered is that of the high risk of occurrence of shortfalls in moisture supply at critical growth stages. The aim has been to enable farmers to achieve plant establishment in an appropriate seed-bed and to assist them to ensure that plant growth and development takes place in a relatively weed and pest free environment. Therefore, timely and effective seed-bed preparation and timely field operations are essential.

Strategies that are described in the following sections are intended to facilitate efficient use of resources to achieve land preparation, seeding, weed control and fertilization in an effective and timely manner.

1.7.2 Field operations

In order to make the best use of available soil moisture, farmers are advised to exercise care in the timing of field operations. The basis of this advice is to be found in the existing body of evidence in support of the proposition that timing of operations alone can lead to large improvements in crop performance (Marimi 1978; Nadar 1984a). Equipment for use in land preparation, seeding and weed control is essential to the realization of these timeliness objectives.

The victory-type mould board plough was adopted by the majority of farmers over a relatively short period of time. This is an example of an innovation whose diffusion took place 'under own steam,' so to speak. There is little evidence of large-scale promotional effort in the form of extension or credit schemes or other external intervention to provide either initial stimulus or to maintain the momentum once the innovation was under way. By 1980, 78 per cent of the farms that were surveyed by Rukandema, Mavua and Audi (1981) had not only adopted the plough but also adapted it for use in seeding and weed control. This is yet another instance where farmers have demonstrated extraordinary preserve of initiative, skill and resourcefulness when convinced about the usefulness of an innovation.

With the introduction of the plough, relatively high rates of work can now be achieved. Households which have adopted this innovation are able to bring under cultivation up to six hectares (Muchiri 1981). In practice, however, maximum crop land is limited to the 3.5 hectares that can be weeded effectively by available household labour.

Although this technology is immensely successful, several criticisms of the adoption of the plough have been aired. From the socio-economic point of view, it has been suggested that adoption of the plough has contributed to the extension of the cultivation margin into more fragile ecologies in recent years. The proponents of this thesis lay at least some of the blame for the undesirable developments that have ensued on this particular technology. However, it is to the criticisms based on agronomic and engineering design grounds that the discussion now turns.

The objectives of tillage in the semi-arid environment are improved soil structure, reduction of bulk density to enhance water infiltration, and effective weed control to minimize loss of soil moisture through evapotranspiration. The mould board plough is considered to be somewhat unsuitable for the pursuit of these objectives. Evaluation and testing of a wide range of tillage equipment against technical and economic performance criteria showed that most of the single purpose type equipment are unsuitable for smallholder operations in Kenya (Figueroa and Mburu 1984). The tool frame chassis with provision for different attachments was developed to replace the mould board plough. So far, adoption of this replacement has not attained the high rates that have been described for the mould board plough.

1.7.2.1 Planting date

Planting should be completed as early in the season as possible. The specific recommendation is that one-third of the field should be planted before the onset of the rains and the remainder of the crop area should be completed not later than two weeks after onset (Weir 1986). This recommendation appears to have originated from agronomic and meteorological research in the region. The principle is that the soil profile should have enough moisture to enable germination and that sufficient rainfall to support subsequent crop development can be expected.

The meteorological department provides predictions of the opening rains from synoptic forecasts and recommends that farmers dry-plant just before onset. When the prediction is successful, this strategy speeds up crop establishment and maximizes season potential. However, as farmers seem to have realized, this strategy has three undesirable outcomes. False starts followed by prolonged dry spells after sowing tend to lead to poor plant establishment and another round of expenditure in form of seeds and labour (Stewart and Hash 1982). Secondly, seasonal onset is always preceded by a period of serious shortages of feed for oxen and hence, draft which is required for dry planting. Thirdly, dry planting has been shown to worsen the weed control problem (Nadar 1984a).

1.7.2.2 Weed management

Because of the need to minimize the negative impact on crop performance arising from adverse competition for resources required for crop growth and development, proper weed control has been recognized as a critical agronomic input (Aldrich 1984; Fletcher 1983). As the most critical crop growth stage for maize falls within 30-45 days after germination, the first weeding should be achieved within the first two to three weeks after emergence if severe penalties in the form of yield reductions are to be avoided. A second weeding is strongly advisable. An overwhelming majority of farmers in the region have intimated that quite often up to three weedings are needed in seasons with above average rainfall.

1.7.2.3 Plant arrangements and planting densities

Grain yield (unit weight/ha) is a function of the weight per grain multiplied by the number of grains per cob multiplied by the number of cobs per plant multiplied by the number of plants per hectare. Thus, the higher the number of plants, other things held constant, the higher the yield expectation. However, if plant densities are too high, competition for resources especially nutrients and soil moisture will cause yield reductions. In the semi-arid environment, determination and use of optimal densities as well as spatial arrangements is an absolute necessity. It is recommended that sufficient space to permit performance of operations while allowing for the maximum number of plants that can optimize exploitation of soil resources is maintained. Inter-row spacing of 75cm and intra-row spacing of 25cm comprise the recommended practice. This is equivalent to a planting density of 5.3 plants/m^2. Previously, the recommendation was 3.7 plants/m^2 (90 cm by 30 cm).

In practice farmers rarely achieve high planting densities. At the farm level, there is considerable variation in the planting densities that can be found (Nadar 1984b; Ockwell, Parton, Nguluu, and Muhammad, 1991a). Typical planting densities observed are in the order of 2 plants/m^2 (Nadar 1984b) and 1.2 plants/m^2 to 2.2 plants/m^2 (Ockwell, Muhammad, Nguluu, Parton, Jones, and McCown 1991b). A number of researchable issues are indicated here. Why are proper planting densities not observed in spite of clearly demonstrated advantages of doing so? Are agronomically determined optimal planting densities more risky or simply not sufficiently profitable, or are they simply not a feasible option given the prevailing constraints? Are they unknown to the farmers? Do farmers simply not believe in the superiority of high planting densities? Are farmers simply not interested in the extra benefit for which they have to go to extra trouble? These issues are addressed in later chapters.

1.7.3 Plant nutrition and soil fertility

That soils in the semi-arid tropics are generally low in organic matter content and deficient in plant nutrients are well documented facts (e.g., McCown, Haaland, and de Haan 1979). Soils of the semi-arid eastern Kenya share in these characteristics of SAT soils (Jaetzold and Schimidt 1983). To redress this deficiency, four avenues of remedial action potentially are available. The options that have been considered by researchers are, inorganic and organic fertilizers, and biological nitrogen fixation to be pursued through implementation of cereal/legume crop rotations. While cereal/legume crop rotations represent a potentially cheap way of boosting soil nitrogen through biological nitrogen fixation, research in this area has not progressed to the extent necessary for farmer recommendations to be formulated. Consequently, there is virtually no extension recommendation for cereal/legume rotations. In the foreseeable future, inorganic and organic sources will continue to be the main thrusts of recommendations for the supply of plant nutrients. Chemical fertilizers represent a convenient way of supplying nutrients for which the soils are deficient. Early agronomic research established that economically optimum rates of application are in the order of 40 kg/ha of elemental nitrogen and 40 kg/ha of P_2O_5 (Marimi 1978). These findings have since formed the basis of extension recommendations for the use of inorganic fertilizers.

Organic fertilizers offer a great opportunity for farmers to improve soil fertility. As the majority of farmers own some livestock, this resource is available on those farms virtually free of charge. Not surprisingly, the majority of farmers are now familiar with the benefits of using this resource. However, there is lack of knowledge concerning nutrient content, methods of collection and preservation, mode and rate of application.

Some work has been carried out to determine the rate and frequency of application (Ikombo 1984). Others have sought to relate potential farm-level supply to the numbers of livestock present (Tessema and Emojong' 1984a,b).

The findings of the above researchers suggest that relatively large quantities are required. To obtain reasonable yield responses, appropriate rates of application are in the order of 8-16 t/ha. It seems that to obtain comparable results at the farm level, higher rates must be applied. Supply of this input is highly variable in qualitative and quantitative terms. At the basis of this variability are factors such as numbers of stock and feed supply. High labour inputs required to achieve such rates of application also tend to restrict intensity of use. Some farmers have sought to tackle the labour shortage constraint by investing in transportation equipment.

1.8 Summary and Concluding Remarks

The main features of smallholder agriculture in the semi-arid eastern Kenya as well as the relevant aspects of the meteorological, institutional and socio-cultural environment within which the evolution of smallholder farming takes place have been highlighted. As a useful prelude to the discussion of technical change and its determinants, a brief account of the evolution of the local and national institutions was given. Environmental parameters within which production and exchange relationships are set received a fairly detailed treatment in this chapter. Since research that is reported in this thesis is built around the examination of factors that are responsible for lack of adoption of maize production technology, it was considered appropriate that this commodity be treated in a fair amount of detail. The importance of maize in the local and national economy was reviewed. The need for production technology on the one hand, and, on the other hand, the low rate of adoption were recounted.

To recapitulate, smallholders of the semi-arid eastern Kenya operate complex mixed farming systems that are characterized by low resource productivity and high production risk. The record of adoption of innovations that had been targeted at solving farm-level problems revealed a number of paradoxes. Although rural development in the Machakos area has been the subject of many studies, important gaps in the understanding of smallholder adoption behaviour still remain. Current understanding falls short of what is required to guide research and development strategy. In particular there is no framework within which systematic examination of the roles of the various structures and functions which influence adoption can be analyzed.

Organized around strategically selected substantive issues, this study aimed at applying existing methods and procedures to examine the causes of lack of innovativeness among farmers in the region. The analyses undertaken were designed to lead to cumulative advances in the understanding of the technology adoption process. These analyses focused on the examination of factors which have a potential to impede or promote the technology adoption process. The objective was to yield generalizations which may influence the rate and direction of rural development through research and extension. The underlying assumption was that a better understanding of adoption behaviour and factors which underlie it may lead to the relaxation of the constraints on adoption, thereby promoting the rural development objectives of the country.

Chapter 2

RESEARCH PROBLEM, OBJECTIVES, HYPOTHESES, PROCEDURES AND METHODS

2.1 Introduction

Applied research undertaken from within such a variety of rich disciplinary traditions as social anthropology (O'Leary 1984), rural sociology (Mbithi 1972), development economics (Owako 1969), and agricultural economics (Rukandema 1984) is almost unanimous on one point: that the rate of adoption of innovations in the smallholder farming community has not kept pace with the expectations of those concerned with agricultural research and development. The general finding is that less than 10 per cent of the farm households in the semi-arid region of eastern Kenya have adopted more than 80 per cent of the maize package that was described in chapter 1. These studies indicate considerable variation in the technology adoption record for the agriculture sector.

Within the cash crop sub-sector, much more technical progress was achieved with respect to coffee than for other crops, for example, cotton. The food crops sub-sector has been the least innovative. The desire of the Kenyan community, as indicated by the promotional effort of the education and extension division of the Department of Agriculture and a number of other organizations, is that there should be more farm level innovation. This is essential if the policies that are being formulated in a bid to foster rural development through a more productive farming led by technical progress are to be successful.

As elsewhere in the developing world, the studies cited above find that lack of innovation can be linked to the inability and unwillingness on the part of farmers which in turn can be traced to three related factors. First, patterns of resource endowments and lack of information at the farm level tend to restrict innovativeness. Second, ability to meet the cost of innovation and to bear the risks of innovation tend to be associated with other demographic and other household issues. Third, off-farm factors such as availability and access to economic infrastructure such as transportation, input distribution and produce marketing are also related to adoption.

Two sets of factors have tended to limit the applicability of existing analytical tools for examining smallholder adoption of innovations. First, farming, and indeed, other household survival strategies in general are characterized by a high degree of complexity. Few of the linkages which govern relationships between both on-farm and off-farm and the farm household and which need to be understood are readily amenable to measurement and interpretation. Second, it seems that shifts in the key parameters of the ecological and economic variables play a significant part in smallholder decision making. Some of these shifts are systematic, most are non-systematic. Neither can easily be analyzed with the aim of obtaining reasonable indications as to how farmers are likely to respond to innovations.

A common preoccupation of research on this problem has been the testing of hypotheses of lack of relevant knowledge and capacity to innovate. Very rarely has either of the two hypotheses been rejected. On closer observation of farmer behaviour, however, one finds many instances where capacity to innovate and information should be considered alongside many other hypotheses.

This chapter spans five sections. Presentation of the research problem is preceded by a brief account of innovation, adoption and adaptation of farming technology among farmers of the semi-arid eastern Kenya. Third, an outline of alternative theoretical and conceptual schemes that underpin technology adoption research is presented. Thereafter, hypotheses and objectives of this study are enumerated. While methods and procedures are discussed in detail within the chapters in which specific aspects of the research problem are dealt with, essential features of each are highlighted in this chapter.

2.2 Plan of the Thesis and Notation

This thesis is divided into nine chapters. This section attempts to present the thesis as an organic whole. Chapter 1 and, to a lesser extent, this chapter present the contextual background to the research problem as well as analytical strategy adopted.

Characteristics of the innovators and their socio-economic environment are discussed and analyzed in relation to the overall problem in chapter 3. A logistic framework is employed in the assessment of probability that farm households possessing given attributes will adopt a specified innovation. An assessment of the characteristics of the innovations (the recommended maize production package) with special emphasis on expected profitability and variance of profit are undertaken in chapter 4. Here, stochastic dominance theory is used to assess the profitability characteristics of the various components of the package in comparison with traditional technology.

In chapters 5 and 6, costs and returns associated with other activities in which households are currently engaged are reported. Profitability of the livestock enterprise is pursued in chapter 5. An extension to the Potter (1985) model is presented and applied to the assessment of the livestock sub-system for each of the eight representative farms. A Fortran program designed to facilitate these computations is included in the Appendix.

The other significant aspect of household production strategy that has implications for the adoption decisions is the non-farm sub-system. Two aspects of this sub-system, namely the wage employment and petty trading aspects, imply competition for resources such as household labour supply and cash reserves that is critical to the adoption process. An attempt to examine these and related aspects of rural household undertakings is taken up in chapter 6.

Decision theory is employed in the description of farmer decision making structure in order to identify and characterize important linkages between goals and aspirations on the one hand and available means and responses on the other hand. These concerns are the subjects of chapters 7 and 8. Household goals and strategies for goal attainment, as postulated in previous studies (Heyer 1972; Hunt 1978; O'Leary 1984; Ockwell *et al.* 1991a,b; Parton 1991,1992), are considered in chapter 7.

Having specified the household goal structure and strategies that are available for their attainment, the question of how farm households with different attributes might approach strategy (including those based on new technology) selection can be tackled. Recognizing that farmer strategy selection is likely to be influenced not only by economic concerns, but also by attitudinal considerations, an appropriate analytical procedure was sought. In particular, the necessity to account for production risk arising out of the dynamics of the operating environment and the prevalence of hierarchical goal systems among households suggested that mathematical risk programming may be appropriate. In chapter 8, a risk programming model is employed in the assessment of the potential interactions between household goals and technology choice. Chapter 9 presents a summary of the main results and policy conclusions.

2.2.1 Notation

Owing to the nature of the research problem, a wide range of concepts and analytical procedures had to be chosen from different areas of economic theory. Throughout the thesis, the aim has been to achieve presentation with maximum clarity. However, complete avoidance of algebraic and other symbolic representation has not been possible. Whenever symbolic representation has had to be employed, as far as possible, standard procedure has been resorted to. This subsection is intended to clarify some of these points and indicate where deviations from standard practice may be expected.

2.2.1.1 Symbolic representation

For most of the algebraic representation, the roman script and arabic numerals are used. Variables are designated in (often subscripted) lower case roman letters. Functions may be represented in upper and lower case immediately followed by their arguments delimited in parentheses. Greek symbols in lower case are used to represent unknown parameters. Upper case Greek symbols are also used to represent functions. Matrices are represented as upper case roman script and Greek symbols in bold face. Vectors are written in lower case roman script in bold face (dashed to indicate a row vector). Scalars are invariably represented in lower case Greek symbols, while emphasized lower case roman letters are used to represent constants.

2.3 Technical Change in Smallholder Farming

Maize production technology in semi-arid eastern Kenya represents a story of innovation and adaptation. By the turn of the 19th century, maize was only but one of the food crops in the eastern and central Kenya region, the others being sorghum, millet and cowpeas (O'Leary 1984). The most widely accepted theory of the origin of maize in eastern Africa is that the crop was introduced from the new world via the east African coast during the 15th and 16th centuries. Some accounts based on archaeological evidence and oral tradition have suggested that the presence of maize in Africa pre-dates the colombian era. However, such a view is not universally held (Harrison 1970).

Up until the first decade of the twentieth century, the traditional variety of maize, known locally as *ngasue,* in *kikamba* was widely grown by the Kikuyu, Embu, Mbere, Tharaka and Kamba people. This variety has since been replaced by other superior varieties over the years as narrated in chapter 1. Progressive replacement has culminated in two dominant varieties, Machakos local white and Katumani maize (KCB).

The cut and burn fallow system has been completely replaced by more productive farming methods. More permanent arable systems are the norm. Two crops of maize are typically grown per year. Land preparation and seeding are achieved during the start of the rainy season. The tillage system is as described earlier.

The usual practice is to designate an area of farm land to be used for raising arable crops. Such a portion of farm land is first opened by clearing the bush, removing tree stumps and then constructing soil conservation structures. Terrace bunds are built along contour lines and often blue grass (*Panicum maximum* L. Makarikariensi) is planted on top of them. As hand tools are invariably used, construction of soil conservation measures is a very labour intensive undertaking. One consequence of this is that crop land is used continuously without any rotations whatsoever. This combined with the fact that SAT soils are inherently low in plant nutrients, has tended to lead to soils that are even more depleted. Thus, plant nutrient deficiencies are of common occurrence. A small proportion of farmers apply inorganic fertilizers, as already noted. A rather larger proportion uses organic fertilizers.

2.3.1 Observations on aspects of production technology leading to the research problem

Four specific aspects of the technical change that has taken place in the semi-arid eastern Kenya are offered to illustrate the research problem. Specifically, these discussions are intended to indicate some of the more conspicuous inconsistencies between observed farmer behaviour and explanations which are often proposed by existing research traditions. The first two aspects, adoption of maize seed (KCB) and the mould board plough technology, have been narrated in chapter 1. The other two aspects relate to the fate of the fertilizer technology and the supplanting of the traditional grains with maize as the principal staple.

Dowker (1961) describes how farm households of the region abandoned traditional small grains, namely sorghum and millets, over a relatively short time span. The main stimulus seems to have been the arrival of a superior variety. This outcome appears to have taken the local research and extension community by surprise, not least, because traditional crops are well suited to the local growing conditions. Moreover, because of the growth characteristics of the two sets of 'traditional' cereals, a farmer would face greater variability in grain production (and hence food supplies) with maize than with either of the traditional cereals. If variance is an acceptable proxy of risk, then farmer behaviour, in this case, would appear to be hard to explain on the basis of risk aversion only. It is noteworthy that some effort has been directed at restoring the status of the traditional small grains to previous levels with little success.

A common feature of traditional technology is inter-cropping. Virtually every farmer practices inter-cropping. Investigation of the scientific basis of this practice has indicated that yield advantages accrue during better rainfall seasons (maize and beans based inter-crops). Overall production is adversely affected when seasonal rainfall is less than about 325 mm, since modified to 290 mm (Stewart and Kashasha 1984, p. 59). This suggests that inter-cropping increases production risk, and consequently the behaviour of presumed risk averse farmers in relation to this practice is puzzling. These considerations suggest that the nature of risk and its role in adoption decisions either by itself or in combination with other factors is not well understood. Hence, the risk phenomenon, at least, in the context of farmers of eastern Kenya should receive more attention than before.

A recommendation of the extension services is that farmers should aim at planting seed of appropriate quality at all times. In the case of maize, this recommendation translates into the need to purchase commercial seed every after three seasons (Weir 1986). However, one of the findings of this study is that farmers' source of seed of first choice is own farm. This may be another case of lack of financial resources to support purchases of commercial seed as recommended. However, contending explanations should be contemplated. For example, some studies have shown that maximum purchases of commercial seed coincide with failed seasons (Onchere 1976, cited in Akong'a and Downing 1985). Although own-farm supplies of seed are necessarily low in such seasons, there are also seasons when farmers are expected to have depleted their cash reserves on the purchase of their subsistence requirements. The branch manager of KGGCU, Machakos branch, lamented that he is always unable to meet farmers' requirements (N. Ong'are 1990, pers. comm.) during such seasons.

KCB was selected for its lower than average plant size associated with lower requirements for moisture, on the one hand, and enhanced ability to complete the growth cycle in the shortest period possible, on the other hand. These attributes form the basis of lower yield variance which characterizes KCB. This variety was intended to be part of the farmers' risk management strategy. However, farmer adaptations to this seed technology seem to be at variance with the intentions behind its development. Where own farm is the source, healthy plants with above average ear size and grain weight are selected and preserved for planting during the following season. Farmers believe that home selected seed of this type gives higher yields in seasons of above average soil moisture.

Perhaps, the most widely discussed aspect of smallholder behaviour is non-adoption of fertilizer-based recommendations. Use of fertilizers unquestionably leads to much higher average yields (Marimi 1978; Mavua 1984; Nadar and Faught 1984b; Stewart and Faught 1984; Stewart and Kashasha 1984; Wafula 1989; McCown *et al.* 1991; McCown *et al.* 1992). Indeed, it is thought that current husbandry practices have led to depletion of plant nutrients to such an extent that no yield improving strategy without a fertilizer component can have a reasonable chance of success. Higher average production tends to be achieved at the expense of higher variance in production (Hassan and Hallam 1990) and gross margins (Anderson 1974). On the other hand, use of fertilizers at least in the case of the semi-arid eastern Kenya, tends to reduce the amount of moisture required before grain production can start.

Stewart and Hash (1982), quantifies the contribution of nitrogen fertilizers to water use efficiency, noting its particular importance in low rainfall conditions. He concludes that each plant must attain a certain mass before grain production can begin, that critical mass is somewhat greater for plants grown in infertile soils and that production of dry matter per unit of water is less for crops grown on infertile soil, resulting in a much greater rainfall requirement to begin grain production in infertile soil conditions. The addition of 40 kg/ha of nitrogenous fertilizers resulted in grain production beginning with 218mm of actual evapotranspiration as against 298 mm without nitrogen.

On the face of it, these results suggest that use of nitrogen should achieve two things, namely, reduction in variance of production, and increases in minimum production levels. It can be argued that farmers for whom the attainment of minimum production to meet subsistence needs is the overriding concern would strive to use at least some fertilizers. The main question here is why after years of extension effort, levels of adoption are still so low. Here again, the role of factors such as capacity to innovate and risk needs to be examined.

Lack of capacity to innovate is usually considered to be a major impediment to technical progress among smallholders in general. For farm households in the semi-arid eastern Kenya, this impediment may be particularly severe, given that household incomes are well below the national average (Republic of Kenya 1981; Rukandema *et al.* 1981). Adoption of innovations which require large financial outlays such as fertilizers are probably constrained by lack of cash.

Whilst there can be little doubt that financial constraints act to limit adoption of innovations such as fertilizers, farmers have demonstrated that resources for investment into profitable lines could be sought successfully. This point is exemplified by innovations that were discussed in chapter 1. The mould board plough, for example, has as noted, been adopted by most of the farmers whose farm size justifies investment into the necessary equipment, that is, six hectares or more. One unit would cost, on average, KShs. 1 050.00., or the equivalent of the annual income for the average household (Rukandema *et al.* 1981). An additional expenditure to the tune of KShs. 200.00 for repairs and maintenance has to be incurred annually. Opportunity cost on a team of oxen would be additional to the costs already itemized.

Despite the effort that has been directed at the study of farmer adoption behaviour, many of the phenomena involved are still poorly understood. In particular, there is a need to gain a better appreciation of the mechanisms that underlie the lack of innovation in order to help guide on-going and planned research and promotional effort. Such an appreciation is the basis of the research problem to be pursued in this study.

2.4 Research Problem

Numerous factors are thought to influence the relative lack of innovation in the smallholder community. Persistence of this phenomenon suggests that either the identity of the main impediments to adoption is not as complete as it should be or the nature of the mechanism underlying such impediments is not well understood. Given that further development and promotion of technology for smallholders will continue to absorb a substantial proportion of the budgetary resources devoted to rural development, resolution of these issues can only have beneficial effects on society.

The specific research problem under investigation is lack of understanding of how costs of innovation, expected benefits interact with goals and resource allocations to result in observed responses. Part of the problem is that there is little understanding of the causes of differences among farm households in their adoption behaviour.

The main indications to emerge from the foregoing discussion are that farmers of the region have demonstrated propensities to embrace certain types of technical change and that the rate of acceptance of change has varied among farms. The number of factors which can affect the way farmers interpret and respond to the benefits of taking a particular line of action is large. The key elements of the benefits set are technology and incentives. The main determinants of response patterns would be ecology, resources, management, income and investment strategy.

A wealth of past observations on some of these issues exists. Re-interpretation of existing patterns can be based on at least some of these. Since many of the existing data were not designed to support analysis of changing patterns, there is a gap that needs to be closed. In both cases, appropriate concepts, procedures and analytical tools need to be identified and adapted to the acquisition of additional data and interpretation. This way, useful empirical generalizations may be obtained which can contribute to the development of policy and theory in the area of smallholder innovation.

2.5 Spread of Innovations

Technical progress follows one or more of the steps that are now described. To start with, there would be an *invention*, a discovery typically based on a set of scientific principles, new or well established. The invention is said to acquire the status of *innovation* when it is first used by a firm (*innovator*) in the production of a commodity. As the new innovation gains in recognition as being superior to the traditional counterpart, more firms may come to know about it and begin applying it in their own production activities, and, at that stage, it acquires the status of *diffusion*. Disregarding the unlikely case where adoption by all is instantaneous. diffusion of an innovation may be considered as a transition from one state of equilibrium to another. The old methods may still be used in the production of the output but new methods are now incorporated into this process both at the firm and industry levels. That is, the industry is in a state of disequilibrium with respect to new and old methods.

The focus of theory in this field has been the study of equilibrium conditions. Of immediate interest to policy analysts are a number of questions. The time it takes for equilibrium to be attained, the speed with which it is approached and the final position at equilibrium are the typical questions addressed by analysts. Potential applications of such information are many.

Some of the terms which have been used somewhat loosely are now defined in the sense in which they are used in this thesis.

Imitation. This refers to inter-firm or firm-to-firm diffusion. The appropriate measure of this process is the proportion of firms that have adopted.

Intra-firm diffusion. This indicates the extent to which firms are using more of the innovation in the production of the output in question. The appropriate measure here is the proportion of the firm's output that is produced using the innovation.

Overall diffusion. This is the extent to which the adoption process has gone on in the industry. The indicator is the proportion of output of the industry that is based on the innovation.

Technology. A particular way in which a production process is organized.

New technology. An ordinary technology but incorporating some new component. Inputs not previously used may be used and or factors may be reorganized in a different way as part of the new technology.

Activity. A process using a particular technology to combine input factors to generate a particular type of output.

Evaluation of technology means to determine the advantages of using a technology relative to a set of alternatives, evaluation being undertaken against a set of stated goals.

2.5.1 Theory of the spread of innovations

In this section, elements of established theory of the spread of innovations are presented and evaluated in relation to smallholder farming. Conventionally, the relevant variables and parameters and their relationships are summarized and presented in a logistic function. Equation 2.1 shows the algebraic form and main elements of this function.

Let N be the number of potential adopter firms in the industry, or 'recommendation domain,' in farming systems research usage. Let t_i be the 'adoption start date,' t_f be the 'adoption saturation date', that is, the point in time when all possible adoption has taken place, and n be the number of firms having actually adopted an innovation. The logistic function represents the change in n or, relative change n/N with respect to time as follows.

$$f(t) = \frac{\frac{n_{tf}}{N}}{1 + \frac{n_{ti}}{N} \exp^{\beta t}} \tag{2.1}$$

and the rate of change of $f(t)$, that is, the rate of increase of the proportion of adopters (or dis-adopters) is

$$F(t) = \frac{\frac{(n_{tf})(n_{ti})}{N} \beta \exp^{-} \beta t}{(1 + \frac{n_{ti}}{N} \exp^{-} \beta t)^2} \tag{2.2}$$

where

- n_{tf} / N is, as already noted, the maximum percentage of the firms to adopt the innovation. In the case of adoption of the plough technology in semi-arid eastern Kenya, for example, it would be about 80 per cent. At the point of inflection of the adoption curve,

$f(t) = (n_{tf} / N)/2$. Thus, the range of $f(t) = n_{tf} / N - n_{ti} / N$.

- n_{ti} / N is the control parameter for the value of $f(t)$ when $t = 0$ (starting period) and the domain of $f(t) = t_i - t_f$.

- β is the control parameter for the value of t at the inflection point, and hence, the rate at which n_{tf} / N is approached. This is the slope parameter for $f(t)$.

The value of using equations (2.1) and (2.2) in planning many aspects of research and development can hardly be over-stated. Clearly, answers to many of the questions that frequently arise in this field can be handled within this framework. For example answers to questions such as:

(a) When is adoption likely to reach at least 60 per cent? How many farmers would have been covered by 1992?

(b) Can the rate of adoption be improved upon? What are the causes of differences in adoption behaviour among firms?

(c) Which firms are likely to adopt specific lines of technology?

In this form, equations (2.1) and (2.2) predict that the proportion of adopters *n/N* will increase at an increasing rate until 50 per cent of eventual adoption has taken place and increases at a decreasing rate thereafter, approaching full (n_{ti} / N) adoption. Thus the curve is ***S*** shaped, and has a point of inflection when the rate of adoption is a maximum. Conceptually, this ***S*** shaped adoption curve is justified on grounds of band wagons and imitative behaviour. It might be stated at this point that while many other formulations are commonly employed in similar analyses, the logistic curve is the most commonly used form in the analysis of innovations in the social sciences. Empirical tests commonly employ regression analyses on linear transformations of equation (2.3).

$$\frac{\log n_{ti}/N}{(n_{tf}/N - n_{ti}/N)} = \alpha + \beta \qquad (2.3)$$

In equation (2.3), α is a constant, and, β may be considered to be the rate or speed of adoption. The research of this thesis is primarily concerned with examination of the determinants of β. It may be expected that β will depend on factors such as the propensity of firms to innovate, the "appeal" of the innovation and the intensity and coverage of information as indicated by contact among firms. The validity of this formulation, however, depends upon acceptance of assumptions which are unlikely to obtain in practice. For example, the requirements of constant and equal propensity to innovate among firms and dependency on the proportion of the population that has already adopted, assumptions that are hard to justify, tends to restrict the applicability of this particular formulation. Nevertheless, following Griliches (1957), the logistic curve has been used by researchers to generate parameters of the diffusion curve determined by the characteristics of the innovations and firms concerned. The approach has been applied to the assessment of inter-industry diffusion of innovation (Romeo 1975), and in the study of international diffusion of ar innovation.

2.5.1.1 Determinants of the rate of adoption

Re-interpretation of the Griliches (1957) results has led to the suggestion that the behaviour of both farmers and seed producers is underpinned by expectation of profit (Rosenborg 1971, p. 209). Mansfield (1963a,b) has postulated the following relationship:

$$\begin{aligned} \log d_{ij} = {} & \log Q_i + \log a_{i2} \log H_{ij} + a_{i3} \log Sij \\ & + a_{i4} \log Gija_{i5} \log A_{ij} + a_{i6} \log \pi_{ij} \\ & + a_{i7} \log L_{ij} + a_{i8} \log T_{ij} + \log \epsilon_{ij} \end{aligned} \tag{2.4}$$

where

d_{ij}	is the number of years it takes the j_{th} firm to begin using the i_{th} innovation;
Q_i	the intercept;
S_{ij}	firm size;
G_{ij}	the firm's rate of growth;
π_{ij}	the firm's current profitability;
A_{ij}	the age of the firm's president;
T_{ij}	the firm's profit trend;

H_{ij} a measure of the profitability of the firm's investment in the innovation;

L_{ij} a measure of the firm's liquidity and;

ε_{ij} a disturbance term satisfying standard criteria of Ordinary Least Squares (OLS).

In relation to rural industry, other attitudinal or information related variables have been proposed. For example, the 'non-traditional outlook' of 'opinion leaders,' and other personal characteristics are but some of the variables that are often included as factors affecting innovation (e.g., Rogers 1983). These, however, present serious difficulties for identification, measurement and interpretation, as suggested by Parton (1991). Others, for example, Gold, Pierce and Rosseger (1970) go further. They assert that there is such a great diversity of variables which may affect adoption decisions that it is doubtful whether a general model can be built to handle them satisfactorily. The role of special circumstances, for instance, was apparent for all 13 of the innovations that Gold *et al.* (1970) examined. In a recent paper, however, Griliches (1988) has suggested that on careful examination of these apparently non-economic factors and 'special circumstances,' underlying economic factors often emerge as the real determinants of observed behaviour. The most significant variables tend to be differences in non-economic factors which underpin differences in profitability or change in profitability.

Returning to equation (2.4), not all the variables included have proved to be of equal significance in empirical studies. For the 167 American firms adopting 14 different innovations, for which Mansfield (1963b) fitted equation (2.4), only variables S, π, and H turned out to be highly significant. In all likelihood, each of the three variables will depend on other variables. Although these variables are discussed in greater detail in subsequent chapters, a summary of the main features is included in this section to serve as an introduction to and as a justification for the research strategy that was chosen for this thesis.

2.5.1.2 Firm size

This variable is generally found to be significant in empirical studies. Some of the main reasons for this are now itemized.

(a) Scale economies for some innovations may only be realized by firms above a certain minimum size.

(b) Larger firms may be in a better position to raise the initial resources required for the implementation of the technology.

(c) Bigger firms may be in a better position to meet operating costs.

(d) Smaller firms may be unwilling to innovate if by so doing, the result would be reduced flexibility.

(e) Larger firms may have the capacity that is required to use the innovation more intensively.

(f) Larger firms are more likely to have specialized skills which may be needed.

(g) It is generally believed that larger firms may be better placed to absorb risks which may be associated with the adoption of innovations. Though Selby and Hendrix, (1976) suggest that prestige risk considerations may induce a conservative approach to innovations on behalf of large firms.

The theme of firm size and adoption decision is taken up again in chapter 3 and in chapter 8.

2.5.1.3 Profitability of the innovation

It is widely believed that profitability of a given innovation is an important determinant of adoption decisions. In particular, profitability of an innovation is considered to be the major determinant of the slope of its adoption curve. However, profitability is influenced by many technical, managerial, and other site-specific factors which may be dependent on firm size and profitability of the existing enterprise. There will be many stumbling blocks both in the adoption and in the use of new technology. Mistakes in the early stages increase costs and reduce profits. With the passage of time however, firms learn by doing, attaining a better understanding of technical relationships involved, building up a portfolio of skills. As the advantages of this learning process accumulate, profits are expected to rise and costs are expected to fall. Usually, differences in profitability of the same innovation between firms may arise from:

(a) The nature of the product.
(b) The firms existing technology. One of two otherwise identical firms may adopt a particular technology because it is embedded in technology which it already has.
(c) The nature of inputs required.
(d) Differences in technical skills, often related to educational attainment.

Thus, for the same item of technology, profitability will be expected to vary from firm to firm, and for the same firm through time.

2.5.1.4 Attributes of innovations

The common features that are usually of interest are function, cost and profitability. There is an increasing recognition that these need to be matched with aptitudes and attitudes at the firm level. All the factors vary across firms and, within, firms with time. Other classifications are based on such attributes as impact on labour productivity, yield and quality enhancement, capital use and potential impact upon aesthetic and other non-economic considerations. These issues are taken up again in chapter 4, in chapter 7, and in chapter 8.

2.5.1.5 The pre-adoption 'profitability' levels

The firm's pre-adoption levels of profitability (π, in terms of equation 2.4) seldom feature prominently in adoption research. Given that in practice, multiplicity of goals, strategies and constraints is likely to characterize firm operations, omission of this variable is surprising. In the case of smallholders, adoption decisions can be influenced by the extent to which the innovation is expected to contribute to goal attainment not only in terms of extra cost but also in relation to impacts on existing activities. These issues are taken up again in chapter 5, in chapter 6 and in chapter 8.

2.5.2 Alternative schemes

Concern about failure of the logistic scheme to represent the adoption process adequately has motivated the development of alternative schemes. The stock adjustment formulation (e.g., Wynn and Holden 1975), the vintage model (e.g., Salter 1960) and the consumer durables analogy (e.g., Cramer 1969) are examples. Elements of these 'alternative approaches' are now outlined.

2.5.2.1 The stock adjustment approach

The underlying postulate is that growth in the use of a technology within a given time interval is proportional to the extent to which stock at the beginning of the period falls short of equilibrium stock. The adoption process is driven by the propensity to search for information and returns to effort spent in searching. Economic variables such as costs, output and profits clearly are important determinants of differences in the rate of adoption among firms.

While this approach is well suited to the analysis of within-firm expansion of the use of technology, it is not easily adaptable to assessment of differences between firms in the rate of adoption of innovations, the main concern of this thesis.

2.5.2.2 The vintage approach

Pioneered by Salter (1960), it is assumed in this approach that technology is embodied in new capital equipment and that adoption takes place by way of investment. Old equipment is abandoned in favour of new equipment when operating costs exceed the rent it earns. New equipment is acquired if total costs are covered by the revenue it earns. Whenever cost saving process innovations become available, it becomes profitable to replace some proportion of the existing equipment if total costs are lower than operating costs for equipment replaced. A fall in product prices would be expected, following creation of new capacity. Thus innovation takes place all the time, and 100 per cent adoption is never attained.

2.5.2.3 The consumer durables approach

In this approach, an individual is found to own an item at a particular point in time if his income is at least at some level. Thus, adoption is hypothesized to depend on specific assumptions about attributes of individuals such as income.

2.6 Objectives of the Study

- To identify and analyze factors which constrain the adoption of proven items of maize production technology among small-scale farmers in the semi-arid eastern Kenya.
- To identify, evaluate and extend appropriate concepts and analytical tools for the analysis of smallholder adoption of innovations.
- Having identified and analyzed the factors that impede adoption of innovations, point to potential consequences of alternative research and extension strategies.
- Identify areas in agronomic and farm household issues requiring urgent research.

2.7 Hypotheses

The objectives of this thesis are pursued through examinations of several postulates about smallholder adoption behaviour in relation to the research problem. In this regard, the necessary condition for adoption to take place is that the household will receive a stimulus (information about a particular innovation) of varying degrees of completeness. A complete signal will include sufficient information on such variables as methods of implementation, expected costs and benefits. Still, the household is unlikely to adopt unless it has the required means, and the adoption action is consistent with its beliefs and preferences. It is also widely accepted that risk phenomena like income variance and disaster avoidance create barriers to innovation among smallholders, whether in relation to lack of information or otherwise. Others have postulated imperfections in the factor and product markets, and even drudgery aversion as factors which constitute a brake on innovation by peasants. These are the main considerations which have been distilled into the set of hypotheses that are now listed.

(a) Non-economic elements dominate economic considerations in adoption decisions.

(b) Innovations do not represent relative advantage over traditional practice.

(c) Lack of information about the performance of the innovations has acted as a hindrance to adoption.

(d) Adoption has been hindered by the high cost of innovating.

(e) Farmer perception of risk associated with adoption and risk aversion has acted to reduce the desire to innovate.

2.8 Procedures and Methods

Rather than isolate one aspect of farm-level agricultural processes for analysis, this study seeks to employ advances that have been achieved in existing research traditions in the analysis of household decision making. Eight case studies representing the main categories of farms are identified for detailed study. Mathematical risk programming models for each of these farms are developed to analyze patterns of organization of production and resource use and differential responses to incentives.

In addition to supplementary data obtained from secondary sources, this study uses data collected at three levels. Information pertaining to farm-level resource endowments, and current husbandry practices as well as household information were obtained a random sample survey (n = 94) conducted in 1990. Additional information about farmer assessment of expected performance of innovations was obtained through a survey of a subset of the larger sample. Information on traditional practices was recorded for the eight case studies. Technical coefficients for proposed farming practices that were described in chapter 1 were derived from on-farm observations. Farm produce and input price data, as well as information on wage employment were obtained from secondary sources.

2.8.1 Data categories, sources and procedures of acquisition

Information pertaining to household characteristics, resource endowments, access to information and farm inputs, household and farming goals and available strategies for goal attainment was obtained through a farm household survey. There were 94 farm households in the sample.

Farmers' opinions, beliefs and attitudes were assessed through a survey of a sub-sample of the main sample of household heads. From this survey, knowledge was obtained of farmer assessments of the potential benefits of adopting the innovations. There were 43 farms in this sample. Following the case-study approach, a smaller sub-sample of eight farm-households, each of which represents a grouping with similar characteristics and for whom household and production data for several seasons are available, were marked out for the detailed modelling of adoption decisions.

Farm-level data on crop performance under farmer management was acquired via field measurements and observations during the short rains season of 1990 as part of this study. These data were used in conjunction with similar data for 1986 (Ockwell *et al.* 1991a) and 1981-83 (Bakhtri *et al.* 1984) as well as time-series data on farm inputs and produce prices obtained from the district statistics office in Machakos.

Data generated through the on-farm research program at the NDFRC for 1978-1982 on agronomic responses to components of the maize production technology (Nadar 1984a,b) that are being assessed in this thesis have been re-processed for use in modelling aspects of technical performance and adoption decisions.

High climatic variability was shown to feature prominently in the production environment of the semi-arid region of Kenya in chapter 1. This climatic variability has tended to complicate the interpretation of results of agronomic trials as well as the derivation of farmer recommendations in near absence of reliable time series data. CM-KEN, a locally adapted version of the CERES-Maize crop growth model (Keating, Wafula and Watiki 1992b) was used to simulate grain yield data for the time of planting, sowing density and fertilizer innovations. Climatic and soil data for representative sites were used as inputs into the simulation runs. Yield data that were obtained as a result of these simulation runs were used to extend the stochastic efficiency assessments (Chapter 4) and the risk programming models (Chapter 8).

2.8.2 Analytical methods

A Binary Choice Model (Logit) was used to facilitate assessment of association of likelihood of adoption and household/innovation attributes.

Because superiority of innovations was previously established on the basis of point estimates (arithmetic means), it was necessary to re-assess these innovations on the basis of other parameters of the distributions of their respective performance measures. Stochastic efficiency is applied in this particular aspect of analysis.

Established theory of adoption of innovations suggests that profitability or expected benefits from the firm's other production activities are almost always significant determinants of adoption decisions. In the case of Kenyan smallholders, this set comprises livestock and non-farm enterprises. Analytical procedures in these areas are poorly developed and not easily adaptable to smallholder analysis. An attempt has been made to adapt the Potter (1985) model to the development of yield distributions for livestock and to extend it to the assessment of expected returns from this enterprise. No suitable mathematical procedure for the analysis of the non-farm sector is available.

Standard procedures are used to assess levels of farmer risk aversion. Elicitation was carried out via the ELCE method (Anderson, Dillon, and Hardaker 1977), adapted to the realities of eastern Kenya.

Analysis of adoption decisions for each of the eight farm households was undertaken within a risk programming framework. This procedure can handle production dynamics, security, subsistence and income goals and the multiplicity of enterprises and resource constraints that characterize smallholder farming.

2.9 Summary and Concluding Remarks

A problem requiring research attention was identified as the lack of adequate understanding of smallholder behaviour in relation to adoption of innovations. The need for such improved understanding is urgent in view of the low rates of adoption of proven innovations on the one hand and continued effort in research and extension in relative ignorance.

Review of existing theory revealed that many variables and interrelationships are involved in smallholder adoption decisions. This review also showed that adoption is not instantaneous, and firms differ in the speed with which they adopt given innovations, that is they respond to or interpret identical signals differently.

Arising from the review of relevant theory were the following issues. Despite much effort, economic theory has not developed far enough to handle problems of the type identified for this study satisfactorily. At the theoretical and conceptual levels, it is clear that the main issues and relationships are poorly understood. At the empirical level, many of the identification, measurement, and interpretation problems still remain unresolved. Moreover, for many of the analytical procedures that are commonly used, data requirements are very high.

The objectives of the research were stated as follows: to identify and analyze constraints to adoption of innovations, and to identify critical areas of agronomic and socio-economic issues which need to be addressed in order to promote adoption of innovations. These objectives are pursued through examination of hypotheses related to factors affecting the household's ability and willingness to adopt innovations.

Data from surveys of farm households are used to analyze both attitudinal and informational factors that are likely to affect adoption. Agronomic response data that were obtained from the on-farm research program are used to assess the various attributes of innovations within the economic theory of stochastic efficiency. Last but not least, adoption related-decisions are analyzed in relation to household goals within a stochastic programming framework.

Chapter 3

NON-ECONOMIC FACTORS AND ADOPTION OF INNOVATIONS

3.1 Introduction

Empirical studies have shown that diffusion depends on complex relationships among characteristics of potential innovators (farms), attributes of innovations (technology that is embedded in them) and the ecological and socio-economic (climate, soils, factor and product markets, etc.) environment within which adoption must take place. A number of attitudinal and informational factors have also been hypothesized to have significant influences on inter-firm differences in rates of adoption of innovations. These are thought to work through interactions with institutional, social and cultural mechanisms as well as economic factors (Feder, Just and Zilberman 1984).

In this chapter, procedures used in data acquisition and analytical methods and results of a survey of factors that have been hypothesized to affect the speed of diffusion of innovations for maize production are presented and discussed. Responses to questions on a variety of capacity to innovate, attitudinal and socio-cultural factors were sought from 94 households in the semi-arid region of Kenya. Additional information was obtained from secondary sources to aid with elucidation of linkages that are operative beyond the farm gate. A qualitative dependent variable model of adoption decisions and non-economic factors was developed and applied to the analysis of these relationships. Results of these analyses are reported in subsequent sections of this chapter.

3.2 Adoption of Maize Technology in a Semi-arid District in Kenya

The Machakos Integrated Development Program (MIDP) carried out a district-wide appraisal of key extension messages (Weir 1986). The survey involved 20 540 farmers out of 210 000 in the district. The main conclusion to emerge from this survey was that messages for maize are widely known. Non-contact farmers appear to be as knowledgeable as contact farmers (p.12). Most of the Front-line Extension Staff (FES) who participated in the Weir study held the view that farmers considered the messages they (FES) bore to be rather obvious. Their suggestion was that Subject Matter Specialists (SMS) and researchers should direct more attention at developing messages that are less obvious.

Concerning changes in maize yield which might have resulted at least in part, from extension effort, no apparent difference in yield between regular fields of contact farms and non-contact farms could be established. There was however, considerable (70 per cent) yield improvement on the farmers' plots on which the messages were implemented in collaboration with researchers as part of the pre-extension trials program. Though not stated, the implication would seem to be that little discernible impact on farm-level production has occurred following improved extension effort. The reason is that even contact farmers were not implementing the messages on their own plots. This lack of implementation of the messages was attributed to 'the myriad of constraints facing farmers.'

3.3 Perspectives on Smallholders and Rural Development

Earlier sociology and social anthropological studies (e.g., Colson 1959; Lloyd 1967) laid much emphasis on the nature of third world societies themselves. According to these views, pre-modern values and practices are responsible for perpetuating backwardness through the way rural production systems react to externally induced change. According to this model, rural folk are typified by a fatalistic outlook, and lack confidence in their own ability to influence or control events. For individuals, this tends to promote dependence on others, unwillingness to innovate and high desire to avoid risk. If the farmer views farming as a struggle against supernatural forces which, in his experience, have always been stronger than himself, the best course is to be prepared for the worst and confine oneself to reliable and well tried practices.

Moreover, from this perspective, remoteness and lack of opportunity to learn about the world beyond, because of poor communications have tended to result in limited horizons and aspirations. Furthermore, little access to information about the full range of consumer goods tends to lead to little incentive to produce beyond subsistence needs. On the whole, time preference for consumption is thought to be high and, hence the opportunity cost of saving too is high. A number of studies on these issues (e.g., Collinson 1983) have since indicated that these factors do not necessarily represent insurmountable obstacles to rural development. Moreover, personal and group characteristics that are likely to impede progress have been shown to change where opportunities for change have occurred. Recent research has shown that great diversity in outlook, ability and attitudes exists among farmers. More contractual arrangements appear to have been systematically and progressively taking hold as horizons and aspirations change.

The hypothesis that 'there are comparatively few significant inefficiencies in the allocation of factors of production in traditional agriculture' (Shultz 1964) continued to exert influence upon research in the development economics discipline for more than two decades after it had been proposed. Here, allocative efficiency was defined in terms of the balance between marginal value products and marginal factors costs (profit maximization). Based on production function analyses of cross-section data, some of the empirical tests of this hypothesis (e.g., Hopper 1965), were in support of it while others, for example, Massel (1967), were non-committal. Dillon and Anderson (1971) carried out appraisals of the data and found only mixed support for the profit maximization hypothesis.

Other researchers have sought to explain rural poverty from the political economy perspective. Severe shortage of resources and unfavourable environmental conditions are such that it is not possible to bring about appreciable improvement in farm production without technical change at the farm level. Technical change in the form of new crops and more productive methods is required.

However, access to wealth, political power, and productive resources for those who need them most are limited. This is partly because such people have little bargaining power in relation to those who control access (e.g., officials, merchants, etc.). Inability to innovate accentuates the position of poverty and tends to entrench the unfavorable attitudes among the majority. Because existence is precarious, ability to break out of the cycle and innovate, and thereby increase power is correspondingly limited.

Unequal exchange relationships that are administered beyond national borders are also thought to constrain rural development in low income countries. According to this assumption, extraction of surplus production under colonialism, and international capital is designed to operate to the disadvantage of these countries. This is often done in collusion with nationals of third world countries who have been co-opted into the international elite to the disadvantage of the rural masses. These tendencies are reinforced by uneven exchanges between the developed countries and the third world at one level and between the urban and rural groups at the local level within the third-world. Although structure and functional organization at the level of individual households can be important determinants of rural development in the aggregate, intra-household issues are seldom addressed. The need to recognize the family as the coalescence of demographic, production and consumption decisions is often overlooked. The locus of demographic decisions such as marriage, having children, migration, co-optation of others into the household or provision of education is the family. It is the outcome of such decisions which characterizes the age structure, size and type of family. Therefore, specification of the institutional arrangements within the family has important economic connotations. Subsistence production activities and maintenance activities such as cooking and caring for children are all undertaken within the household. The family is also the unit within which the household budget is established. It is because of these considerations that unequal distribution within households should be considered as a constraint to development.

3.4 Adoption of Innovations in Traditional Agriculture

Some innovations spread rapidly among the farming community, requiring little promotional effort; for example, cocoa in Nigeria in the 1940s (Röling 1988), hybrid maize in western Kenya (Johnson 1979) and new maize seed in the Machakos area (Dowker 1961). In general, extension recommendations requiring application of inorganic fertilizers appear generally to have encountered considerable resistance in traditional farming systems.

Reluctance on the part of farmers to innovate can be traced to three categories of factors as shown in Figure 3.1, namely, farmer characteristics, attributes of the innovations and off-farm factors.

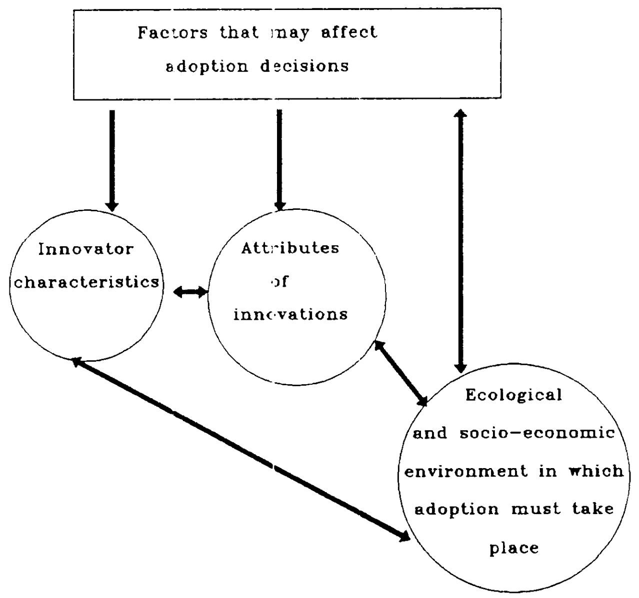

Fig. 3.1 Factors that May Influence Smallholder

3.4.1 Farmers

The innovation may not be known or understood by farmers. Lack of awareness among farmers about the relative advantages of an innovation or proper implementation will reduce the chances of adoption. Lack of awareness may be a cumulative result of inadequate promotion and the farmers' inability to seek, acquire and utilize specialized information. A number of researchers (e.g., Low 1982; Hunt 1978; Collinson 1983) have suggested that farmers' age, education and contact with the world beyond the confines of their own locality may be associated with innovation. If farmers lack the ability to innovate, this may also reduce the chances of a new practice being adopted. Inability to innovate may come about as a result of lack of resources or from the demands on available resources not allowing allocations for new undertakings. A number of personal characteristics which are thought to affect managerial ability in concert with information flows are now itemized.

(a) Ability to recognize problems will vary across otherwise similar farms and may account for a fair measure of observed differences in innovativeness among farms. Characteristics which underlie this variable clearly have a bearing on the present research problem.
(b) Closely related to (a) is the ability to gather facts that have direct bearing on a particular problem.
(c) Ability to specify and evaluate alternative courses of action in relation to consequences and arrive at choices is another requirement.
(d) Ability to take particular lines of action once appropriate decisions have been reached can be influenced by various knowledge and resource access variables.
(e) Because farm production is undertaken in a co-operative decision environment, both efficiency of decision making and actual distribution of functions need to be adequately catered for. Ability to motivate and control others varies from farm to farm, leading to differences in innovation behaviour.

3.4.1.1 Capacity to innovate

Ability to assemble the required financial, managerial and other resources is an indicator of firm size. Empirical studies have concluded that firm size is a major determinant of adoption decisions (e.g., Mansfield 1963a). Access to information and the farmer's ability to assess innovations efficiently seems to be determined by age, experience and education of the main decision makers (Rogers 1983).

3.4.1.2 Capacity variables

Economic and informational variables, have been proposed. Economic variables embrace income, wealth level, potential labour supply and farm size as a sub-category. Informational variables include age, off-farm experience, formal education, skills acquired through other training and access to extension services. This list is not exhaustive.

3.4.1.3 Farmer's preferences

Most of the capacity variables will also influence the farmer's disposition towards adoption, perhaps, in concert with assessments of the attributes of innovations. Farm size might influence both wealth and capacity for investment as will the farmer's capacity to bear risk. Household size is a critical determinant of subsistence requirements as well as potential labour supply. As an element of subsistence requirements, household size could provide motivations for higher levels of production, other things being equal. Potential labour supply may well be the indicator of additional changes in farming that the household can successfully implement. Age and education may represent exposure that is required for awareness about the range of possibilities that exist beyond the immediate confines of the village.

3.4.1.4 Personal characteristics

Personal characteristics such as age, affluence, 'opinion leaderships', are commonly discussed in relation to diffusion of innovations (e.g., Rogers 1983). These variables present many difficulties associated with measurement and interpretation. This is mainly because:

The effects of such factors are difficult to assess without resorting to ad hoc construction of arbitrary indexes and the possibility that circular results may arise.

Where farm decision making is dominated by one individual whose personal characteristics play a significant role, the case for inclusion of such variables into analyses would be strong. For smallholdings, this is not generally true, and aggregating this type of data across a group of decision makers is fraught with difficulties. The effects of such factors are rarely independent of economic characteristics such as farm size, profitability, wealth, etc.

3.4.2 The nature of innovations

All potential adopters can be expected to be influenced to a greater or lesser extent by attributes of innovations. Unfortunately, the number of such attributes can be large. Relative advantage (with respect to profitability, resource saving, risk, returns to resources, costs, enhancement in quality, etc.) associated with the innovation can be expected to feature prominently in adoption decisions. If the innovation is based upon technology that is easy to experiment with, then more people will try it out, thereby increasing the evidence of the worth of the innovation. Some innovations may be inconsistent with key aspects of group value systems. The innovation may not be technically viable or adequately adapted to specific conditions that obtain on a given farm even if it is well suited to the typical farm. The technology which is superior in physical terms may not be economically attractive. If the farmer assesses what is required by way of changes in the input mix against expected gain, the new technology may be found to be unattractive. Clearly, this topic calls for greater coverage than can be achieved within this chapter. Further discussion of characteristics of innovations is deferred to chapter four.

3.4.3 Off-farm factors

The usual practice is to promote innovations in "packages" rather than individual components. Technologies which are embedded in physical items such as new seeds, fertilizers and equipment will call for the timely availability of these inputs for adoption to take place.

The structure of an industry can affect the manner in which firms might acquire the relevant information on costs and expected rewards that they associate with an innovation. As relative advantage may, in many respects depend on the prices that firms pay and receive for inputs and produce, the structure of the rural industry can have indirect effects through influences on efficiency of production and exchange. Efficiency of information flows among relevant actors in the industry (farmers, merchants, markets etc.) will play a crucial role in the decisions of the players.

The structure of the agricultural industry helps set the levels of parameters of variables such as prices of both products and factors. Through interactions between firms and households, information about availability of products, cost, and distances becomes available to farms.

3.4.4 Information flows and adoption of innovations

The role of information in adoption does not need emphasizing. When an innovation becomes available, firms need to have knowledge about existence, availability, methods of implementation, and, more importantly, costs and returns associated with its use. In industry, the most important source of information early in the life cycle of an innovation is the firm which develops the innovation.
With time, other sources gain in importance. Advertising by retail outlets, and firm-to-firm channels become increasingly important as sources of information. Acquisition of information from all these sources represents costs to firms. The incentive and capacity to acquire and use information will probably differ between firms, according to characteristics of those firms.

In terms of farmers-to-frontline worker ratios, the Kenyan extension service does not have the capacity to take the extension messages to each farmer's door step. However, the delivery system for extension messages is well developed. Delivery is undertaken through a fairly extensive network of frontline workers complemented by farmer training centre activities, barazas, non-governmental organizations and the co-operative movement, not to mention twice weekly radio broadcasts. This is in addition to a fairly intricate network of informal relationships.

New innovations of potential economic significance are launched at 'official release ceremonies' which are usually well attended and publicized. Given this background, it is unlikely that farmers will remain ignorant about innovations long after they have been officially launched. Procedures and methods that were adopted for use in the household surveys were based on the issues that were considered in preceding sections.

3.5 Procedures and Methods

In the following two sections, procedures and methods that were used to assess possible roles of non-economic factors in adoption decisions are described. Procedures that were used in the planning and execution of household surveys are described in this section.

A comprehensive exposition of techniques and their application in field research can be found in Moser and Kalton (1975). Belsen (1986), for example, has given useful tips concerning questioning procedures on matters such as claims about purchases, readership of publications, and methods of dealing with statement of opinion. The interview technique and theory as well as interviewer bias in survey variables and means of improving output are considered at length in Beed and Stinson (1985). Suitable field procedures and analytical methods were selected from a large number of contending alternatives and adapted to specific conditions of agriculture in the semi-arid region of Kenya.

3.5.1 Data acquisition procedures

The FAO's *Farm Management Data Collection and Analysis System* , FMDCAS (Friedrich 1977) was used for the recording of various items of farm and household information. Because of the large number of data items, the FAO system was adapted so as to enable speedy processing of data by commercially available software. A second questionnaire was drawn up for use in the elicitation of the farmer's subjective assessment of technology and related issues. Although copies of the recording instruments mentioned are included in this thesis as appendix A, a summary of data items on each instrument is shown in Table 3.1.

Table 3.1: Items on the farm household survey schedules

Section	Record type	Type of data
Schedule A (FMDCAS)		
Section 1	Record 910	Farm identification
Section 2	Record 911	Farmer (occupational profiles)
Section 3	Record 930	All other family members
Section 4	Record 901	Permanent farm employees
Section 5	Record 918	Farm buildings
Section 6	Record 919	Tools and implements
Section 7	Record 916	Draft and pack animals
Section 8	Record 917	Productive livestock
Section 9	Record 920	Financial liability
Section 10	Record 921	Inventory change
Section 11	Record 912	Farm land
Section 12	Record 913	Crop information
Section 13		Resource use information
Section 14	Record 915	Subjective yield and price assessments
Schedule B: Farmer assessment of innovations		
Section 1	Record A	Farm identification
Section 2	Record B	Improved seed
Section 3	Record C	Field operations
Section 4	Record D	Soil fertility and plant nutrition
Section 5	Record E	Sources and applications of funds
Section 6	Record F	Labour information
Section 7	Record G	Soil and water management
Section 8	Record H	Farming information

The original plan was to interview farmers who had participated in an earlier survey (Rukandema, Mavua and Audi 1981). The sampling unit was the farm household. A random sample (n = 100 households) had been drawn from the register of land owners in Mwala location in Machakos district. Due to migration and other changes, the original sample had been reduced to 94. Field work started in December 1989 and ended in June 1990.

Inventories of farm resources, descriptions of husbandry practices and structural and functional organization of farm households were recorded on the first schedule of the questionnaire. Assessment of the current status of the farmers' understanding of the innovations, extent of implementation as well as the farmers' views about advantages and disadvantages and constraints were recorded on the second schedule.

Improved practices included timeliness of planting, use of recommended seed rates, and the use of inorganic fertilizers for the improvement of soil fertility and plant nutrition. The data recording instruments that are summarized in Table 3.1 were designed to facilitate elicitation of the following items of data.

(a) Individual household characteristics include:

- Personal attributes such as age, gender, level of education, employment, and contact with the world beyond the immediate village.
- Attitudinal information such as the way the innovations are assessed in terms of costs and returns.
- Factors which would determine the need for consumption such as household size and role and status in the clan or locality.
- Factors which determine farm size such as area and income.
- Production data (enterprises operated, and husbandry practices and production levels).

(b) Production environment was analyzed according to:

- Land quality.

- Factor and product prices.
- Input availability and access to infrastructure.
- Credit sources, extent of farmer patronage and constraints to access to credit facilities.

(c) Additional items include:

- A component of the maize package was considered 'adopted', if it had become a normal crop husbandry practice for the farm under consideration. Some researchers (e.g., Feder *et al.* 1984) have cautioned against the tendency to consider adoption in dichotomous terms on the basis that actual decisions made by farmers are defined over continuous ranges. Because quantities applied are expected to vary from field to field and season to season for any farm, it was decided that extra effort that was required to unravel the added complexity was hard to justify.
- In the case of non-adoption, the farmer was asked to state the main causes.
- Sources of information about farming as well as relative importance of different sources and predominant mode of transmission were recorded. As contact with extension services is usually considered to be an important source of information the survey sought to highlight the significance of such contacts.
- The 'capacity' to innovate variables, namely, education, wealth, and farm size were recorded.
- Inventories of crops, livestock and equipment.
- The questions pertaining to husbandry practices were designed so as to bring to light divergences between the recommended and actual practices if any.
- Information was collected on the extent of knowledge about innovations, how they were supposed to be implemented, where inputs may be obtained, prices, costs, access to sources of information and involvement in produce and factor markets.

  Ideally, frequent visits to collect labour-use data by membership, task, date performed and by duration would have been desirable. However, available resources could not permit such an approach. Besides, some of the farmers might have objected at being cross-questioned so intensely.

The most senior member of the household present was interviewed either alone or with assistance from other members of the household whenever this was appropriate. Each farm was covered in over 3 to 4 visits. Farmer responses were as far as possible supplemented by confirmation by actual observations.

3.5.2 Methods of empirical analysis

Consistency checks and scanning for errors were carried out for each recording instrument soon after completion. Data were then entered into a data base (dBASE III PLUS[3]). The next step was to identify and apply analytical methods that would enable inferences to be made about smallholder farming. The first step was to cross-tabulate the data in order to assess orders of magnitudes as well as trends in the data if any. Such cross-tabulations could also reveal obvious interrelationships that may exist thereby lessening the need for further analyses.

For a number of variables, only categorical data could be obtained. Sources of information by importance and preferred sources of seed are but two examples. Rank correlations were calculated for this type of variable. In attempting to identify and analyze causal asymmetry between the variables that was introduced in the previous sections and adoption decisions, it was necessary to supplement cross-tabulations, visual scanning and rank correlations with appropriate econometric methods.

Postulates about causality relationships between adoption of a given innovation (dependent variable) and farmer characteristics (independent variables) were assessed from within a Qualitative Dependent Variables Model (QDVM). Two variants of this model, the logistic function (Logit), and the normal density function (Probit) were evaluated for suitability for representing the smallholder choice situations. The Logit function was chosen. Justification for this choice is to be found in Appendix B, wherein the essential elements of the QDVM theory are outlined.

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[3]Copyright©Ashton Tate Corporation 1984.

3.6 Interpretation of the Logit Model

Interpretation of the logit analysis is analogous to interpretation of the results of ordinary least squares analysis (Judge, Hill, Griffiths, Lutkepohl and Lee 1988, ch. 19.). The suggested procedure has the following steps:

- Coefficients of regressor variables bear signs which indicate the direction of relationship with the independent variable. These should carry signs that accord with a prior expectation.

- Standard errors are square roots of the diagonal elements of $-[\partial^2 \ln \ell / \partial\beta\partial\beta']^{-1}$, the matrix of the second partial derivatives. These have only asymptotic justification.

- While the sign of the coefficient does indicate the *direction* of the change, the magnitude depends upon $f x_i' \beta$, which reflects the steepness of the CDF at $x_i' \beta$. The steeper the CDF, the greater the impact.

- Asymptotic *t*-ratios are values of the test statistic for the hypothesis that the associated parameter is zero, that is, that it has no influence. Asymptotically, the test statistic is distributed as an $N(0, 1)$ random variable if the hypothesis is true. At $\alpha = 0.05$ level of significance, the critical value is 1.96.

3.6.1 The likelihood ratio test

The likelihood ratio statistic tests the hypothesis that explanatory variables other than the intercept have no impact on the choice probabilities, i.e., that

$$\beta_1 = \beta_2 = \ldots \beta_k = 0$$

This test statistic is calculated as

$$2 - \ln\lambda = 2\,[\ln \hat{\imath}\,(\Omega) - \ln \hat{\imath}\,(\omega)]$$

where $\hat{l}(\Omega)$ is the value of the likelihood function evaluated at the maximum likelihood estimates and $\hat{l}(\omega)$ is the maximum likelihood value of the likelihood function under the hypothesis that

$$\beta_1 = \beta_2 = \beta_k = 0$$

If the hypothesis is true, then asymptotically, the test statistic has a $\chi_{(k-1)}^2$ distribution, where k is the number of independent variables.

If MLR test statistic is greater than χ^2 critical, then, on the basis of the data, the hypothesis that

Ho: $\beta_1 = \beta_2 = \beta_k = 0$

would be rejected.

Another statistic is the pseudo R^2, calculated as

$$R^2 = 1 - ln\hat{l}(\Omega) / ln\,\hat{l}(\omega)$$

This R^2 is analogous to the coefficient of multiple determination of regression analysis.

. $R^2 = 0$ if $\hat{\beta}_2 = \hat{\beta}_3 = \hat{\beta}_k = 0$.

. $R^2 = 1$ if the model is a perfect predictor in the sense that $P_i = F(x_i'\beta) = Y_i$. Between these limits, the value of this statistic has no intuitive interpretation (Judge, Griffiths, Hill, Lutkepohl and Lee 1985, ch. 18). Specifically, R^2 measures the proportion of 'uncertainty' in the data explained by the results.

3.7 Results and Discussion

A major objective of the surveys reported in this chapter was to establish the extent to which adoption of three innovations for maize production in the semi-arid region had progressed. In pursuit of this objective, a wide range of related issues were covered in the study as discussed in previous sections. The main findings of the surveys are presented in succeeding sections.

3.7.1 Adoption of components of the recommended package of technology for maize production

Results of the surveys permitted comparisons between proportions of farmers who had adopted various aspects of the maize package in 1980 and 1990. These comparisons are shown in Table 3.2.

Table 3.2: Uptake of selected components of maize production package 1980-90

Package	Adopters as % of all farms		
	1980[1]	1990	% change
KCB seed	31	30	-3
Organic fertilizers	68	83	22
Inorganic fertilizers	8	18	125
Early planting date	n.a.	56	n.a.
Late planting date	n.a.	44	n.a.
Pesticides	14.7	17	16

a: Rukandema *et al.* (1981)

Table 3.2 shows improvements in adoption of organic fertilizers (22 per cent), inorganic fertilizers (125 per cent), and pesticides (16 per cent). There was an apparent decline in the use of commercial maize seed (3 per cent). The majority of farmers achieved early land preparation and planting during the short-rains season (56 per cent). However, a disquietingly large proportion were apparently unable to implement the agronomic recommendation for timely planting (44 per cent).

3.7.2 Farm and household characteristics

Some items of the required information such as income and wealth could not be obtained for the majority of farms. Household wealth was presented in terms of the value of farm buildings. Information on other farm and household characteristics were obtained in a more direct way. These results are presented in Table 3.3.

Table 3.3: Farm and household characteristics

Variable	mean	median	mode
farm size (ha)	7.19	5.00	3.00
age of head of household (years)	55.00	54.00	60.00
formal education (years)	7 7	6.00	8.00
household size	7 13	6.00	2.00
wage earners per household	8 11	2.00	1.00
wealth[a]	27007.00	7500.00	2000.00

Note
a: The value of farm buildings was taken to represent the wealth level of the household.

The modal age of the head of household was 60 years. As diffusion studies have shown, age and adoption of innovations tend to be negatively correlated. The age factor alone may suggest that slow rates of adoption are to be expected. The age distribution, however, does not take into account the whole household. It is clear that holding size has changed little between 1980 and 1990. Given the increase in population over the same period, this result is surprising. A partial explanation is that the custom of subdivision of holdings is declining in importance. Mean household size stood at seven persons each. On the face of it, this last result might suggest the existence of a sizeable reserve of labour. Once seasonality of field operations and 'inactive' membership in the household are taken into account, actual labour supply may well vary from household to household.

3.7.2.1 Level of formal education attained by heads of household

In the diffusion of innovations literature (e.g., Röling 1988; Hunt 1978), the level of education of farmers is generally held to be a relevant explanatory variable. Table 3.4 shows the level of education of heads of households. Education is defined as the number of years spent in formal training in this context.

Table 3.4: Farmer characteristics: (Level of formal education)

Level(years)	Respondents (per cent)		
	Male	Female	Total
< 1.00	27.64	26.64	53.92
1.00-4.00	13.73	3.92	17.65
4.10-8.00	15.68	5.88	21.57
8.10-15.00	6.86	n.a	6.86
≥15.10	0.09	n.a	0.09

Results of this survey showed that more than half of the household heads (about 53 per cent) had no formal education at all. Of these, the male illiterates outnumber the female illiterates 28 per cent to 27 per cent. In the context of the Kenyan education system, farmers with eight years of formal education can read and write in official languages and also carry out simple calculations. This category accounted for about one fifth of the households in the sample. For those with twelve years of formal education, it is likely that one of the principles of agriculture courses would have been part of the curriculum. This category accounted for about seven per cent of the household. In all these 'literate' categories, women heads of household are not well represented.

3.7.2.2 Participation in wage employment

One of the aims of the survey was to establish the extent of participation in wage employment by farm households. The results of this assessment are summarized in Table 3.5.

Table 3.5: Farmer characteristics: (participation in wage employment)

Number per household	per cent	cumulative
<1	20.50	20.50
1	25.49	45.99
2	18.63	64.65
3	17.65	82.29
>4	17.65	99.94

About one in five households had no participation in wage employment. Membership of this group was dominated by women and relatively young farmers with young families. Over one quarter of the households have one member in wage employment and over one third had two or three members in wage employment. These results can be interpreted as suggesting that estimates of potential labour supply at the household level need to be adjusted so as to reflect participation in wage employment. As participants in wage employment are likely to be in the most productive category, adoption decisions could be affected through influences on capacity as well as willingness to innovate.

3.7.3 Sources of information on farming

The adoption of technology involves acquisition of knowledge about a particular technique or material input. Such information can be obtained from a variety of sources. Among the official sources examined in this study were contact with the extension services of the Agriculture Department, the co-operative movement and non-governmental organizations (NGO's). Farmers were accorded ample opportunity to discuss this subject at considerable length. The results of these discussions are summarized in Figure 3.2.

It is apparent that apart from own experience, exchange of information within the local community is regarded by farmers as an important source of ideas. The official channels, especially radio broadcasts also appear to be reaching a significant proportion of farmers. As the official sources are likely to be the bearers of the most reliable technical information, the nature of farmer interaction with them was followed in greater detail. The extension process in Kenya utilizes frontline workers to reach farmers through exchange of visits, farmer training and demonstrations and local meetings (*Barazas*). The relative effectiveness of each of these methods is shown in Figure 3.3.

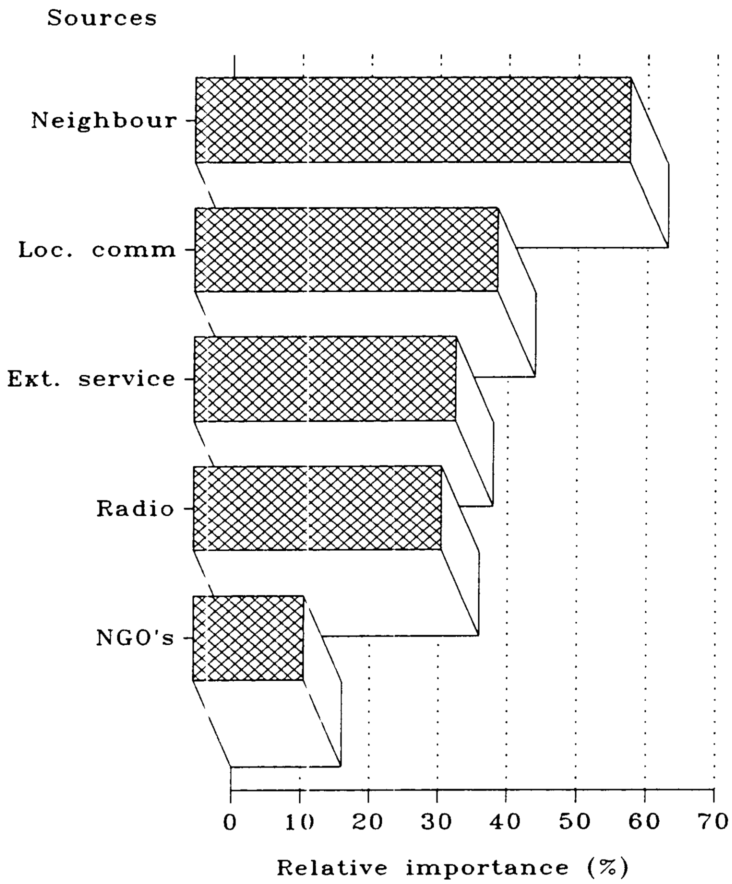

Fig. 3.2. Sources of information on farming

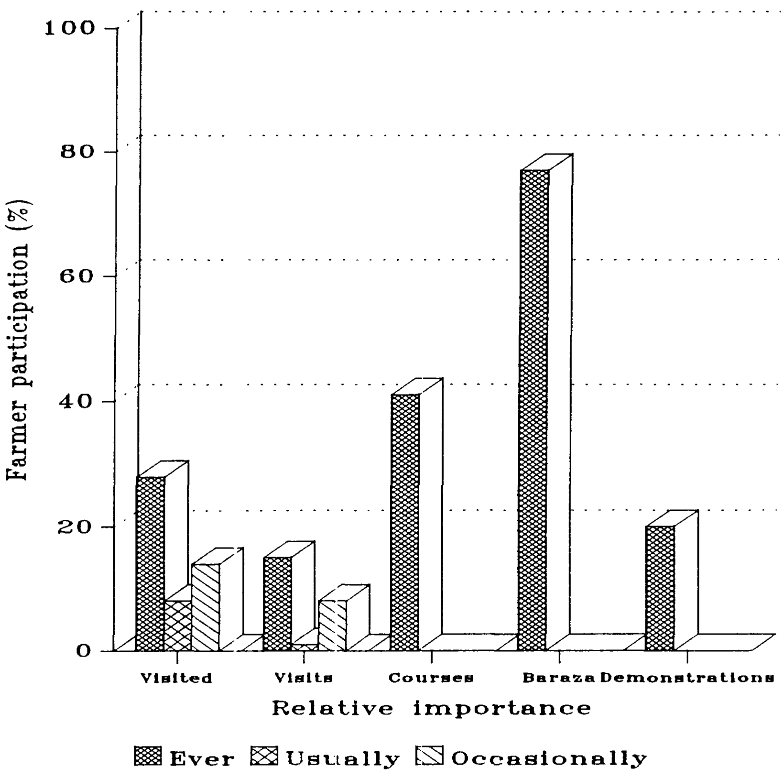

Fig. 3.3. Relative importance of modes of extension

A small minority actively sought advice from the extension workers but the most prevalent mode of interaction was through extension workers visiting farmers. As Figure 3.4 shows, crops accounted for most of the extension advice, followed by soil conservation, with livestock coming third.

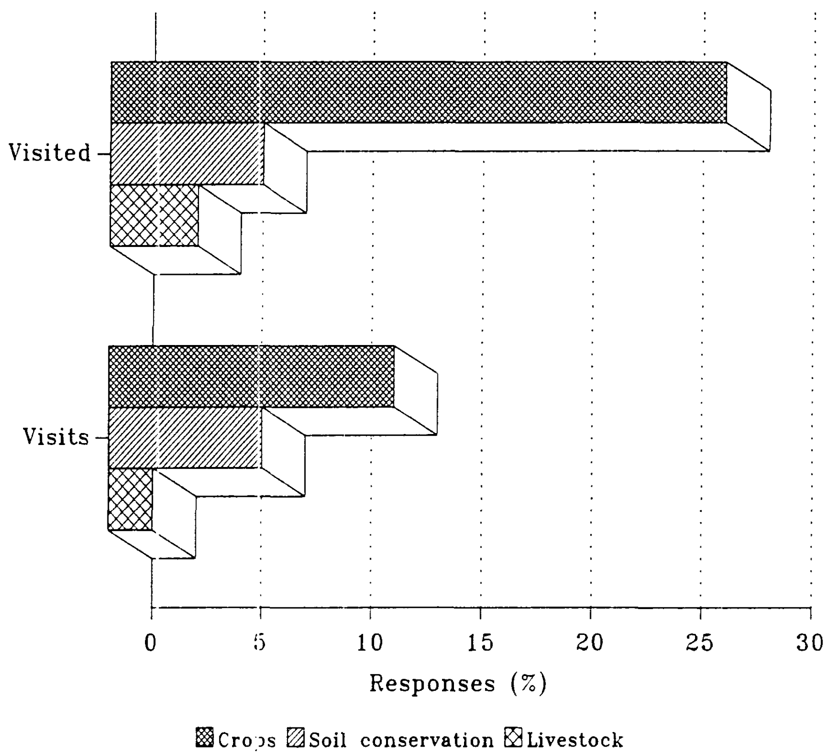

Fig. 3.4. Subject of extension advice

3.8 The Effect of Attributes of Farm Households on Adoption of Innovations

The aim of this study was to explore the causes of non-adoption of the plant populations, timing of field operations and use of fertilizer innovations in smallholder farming. Information on the plant populations innovation could not be obtained from the farms at reasonable cost. However, farmers were able to give information on the second and third innovations as categorical phenomena. To assess the effects (if any) of farm household attributes on adoption of these innovations, survey data was fitted to the logit function. Parameters of the resulting probability model were estimated via maximum likelihood methods. Actual computations were implemented by the *SHAZAM* econometric computer software (White *et al.* 1990). Results of these assessments are summarized and discussed in the following sections.

3.8.1 Timing of field operations

Seeding was the specific field operation that was the focus of analysis. The model was set up to test the hypothesis that size of holding, household size, gender, age, education and extent of participation in wage employment had no significant influence on the probability that this particular innovation would be adopted. Results of the logit analysis are summarized in Table 5.6.

In the logit analysis, the value zero was assigned to early planting (the innovation), and one to late planting. The analysis yielded coefficients bearing negative signs for the farm size, household size, and education variables. This means that other things being equal, increases in the values of those variables should lead to the adoption of the early seeding innovation. In general, these results are consistent with established theory of diffusion of innovations.

Table 3.6: Adoption of innovations vs farm attributes: model parameters (sowing time)

	Variable						
	constant	farm size	household size	gender of head	age	formal education	wage employment
Timing of operations							
Coefficient	-3.3681	-0.0108	-0.0002	0.0727	0.0267	-0.0001	0.0012
Asymptotic t-ratio	-2.4835	-06524	-01175	2.501	0.1768	-0.8846	0.8595

Adjusted $R^2 = 0.4006$

L-R test statistic = 16.3788 with 6 degrees of freedom

$X^2 = 12.5916$; $\alpha = 0.05$

The coefficients of the gender, age and wage employment variables were shown to bear positive signs. For the gender variable, this indicated that other things being equal, male farmers were less likely to adopt the early planting innovation than their female counterparts. This result seems to run counter to established opinion in the district. An explanation for this apparent anomaly may be that female farmers have less involvement with non-farm undertakings than their male counterparts. The finding that the older the farmer, the less likely that the early seeding innovation will be adopted is consistent with established theory. The wage employment variable could influence the adoption decision in either way. Wage employment would normally represent a drain on the farm's labour resources. Wages earned could also be used to employ casual labour, thereby boosting the farm's labour supply position.

As far as the significance of each of these variables is concerned, only the gender coefficient has an asymptotic t-ratio that is significant at $\alpha = 0.05$. The L-R test statistic, however, is significant. On the basis of this last test statistic, the hypothesis that all the variables have no influence on the probability of adoption of the early planting innovation should be rejected.

These results suggest that policies which are designed to increase opportunities for formal education could also improve the chance of success of the timeliness innovation. Even though farm size appears to be related to adoption, in Kenya, there is little scope for influencing availability of farm land through public policy instruments.

3.8.2 Farm attributes and adoption of purchased inputs innovation

Although there are several innovations that are based on the use of purchased inputs, only that using inorganic fertilizers was considered. The results of the logit analysis for this innovation are summarized in Table 3.7.

Table 3.7: Adoption of innovations vs farm attributes: model parameters (purchased inputs)

	Variable			
	constant	farm size	household size	gender
Purchased inputs				
Coefficient	-9.866	0.1119	0.0001	0.0312
Asymptotic t-ratio	-2.6280	1.3083	0.0096	1.371

Adjusted R^2 = 0.29780

L-R test statistic = 12.78736 with 3 degrees of freedom

X^2 = 7.81473; α = 0.05

The logit analysis yielded coefficients bearing positive signs for all the variables included. For the holding size and household size variables this indicated that increases in the values of these variables would lead to increases in probability of adoption of the innovation. The gender result indicated that female headed households stood a lesser chance of adopting the fertilizer innovation than their male counterpart, other things being equal. While the gender and farm size results are consistent with widely held views, interpretation of the household size result is less intuitively obvious.

On the basis of asymptotic t-ratios that were associated with the coefficients of regressor variables, the hypothesis of irrelevance for individual coefficients cannot be rejected. The L-R test statistic, however, is significant. Therefore, the hypothesis that all the variables concerned, taken together are irrelevant should be rejected.

The main practical recommendation to emerge from this analysis is that there is greater need to look into the reasons for greater reluctance to adopt this innovation.

3.9 Farmers' Evaluation of Recommended Practices

Where lack of adoption of an innovation is apparent, elicitation of the farmers' understanding of the technology on which the innovation is based may be worth undertaking. Personal assessments by farmers can lead to intuitively transparent explanation of lack of adoption. In this section, survey results covering this aspect of the study are presented.

3.9.1 Timing of planting

The current recommendation is that at least part of the crop land should be dry-planted, and that planting should be completed within one week of the onset of the rains (Weir 1986). Most farmers are aware of this recommendation. They see the main advantages as better plant establishment leading to higher yields (43 per cent) and early availability of food (31 per cent). On the other hand, the risk of losing seed (32 per cent) and pest damage (30 per cent) were seen as the main disadvantages of dry-planting. A surprisingly small proportion of farmers thought that weed management was a serious consideration in planting time decisions. The main complaints were that the tasks implied by this type of innovation called for more labour than was available on the farm. Lack of money to employ casual labour at peak times, combined with the fact that higher wages are usually demanded at such times, were seen as additional problems.

3.9.2 Improved seeds

Virtually all respondents have had some first hand experience with the improved maize seed (KCB). Earliness (22 per cent) and drought escape/tolerance (60 per cent) came out as the main advantages of KCB over local types. However, local varieties were considered to yield higher on average (62 per cent of respondents). Another advantage of local seed over improved seed was that reasonable yields could be obtained even with a relatively low level of management. The price of improved seed was also considered to be too high. This could also suggest that farmers' perceptions are that at prevailing levels of management, performance of local seed is considered to be satisfactory. Most farmers felt that there was little incentive to spend money on the purchase of improved seed. Consequently, less than one-third of the farmers purchased at least some KCB for the long-rains season of 1990. Information obtained from the principal supplier of seed indicates that annually, the quantities of seed purchased are low, although there is a slight upward trend.

Most respondents were aware that seed can be purchased from the agent of KGGCU, the local co-operative shop. However, preferred source of seed was own farm (52 per cent). The local market was the second choice source of seed. The usual practice is to select vigorous plants with big cobs and save the grain from these for next season's planting.

3.9.3 Fertilizers

3.9.3.1 Inorganic fertilizers

Like improved seed, all farmers in the sample have used inorganic fertilizers before. Most were aware that fertilizers could be bought at the local co-operative store. Unlike KCB seed, however, knowledge of different types of fertilizers, correct rates and timing of application and proper storage and handling, and, possible side effects relating to the use of chemical fertilizers was virtually absent even among those who were implementing the technology during the long-rains season of 1990. Farmers put forward lack of money as the main constraint to the use of fertilizer technology.

3.9.3.2 Organic fertilizers

Increasing awareness of the value of this locally available resource is evident. Nearly all farmers who have livestock apply some manure on crop land. The findings of this study were that none of the farmers applied all the manure that was available and also, none of the farmers succeeded in applying to all his fields. As a rule, organic fertilizer was applied during the long-dry season. A few farmers applied it in both seasons. As there are no standard recommendations, there is great variation in the methods of application. Again lack of labour was the main constraint to greater use.

3.10 Summary and Concluding Remarks

In this chapter, possible roles of a number of farmer characteristics that have been hypothesized to have causal relationships with adoption of innovations were examined. Data to facilitate such examination had been acquired through field surveys in Myanyani and Kyawango sub-locations in Mwala location of Machakos district in Kenya. Using a combination of survey methods, data were acquired for 94 farm households. As well as simple cross tabulations and rank correlations, a binary choice model technique was used to analyze the possible existence of cause-effect relationships and the nature of such relationships. The purpose was to suggest what needs to be done in relation to factors that need urgent attention and the nature of attention that is required. Several informational and attitudinal factors were examined.

The main results were:

- In the interval between 1980 and 1990, changes in the adoption of the maize package have been varied. Over the interval, 16 per cent, 22 per cent and 125 per cent increases in the adoption of pesticides, organic fertilizers, and inorganic fertilizers respectively, were achieved. Over the same period, a 3 per cent fall in adoption (3 per cent disadoption) of commercial seed was registered.
- The data revealed considerable inter-farm variation in the characteristics that were studied. Distributions of farm size, farmer's age and years in formal education were fairly symmetric. Household size, numbers of participants in wage employment per household and wealth variables exhibited skewed distributions.
- When causality relationships were examined within the qualitative dependent variable (logit) framework, the following results were obtained.
  - (a) Results showed expected signs on coefficients but low coefficient values.
  - (b) On the basis of insignificant asymptotic t-ratios, statistical significance could not be established for most of the variables.
  - (c) The hypotheses that all the variables except the constant were irrelevant could only be rejected on the basis of the maximum likelihood ratio (MLR) test.
  - (d) Low pseudo R^2 values were obtained, indicating that small proportions of variation were explained by these models.

- The results of the econometric analysis may indicate that although the factors that have been examined for their possible role in adoption decisions have some relevance, other factors which cannot be analyzed within the same framework may be exerting more significant influences.

These analyses indicated that other factors such as profitability of innovations, uncertainty and goal strategy systems, and their role in adoption decisions should be analyzed. Although farmer characteristics such as age and education feature prominently in the diffusion literature, the results of the econometric (QDVM) analyses showed that such variables did not explain a significant measure of the adoption behaviour of farmers in eastern Kenya. Recent studies (e.g., Adesina and Zinnah 1993) have also shown that traditional indicators of adoption determinants were not important in explaining farmer adoption behaviour. Farmer perceptions of the technology specific attributes of plant varieties were the major factors determining adoption. Whilst profitability is known to be one of the major influences on adoption decisions, it was not possible to obtain information that might have led to realistic assessments of profitability within the sample survey context.

Based on the results reported in this chapter the following conclusions could be drawn:

(a) Implications of farmer behaviour with respect to katumani maize (KCB) and local maize seed for agronomy research and the pricing policy for seed need to be examined further.

(b) The majority of farmers professed that they possess adequate understanding of the extension recommendations for inorganic fertilizers, yet further discussion invariably revealed significant divergences between farmer understanding and recommended practice. Why is this still the case in spite of years of extension?

(c) Most farmers appear to be conversant with the benefits of organic fertilizers. The current emphasis in agronomic research on this topic seems to be demonstrating the usefulness of organic fertilizers. The findings of the analyses reported in this chapter suggest that a shift in emphasis in favour of finding ways and means of helping farmers with the problem of delivery to the field in addition to demonstrating its usefulness.