Smallholder Dairy Technology in Coastal Kenya

An adoption and impact study

ILRI Impact Assessment Series 5

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Abstract

This study examined the factors influencing adoption of three related dairy technologies in coastal Kenya, and assessed the impacts of dairy adoption on household income, employment generation and nutritional status of pre-school children. The technologies studied were adoption of grade and crossbred dairy animals, planting of the fodder Napier grass and use of the infection and treatment method of immunisation against East Coast fever. A series of household surveys was conducted from mid-1997 to mid-1998. The descriptive results from surveys of 202 households in Coast Province indicate that adoption of a grade or crossbred dairy animal may result in substantial increases in household income, can generate paid (secondary) employment, and may improve the nutritional status of pre-school-age children in the household. Econometric analyses, which controlled for numerous confounding factors, provided less consistent support for the impact of adoption on household income and paid employment. It appears that neither the adoption nor productivity of dairying are constrained by poor availability of technology options. For dairy development activities on the coast, two areas merit attention: mechanisms for easing access to grade and crossbred dairy cattle, either through credit schemes or through self-help smallholder co-operatives, and reducing the disease risks associated with grade and crossbred dairy animals.

1 Introduction

In many parts of Africa, smallholder farmers are being compelled by policy and markets to diversify their traditional export crops, whose potential for growth remains uncertain. Alternative agricultural activities are needed which offer higher returns to land and labour, offer the expectation of future growth, and which are suitable for adoption by the resource-poor smallholder farmers who continue to dominate African production. Market-oriented dairy production may fill this need for some smallholder producers.

The reasons for promoting dairy research have fundamentally to do with improving the opportunities and welfare of smallholder farmers and the consequent effects on agricultural development. The avenues of this impact are several:

1. There is good potential for increased demand and higher real prices for dairy products.
2. Dairying can lead to increased levels and stability of income generation for producers.
3. Dairying can increase employment in rural areas both directly and indirectly through supply of inputs and locally produced household items, and through increases in rural capital accumulation.

Other impacts may be either positive or negative, including the impact on women in the household in terms of income generation and access, and labour demands and allocation. Similarly, the impacts of intensive dairy development on the poorest households may be indeterminate. Finally, dairying can have positive impacts on soil fertility maintenance in intensive mixed cropping systems, a role that may grow with intensification.

Various previous studies have examined the adoption of dairy technologies and their impacts on smallholders in Kenya (some of these are summarised in Appendix 1). The objectives and focal points of these studies are diverse. Previous adoption-oriented research has examined the use and diffusion of dairy-related technologies (Metz 1993; Metz et al 1995) and the factors affecting adoption of Napier grass on smallholder farms (Irungu et al 1998). Impact-oriented studies have examined changes in the roles of women in livestock production and marketing (Price Waterhouse 1990; Mugo 1994; Mullins et al 1996), and how dairying affects the nutritional status of households (Launonon et al 1985; Leegwater et al 1991; Huss-Ashmore 1992). Many of these studies were motivated, at least in part, by the efforts of the National Dairy Development Project (NDDP), which was active in 24 districts in Kenya at the time of its completion in 1995.

Previous technology adoption and diffusion studies emphasise the high variation in adoption rates and factors apparently influencing the adoption of dairy-related technologies and practices. The impacts of dairy adoption, like the prevalence of adoption itself, vary by location in Kenya. These studies provide useful if inconclusive evidence that households benefit in certain ways from the adoption of smallholder dairy production and marketing. A number of important issues remain unresolved, however. These include:

- Is off-farm income a prerequisite for adoption of dairying, and by how much does dairy increase total household incomes?
- How much, if any, paid (secondary) employment does the adoption of dairy generate?

- To what extent does dairying itself improve nutritional outcomes for pre-school age children?

This study attempts to address these issues through the application of quantitative methods that use samples of households with and without dairy production and allow for controlling of multiple confounding factors (von Braun et al 1989; Randolph 1992). The study constituted one of the case studies carried out under the auspices of the Impact Assessment and Evaluation Group (IAEG) of the Consultative Group on International Agricultural Research (CGIAR), as part of the project 'Assessment of the adoption of CGIAR agricultural innovations'. This study set out to identify the factors that lead farmers to adopt or not adopt agricultural innovations, through a synthesis of nine case studies. The IAEG project was designed to help produce persuasive and conclusive information to CGIAR donors, and formulate recommendations for improving the rate and extent of adoption of innovations.

The objectives of this study were therefore:

- to examine the factors influencing adoption of three related dairy technologies in coastal Kenya
- to assess the impacts of dairy adoption on household income, employment generation, and nutritional status of pre-school children.

Research results from studying the adoption and impact of dairy technologies in coastal Kenya can be expected to inform ongoing KARI and ILRI research on smallholder dairying in other parts of Kenya. The results will also benefit other ILRI dairy-related research being carried out with national partners in Ethiopia, Tanzania, Uganda, West Africa and elsewhere in the tropics. More generally, the results and conclusions will be relevant for informing policy makers and development agencies interested in supporting smallholder dairy production in difficult and risky production environments.

2 KARI–ILRI collaborative research and development support to smallholder dairy in coastal Kenya

Coast Province, Kenya, and the environment for smallholder dairying

Coast Province covers over 80,000 km^2 in the south-eastern part of Kenya, constituting about 15% of the country's land area. Most of the province's population resides within 100 km of the Indian Ocean, although large areas of the province are up to 400 km from the coast (Figure 1). The population is estimated at over 2 million inhabitants, or about 7% of Kenya's total population of 28.8 million (1997 estimate). Coast Province is home to a large number of ethnic groups; an estimated two-thirds of the population are members of related ethnic groups referred to collectively as the Mijikenda. The Mijikenda have a history in the area stretching back at least two centuries (Waaijenberg 1994). The other one-third of the province's inhabitants are migrants from Kenya's highlands. These migrants are primarily from the Machakos area of Eastern Province, the densely populated areas of western Kenya, and from central Kenya. These migrants generally have a stronger tradition of dairy cattle keeping than the Mijikenda. Increasingly, the population of the province lives in urban areas; at present about 45% live in Mombasa and other urban centres.

The economic development of Coast Province has lagged behind other areas of Kenya (Leegwater et al 1991). The province suffers from 20% higher infant mortality than other parts of the country. Malnutrition of children is common—nearly 40% of the children are stunted to some degree—and the prevalence of rural poverty may be more than 40% of all households. The percentage of girls enrolled in primary education is only two-thirds that of the rest of the country (Greer and Thorbecke 1986; Foeken et al 1989). As a result, living conditions in large parts of the province have been described as 'harsh' (Leegwater et al 1991).

The climate of the region varies with distance from the coast and the border with Tanzania. The climate becomes drier moving inland from the ocean and from south to north. The most commonly used classification scheme defines the region's agro-ecozones based on mean annual rainfall, temperature and soil type (Jaetzold and Schmidt 1983). Much of the province is classified as coastal lowland (CL) zones. The CL zones (Figure 1) are subdivided into the Coconut–Cassava zone (CL3), Coconut–Cashew zone (CL4), and Livestock–Millet zone (CL5). Annual rainfall is highest in CL3 (1000 mm per year), lower in CL4 (900 mm per year), and lowest in CL5 (700 to 900 mm per year). Rainfall in the entire area is bi-modal, with the long rains beginning around April and the short rains beginning in October. Mean annual temperature ranges from 24°C to 27°C, but maximum temperature averages over 30°C during the hottest months, January to April.

Most rural households in the region engage in diverse agricultural and non-agricultural activities. Maize, cassava and cowpea are the staple foods grown in the area, although it is

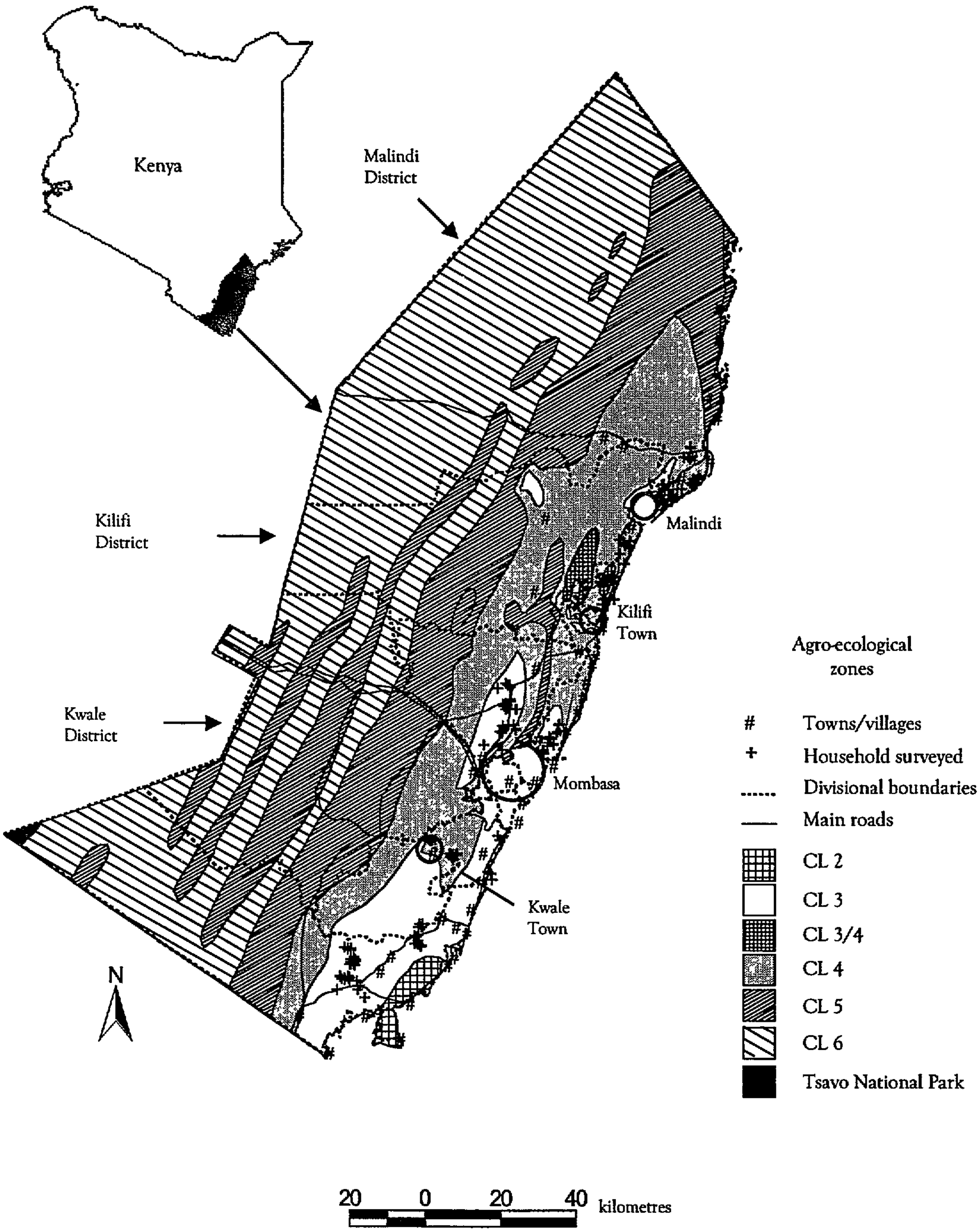

Figure 1. *Study region for the adoption and impact study.*

estimated that own-production accounts for less than half of the amount of these staples consumed by the majority of households (Leegwater et al 1991). The region is thus a food deficit area that imports staple foods from other parts of the country. Coconut palms and cashew trees provide important sources of cash income for many rural households; oranges and mangoes are widely produced and sold, and bixa is a common cash crop in Kwale District. In the CL zones, cattle are owned by about 20% of rural households (Thorpe et al 1993), whereas ownership of goats and sheep is more common. Most households also raise poultry for home consumption.

Employment off farm has become an important source of income for rural households, in part because of the development of the tourism industry in coastal Kenya. Most studies report that about two-thirds of rural households have income from non-farm activities. Leegwater et al (1991) reported that one-quarter of all adults in rural households worked off farm; women were less likely to work off farm than men were. In Kilifi and Kwale districts, income from off-farm employment represented 60% of household income in the late 1980s (Foeken et al 1989; Hoorweg et al 1990). In addition to wages and salaries, some rural households operate small businesses such as water and tea kiosks. This importance of non-farm activities results from the low-to-moderate potential of the region for intensification of agriculture, and the need to diversify household activities to reduce risk. Waaijenberg (1994) asserts that the adoption of productivity-enhancing technologies is low due to the lack of emphasis placed by many households on agricultural activities.

Peeler and Omore (1997) estimated that Coast Province produced about 3% of Kenya's total milk supply in 1993. The coast is a milk deficit area; as much as 45% of the region's dairy consumption is supplied by other parts of Kenya. In the early 1990s many of these 'imports' were in the form of milk powder reconstituted in local processing facilities. In recent years shipments of pasteurised milk to the region have increased as the number of private dairy processors in Kenya has grown. The amount of milk brought to the province from elsewhere in Kenya during a year is equivalent to the production of about 20,000 smallholder dairy farms. Since reform of the country's dairy policy in 1992, milk prices at the coast have increased relative to those in other parts of Kenya; farm-level milk prices in the area are twice those paid in Kenya's highlands (Thorpe et al 1993). Milk and milk products enjoy a strong demand. Consumer surveys indicate that fresh ('raw') milk is preferred over packaged pasteurised and UHT (long-life) milk (Staal and Mullins 1996). The strong demand for milk and higher farm-level prices have been taken as indicators of the potential for dairy development in the region.

Although a few large and successful dairy farms have been established in the area, most of the milk production occurs on smallholder farms. The majority of milk is produced by local zebu-type cattle; based on data from this study, only about 1% of households with cattle in the area own grade or crossbred (G/C) animals. Peeler and Omore (1997) estimated that G/C animals owned by smallholders accounted for less than 4% of all cattle in Coast Province. Growth in milk production by smallholders has lagged behind demand mostly due to technical constraints. Grade and crossbred animals are more susceptible to diseases common at the coast, such as the tick-borne East Coast fever (theileriosis), anaplasmosis and babesiosis. Theileriosis is responsible for about 60% of all clinical cases, and an annual mortality rate of about 30% (Maloo et al 1994). Trypanosomosis, carried by the tsetse fly, is another important health problem for smallholders, particularly in Kwale District. In addition, seasonal shortages of feed for higher-producing dairy cows have been identified as a major constraint to milk production. The development of formal (commercial) milk marketing is limited in some areas, despite the strong local demand for milk.(Thorpe et al 1993).

The contribution of grade and crossbred cattle to production of milk by smallholders is somewhat difficult to assess based on available information. The number of adopters in the three coast districts where the KARI–ILRI work was conducted (Kwale, Kilifi and Malindi districts) is small; about 750 households of an estimated 127,000 total households own grade or crossbred animals. Some of the owners of these animals reside in urban areas and maintain rural farms with 5–10 dairy cattle as small-scale commercial operations (KARI–ILRI Impact Survey preliminary results 1998). These dairy operators are thus not typical rural smallholders. The total number of grade and crossbred cattle on smallholder farms in these three districts is estimated to be between 5000 (KARI–ILRI Adoption Survey results 1997) and 21,000 (Peeler and Omore 1997). Although small in numbers, grade and crossbred cattle are estimated to provide between 20% and 40% of smallholder milk production in the three districts. Smallholders with G/C cattle may provide up to 30% of total milk production in Kwale, Kilifi and Malindi (Peeler and Omore 1997).

KARI–ILRI collaborative research and development support for smallholder dairy

In response to a need identified by the then Ministry of Livestock Development (MoLD) in 1988, the Kenya Agricultural Research Institute (KARI) and the International Livestock Centre for Africa (ILCA, now the International Livestock Research Institute (ILRI)) established a programme to identify and resolve biological, social and economic constraints to the development, adoption and productivity of smallholder dairy systems in the coastal lowlands. The programme was based at KARI's Regional Research Centre (RRC), Mtwapa in Kilifi District.

The programme, which took a production-to-consumption systems approach (Rey et al 1993), was planned and carried out in close collaboration with MoLD's extension service through its National Dairy Development Project (NDDP) (Maarse et al 1990), and with the participation of other research institutions. The integrated programme of on-farm and on-station research covered farming systems description and constraint identification and technology development and testing. The major research areas were studies of dairy consumption and marketing, smallholder resource management, disease risk to dairy cattle, feeding systems development and dairy cattle breeding.

The results of this work confirmed the following:

- the large milk deficit (Mullins 1995)
- there were seasonal feed shortages and inadequate nutrient concentrations in diets for milk production (Reynolds et al 1993), constraints which were addressed through the development of improved feeding systems based on intercropping fodder grasses and

shrub and herbaceous legumes and the use of maize by-products (Muinga et al 1995; Mureithi et al 1995b)

- East Coast fever (ECF) was shown to cause major losses in smallholder dairy cattle (Maloo et al 1994), losses that could be substantially reduced by immunisation through infection and treatment (Nyangito et al 1994; Mukhebi et al 1995)
- rotational cross-breeding was identified as an efficient breeding system for smallholder milk production (Mackinnon et al 1996).

Collaboration with the NDDP ensured strong research–extension–farmer linkages resulting in, for example, farmer-managed forage trials. Proven on-station technologies (improved germplasm and agronomic practices) for the legumes *Leucaena leucocephala* and *Clitoria ternatea* (Mureithi et al 1995b), were tested systematically with smallholder farmers through a sequence of steps:

- farmer/extension staff visits to the long-term on-station experiments
- research–extension-managed demonstration plots on selected farms
- field days held on these farms and on those of early adopters
- farmer-managed trials on some 300 farms in four districts of Coast Province.

The studies of smallholder farming systems and resource levels (Thorpe et al 1993; Mureithi et al 1995a) indicated that for the majority of households, agricultural change will be a sequential intensification through the adoption of individual technological components rather than through the adoption of a multi-component package, such as the NDDP's zero-grazing package. Current research and extension therefore aims to provide a range of technological options adaptable to individual circumstances (Thorpe 1996).

Underpinning the technical achievements was the effective interaction established between researchers, extension staff and farmers from the beginning of the project. The orientation of the research towards field-based problems and studies and the continuous contact with farmers built up confidence between the three groups and ensured effective and productive working relationships. Contributing to this process were monthly seminars and regular workshops for presenting research proposals and reviewing results from the field studies and the experimental programme.

Subsequently these planning and review processes were institutionalised. In 1991, it was agreed that KARI's Regional Research Centre would host quarterly 'cluster' meetings of research and senior extension staff and other invited participants to review programme activities and to consider new proposals. Initially these meetings were held at the RRC but after 1992 they rotated between Kilifi, Taita/Taveta and Lamu districts. In turn, these quarterly planning and review meetings nominated research–extension working groups to organise specific interventions. For example, a working group developed the protocol for and supervised the implementation of the farmer-managed forage trials referred to above. The success of this 'cluster' mechanism for strengthening research–extension–user linkages was such that KARI and the Ministry of Agriculture, Livestock Development and Marketing (with funding from the Netherlands) replicated it nationally through KARI's regionally mandated Research Centres (Thorpe 1996).

In terms of impact, the development and transfer of appropriate technologies to address the productivity losses resulting from inadequate year-round feed resources and ECF have had a significant effect, particularly in the smallholder sector:

- over 95% of participating farmers subsequently surveyed had recommended the legumes to their neighbours
- approximately 60% of participating farmers adopted the recommended agronomic and feeding practices (Njunie et al 1994)
- application of ECF immunisation in the Kaloleni study area was estimated to have reduced mortality and increased calving rates resulting in an 8.6% annual internal growth of the dairy herd (Mukhebi et al 1995).

These results were expected to stimulate a demand from smallholders for technologies such as immunisation of dairy cattle (the infection and treatment immunisation process is a major output from KARI's National Agricultural Research Laboratories). In this case private veterinarians in the region have been trained as a step towards the sustainable delivery of the immunisation technology. Extension of the technology to smallholder dairy cattle in the high rainfall coastal lowlands may ultimately have a significant impact on the current milk deficit, if institutional problems in service delivery can be overcome.

The KARI–ILRI inter-disciplinary, inter-institutional programme contributed considerably to the development of strong linkages between the research institutions, the extension services and their clients, current and potential smallholder dairy farmers in coastal Kenya. It ensured a more effective development, testing and transfer of appropriate technologies such as improved feeding systems and ECF immunisation. The programme increased the awareness of research and development officials of the importance of effective input and output markets for smallholder dairy development. It has served as a model for the strengthening of research–extension–farmer linkages for smallholder dairy development and related agricultural development in the high potential regions of Kenya. Various important lessons were learnt from the coast programme, including the need for:

- active participation of all major stakeholders and key players in the identification and resolution of the technical, socio-economic and policy constraints along the dairy production-to-consumption chain
- effective linkages with MoALDM and related ministries at policy as well as operational level
- effective linkages with the private sector for the provision of output and input services
- effective means to implement proposals by feeding directly into the design of pilot initiatives.

3 Adoption and impact surveys of smallholder dairying in coastal Kenya

Numerous dairy-related technologies and practices could be considered in a study of adoption. Previous studies have examined the use of 20 technologies and practices associated with smallholder dairying in six districts of Kenya (Metz et al 1995), but not the factors associated with their adoption. This study focuses on a smaller number of related adoption decisions faced by smallholder farmers in coastal Kenya. The ownership of grade or crossbred animals is a key element in the development of intensive dairy production. Grade and crossbred (G/C) dairy cows have higher potential for milk production when adequately fed, and yet are more susceptible to diseases (e.g. ECF and trypanosomosis) common in many areas of Coast Province (Maloo et al 1994). Grade and crossbred cows require more feed than local cows to produce milk up to their potential. Because seasonal feed shortages have been identified as constraining milk production, the development of improved feeding systems has been a focal point for previous research (Reynolds et al 1993).

Work started in early 1997 on planning the adoption and impact study. The objective of the study was to determine the factors that influence partial or complete adoption of dairy technology. The technology was defined as ownership of a crossbred or grade dairy animal, the planting of the forage Napier grass, and the use of the infection and treatment method of immunisation against ECF. Questions as to whether adopters of this technology later 'de-adopted' or substantially modified their practices after the initial adoption decision was made, were felt to be particularly important in Coast Province. In addition, the adoption survey was to deal with three complementary technologies: crossbred dairy cows, Napier grass and ECF vaccination. There are clear interdependences between the decisions to adopt the three technologies. This is complicated somewhat by the possibility of lags (and sequencing) of adoption. For example, in some cases the decision to adopt Napier grass may be conditional on the decision to adopt cows, but the decision to adopt cows may not be conditional on the decision to adopt Napier grass, if the forage was planted a number of years after the crossbred cows arrived. Alternatively, to the extent that a package of technologies was required by the NDDP, the interdependence of adoption decisions may be mostly due to programme requirements. A series of surveys was designed to address these and other issues.

Studies of the factors influencing adoption of agricultural technologies often focus on household resource endowments, characteristics of the household head, location of the household, the nature and extent of information provided before adoption, and the characteristics of the technology (Feder et al 1985). In coastal Kenya non-farm jobs and businesses are key alternatives to intensification of agriculture for farm households (Waaijenberg 1994), but may also provide income needed for investment in more intensive dairying. Accordingly, the surveys were required to collect information on location, characteristics of the household head and sources of information used by the household head to make decisions about the choice of agricultural technologies. The surveys also included information about the characteristics of the household, perceptions about the availability of the G/C animals, availability of seeds and planting materials for Napier grass, and access to ECF immunisation. Households were also asked about their perceptions of the accessibility of the inputs and services associated with the three technologies. This information was then to be used to develop econometric models of adoption and impact (Nicholson et al 1999).

The first task was to compile a complete inventory of all households with small- or medium-scale farmers with dairy cows for the project area. The project area (Figure 1) encompassed agro-ecologies CL3 and CL4 in Kilifi District (Bahari, Kaloleni and southern Malindi divisions) and Kwale District (Kubo, Matuga and Msambweni divisions). In 1998, the boundaries of Kilifi District were adjusted to accommodate a new district, Malindi, and Malindi Division of the old Kilifi District became part of this new district. The areas south and north of Mombasa afford a substantial contrast in conditions, notably differences in trypanosomosis challenge and infrastructural development. Ministry of Agriculture staff completed the inventory, essentially a census of dairy households, early in 1997. Three separate surveys of farm households were conducted during 1997 and 1998, based on the inventory of 750 households with dairy cows in the three districts.

Adoption Survey

For the 'Adoption Survey' in June and July 1997, 75 dairy adopters and 125 non-adopters were surveyed in the three districts. The adopters, defined as households owning at least one grade or crossbred (G/C) dairy animal, were randomly selected from the inventory of all adopting households. The sample of adopters was stratified by division, the administrative unit below the district level. The total number of farmers interviewed from each division was proportional to the number of households in that location (Table 1). Non-adopting households were selected randomly from lists of 20 neighbours of adopting households.

Table 1. *Households, adopters and number of survey respondents by division.*

District	Division	Households[1]	Number of adopters	Adopters surveyed	Non-adopters surveyed	Total surveyed
Kwale	Matuga	11,010	53	6	12	18
	Kubo	6,434	20	2	8	10
	Msambweni	30,272	73	8	40	48
Kilifi	Malindi	30,243	184	19	28	47
	Kaloleni	26,167	115	12	29	41
	Bahari	23,250				
	Bahari South		89	9	4	13
	Bahari North		185	19	4	23
Total		127,376	719	75	125	200

1. Source: CBS (1994).

Impact Survey

The 'Impact Survey' administered during February to April 1998 followed the same sampling procedure; some 200 households not contacted during the adoption survey were interviewed. Indicators of nutritional status for pre-school children were collected for 112 children in these households.

Detailed Survey

The 'Detailed Survey of Dairy Adoption History' consisted of semi-structured interviews with 29 farm households randomly selected from the households participating in the impact survey. Of the 29 households, 15 had previous experience with G/C dairy cattle and 14 had no experience with more intensive dairying.

4 Results of the adoption surveys

Overview of sample household characteristics

The characteristics of the households in the sample for the Adoption Survey vary by district and adoption status (Table 2). The mean number of household members exceeds seven in all districts, but is twice that number in Malindi District. (Household size is often difficult to assess in Coast Province due to difference in the definition of 'household member' and the tendency for some household members to work away from the farmstead during parts of the year.) Kilifi District households appear to be more integrated into the non-agricultural economy of the region, in part due to proximity to Mombasa and coastal hotels. Sample households in Kilifi District were located closer to a market or trading centre, earned higher incomes from off-farm employment, and household heads had higher mean years of education. The proportion of female-headed households is also lower among the households sampled in Kilifi District, perhaps reflecting better economic opportunities for male heads of households in the local area.

Table 2. *Characteristics of Adoption Survey households by district and adoption status.*

	Kwale District		Kilifi District		Malindi District	
Characteristic	Adopter	Non-Adopter	Adopter	Non-Adopter	Adopter	Non-Adopter
Number of households in sample	14	61	41	37	17	29
Household characteristics						
Number of household members	7.8	7.5	9.1	9.3	17	12.2
Female head of household (%)	36	39	20	24	29	30
Education of household head (years)	6.4	4.5	7.2	5.7	5	3.8
Head has non-farm activity (%)	57	42	46	37	41	33
Distance to market or trading centre (km)	18.7	15.1	3.3	3.4	8.5	7.8
Cash income from						
Dairying (KSh/month)	6,086	114	8,694	0	4,701	290
Poultry or eggs (KSh/month)	1,286	568	3,708	778	59	43
Crop sales (KSh/month)	1,469	842	1,305	641	2,215	1,466
Wages, salaries, non-farm (KSh/month)	5,269	1,853	11,041	3,319	9,794	4,128
Remittances (KSh/month)	145	526	124	465	659	328
Other (KSh/month)	705	94	1,256	18	212	400
Total (KSh/month)	15,182	3,937	26,570	5,316	17,640	6,716
Farm characteristics						
Number of G/C cattle owned	5.9	0	5.3	0	3.8	0
Acres of Napier grass planted	1.8	0.1	0.9	0.1	0.4	0.03
Total land area (acres)	21.9	10.2	12.8	9.6	14.8	11.4
Permanent hired labourers	1.6	0.2	1.8	0.3	0.7	0.2
Casual hired labourers	1.7	1.1	1.7	2.2	2.4	0.8

Note: Adopters are households with at least one grade or crossbred animal. Non-adopters own no grade or crossbred animals.

The characteristics of the sample households illustrate the importance of non-farm activities in the region. Between 33% and 57% of household heads were engaged in an off-farm activity. Income from wages, salaries and other non-farm activities is important for sample households in all three districts, ranging from 35% of total cash income for adopters in Kwale to more than 60% of total cash income for non-adopters in Kilifi and Malindi. Cash income from crop sales accounted for only 5% to 21% of total cash income, and was highest in Malindi District. The lower proportion of cash income from crop sales in Kilifi may reflect the trade-offs between allocation of household resources to agricultural and non-agricultural activities. Dairying accounted for 25% to 40% of cash income for adopting households. The proportion of income from dairying was highest in Kwale District, but households in Kilifi had the highest mean cash income from dairying.

Peeler and Omore (1997) reported that a large majority of the G/C animals in the three districts studied was in Kilifi. However, sample households in Kilifi District owned a smaller number of G/C cattle on average than households sampled from Kwale District. The amount of Napier grass planted per farm for adopters also was highest in Kwale. Some non-adopters also planted Napier grass, perhaps for sale or in the expectation of purchasing a G/C animal in the near future. The mean area of total land farmed by sample households ranged from 9 to 21 acres; 12-acre plots promoted under settlement schemes at the coast have meant that average farm sizes are often many times larger than farms in Kenya's highlands. In part, this reflects the lower productivity of land and lower population density in the CL zones. Many sample households hired permanent and casual labourers for farm and non-farm work. The average number of permanent labourers hired per household was highest in Kilifi, which again may reflect the importance of non-farm activities for household members in that district.

Experiences of dairy adopters

Fifteen of the 29 households interviewed for the Detailed Survey had adopted G/C cattle at some time. However, these households acquired their first G/C animal at very different times. The year of adoption varied from 1974 to 1996. Half of the adopters acquired a single cow, purchasing it from another individual with cash saved by the household. In fewer cases, households acquired more than one animal, sometimes with the assistance of a development project or through collective effort. Only 4 of the 15 G/C adopting households interviewed had previous experience with cattle. Most often, the household head and spouse jointly made the decision to acquire a G/C animal. The cost of the animal varied from KSh 5000 to KSh 20,000 (about US$ 80 to US$ 300), the difference being in part because of inflation over time. The KSh 20,000 represents about two times the average monthly cash income reported by households in the Adoption Survey, and three times the average monthly cash income from dairying reported by G/C adopters.

Of the 15 households who had adopted dairying, four no longer owned a G/C animal. One household was awaiting a cow to replace an unproductive animal provided through a development project. For the other three households, the most important reason for getting out of dairying was that their previous animal died and they could not afford to replace it. The households also stated that they found the management of grade and crossbred animals difficult, and that they sometimes had difficulties selling milk produced. Since 1993, the number of these 15 households with G/C animals or planted Napier grass has declined somewhat (Figure 2), although the number of G/C animals owned has increased in recent years. The total number of acres of Napier grass planted on these 15 farms has also declined somewhat. Further research into the extent and causes of this de-adoption process would benefit dairy development efforts in the region.

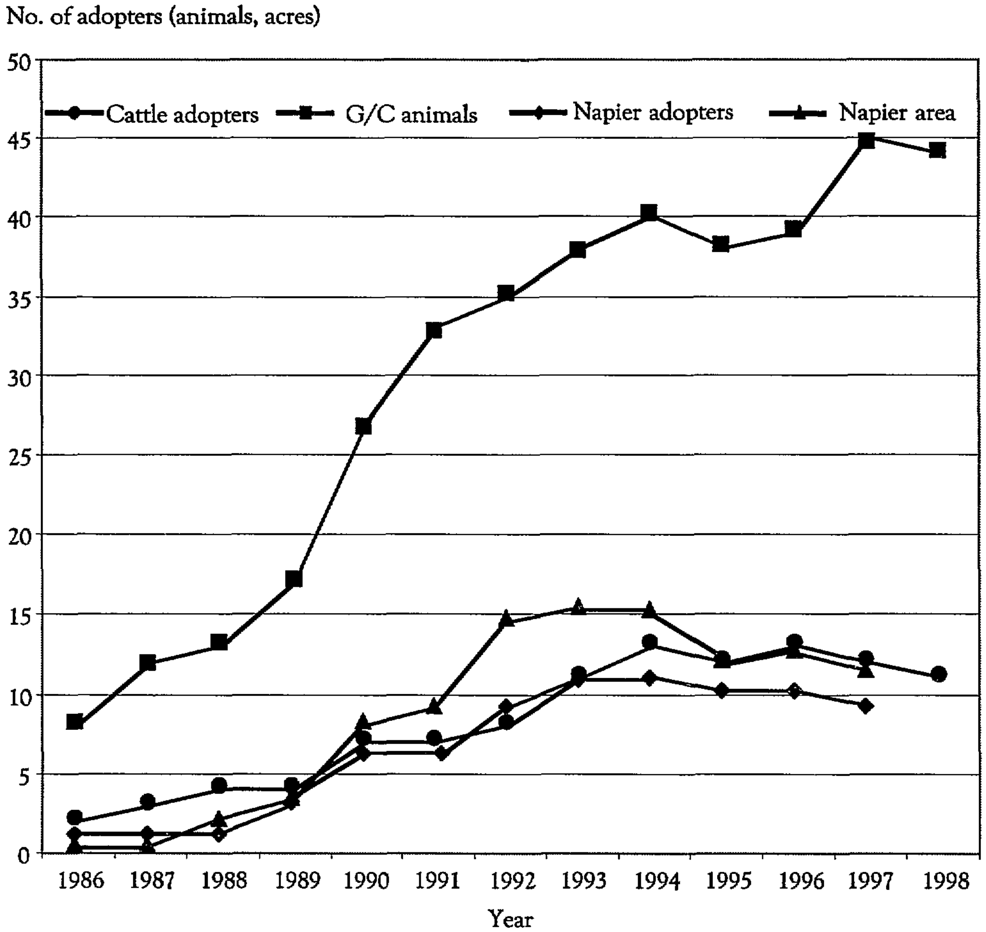

Figure 2. *Patterns of adoption over time for 15 adopters.*

Sources of information used by adopters before adoption

The Detailed Survey gathered data on sources of information used by respondents before the adoption of G/C animals, and the significance of the source to the adoption decision.

The structure of the questions assumed that information of two distinct kinds would be useful to potential adopters. First, potential adopters probably want to know what benefits derive from owning a G/C animal. Second, they may also want information about what practices, inputs and pitfalls are involved in managing grade and crossbred animals—this is particularly true given the limited previous experience of the households with cattle production. Thus, managing a G/C animal may represent a significantly higher degree of management complexity than households are accustomed to.

Households were asked to indicate whether they used an information source 'not at all', 'somewhat' or 'extensively' before obtaining a grade or crossbred animal, and whether the information was 'not at all important', 'somewhat important' or 'very important' to the adoption decision. The most often used, and most important sources of information about the benefits of G/C cattle ownership were extension agents, courses or demonstrations and other households owning G/C cattle (Table 3). These results are consistent with the nature of information flows under NDDP, where extension workers made frequent visits to participating (and presumably non-participating but interested) households. Despite the importance of others with G/C cattle as an information source, only seven of the households reported that another household adopted dairying within a year of the time that they did.

Table 3. *Sources of information about the benefits of grade/crossbred (G/C) cattle ownership and their management before the first animal was acquired.*

Source of information	Benefits		Management	
	Use	Importance	Use	Importance
	(Mean value on a scale of 1 to 3)[1]			
Publications	1.87	1.93	1.60	1.67
Others with G/C cattle	2.20	2.27	2.07	2.40
Farmers' groups	1.87	1.73	1.80	1.80
Salesmen	1.20	1.13	1.13	1.13
Extension agents	2.60	2.60	2.80	2.93
Course or demonstration	2.20	2.00	2.00	2.13
Other source	1.50	1.57	1.43	1.36

1. Values are the means of 15 responses based on the following scales:
   For 'Use of source': 1 = not at all, 2 = some, 3 = extensively.
   For 'Importance of source': 1 = not at all, 2 = some, 3 = extremely.

Information about the management of G/C animals came primarily from the same sources, although the importance of management information from others with G/C cattle surpassed that of information from courses or demonstrations. These results indicate that information used by farmers to make the adoption decision was sought primarily from two distinct sources: government (or project) sources and neighbours already owning grade or crossbred cattle. Other sources, such as farmers' groups, publications or salesmen were less important to the adoption decision.

Reasons for adoption

The Detailed Survey also sought to understand the motivations for the adoption decision, recognising that these may differ depending on whether a female or male G/C animal is acquired first. Households were asked to indicate reasons for their adoption decision, and then whether the reason was 'not at all important', 'somewhat important' or 'very impor- tant' to their adoption decision. The most important reason indicated by households that acquired cows or heifers was their desire for some or more milk for sale (Table 4).

Table 4. *Importance of reasons for adoption decision.*

Reason for adoption decision	Importance (Mean value on a scale of 1 to 3)[1]
For female animals (N=15)	
More milk for family consumption	2.67
More milk for sale (higher income)	2.93
More milk for sale (income more regular)	2.93
Prestige of owning G/C[2] cow	1.40
Others said it was a good idea	1.50
'Other responses'	
To have manure (N=2)	2.00
Money for school fees (N=1)	3.00
Farmer was formerly an extension worker (N=1)	2.00
Biogas (N=1)	3.00
High demand for milk in hotels (N=1)	3.00
For male animals (N=1)	
Crossbreeding with household's local cows	3.00
To offer breeding services to other dairy farmers	3.00
Prestige of owning a crossbred bull	1.00
Others said it was a good idea	2.00
'Other responses'	
Save on expense for artificial insemination (N=1)	3.00

1. Values above are the means of 15 responses based on the following scale:
'Importance to adoption decision': 1 = not at all important, 2 = somewhat important, 3 = very important.
2. G/C = grade or crossbred.

Households wanted to sell more milk to have a higher and more regular income. More milk for family consumption was also an important reason for acquiring a female G/C animal. The prestige of owning a G/C cow and suggestions from others that G/C ownership was a good idea were relatively unimportant. Reasons not suggested by all households included manure production, money for school fees (income related) and personal preferences.

Only one household had first acquired a G/C bull, so the responses must be interpreted cautiously. The major reasons for acquiring a bull were for cross-breeding with the household's local cows (to upgrade the herds milk production potential) and to offer breeding services to other farmers. Saving money previously used for artificial insemination was also a strong motivation for acquiring a G/C bull.

Perceptions of risks before and after adoption

Risk of losing an animal due to disease has been identified as constraining the adoption of smallholder dairy production in coastal Kenya (Maloo et al 1994). Thus, the Detailed Survey asked households to subjectively assess the risks associated with ownership of G/C animals, including the risk of death due to disease. Because perceptions of risk may change as more experience with G/C animals is gained, households were asked to assess risks before adoption and based on their experiences after adoption. Risks important before adoption indicate opportunities to increase adoption by providing information to potential adopters, and risks important after adoption indicate areas to improve the contribution of G/C animals to household welfare. Households were asked to indicate sources of risk in dairying with G/C cattle, and then indicate whether this risk was 'not at all likely to occur', 'somewhat likely to occur' or 'very likely to occur'.

Loss of an animal due to disease was the most important of the risks mentioned by all adopting households, both before and after adoption (Table 5). The assessment of the risk of losing an animal to disease increased somewhat after adoption. Of the other risks mentioned by all households, 'much more work for the household' and 'changes to household routine' were close to disease risk in prevalence. The perceived likelihood of these risks decreased somewhat after adoption, however. The perceived risk of providing the G/C animal with enough feed increased after adoption, but the perceived risk of not being able to sell milk decreased with experience. Other reasons not mentioned by all households included the risk of theft, the possibility of the G/C animal being killed by wildlife and reduced ability of the household to move around.

Table 5. *Perceptions of risk before and after adoption of the first grade or crossbred animal.*

Event or outcome	How likely to occur before adoption	How likely to occur after adoption	Difference before and after adoption
	(Mean on a scale of 1 to 3)[1]		
Loss of G/C animal due to disease	2.27	2.33	0.06
Losing money even if animal survives	1.47	1.47	0.00
Insufficient feed for animal	1.27	1.60	0.33
Could not find a place to sell milk	1.47	1.07	–0.40
Much more work for the household	2.00	1.87	–0.13
Changes the routine of the household	2.20	2.07	–0.13
'Other responses'			
Theft (N=2)	2.50	2.50	0.00
Trypanosomosis (N=1)	3.00	2.00	–1.00
Killed by wildlife (N=1)	2.00	1.00	–1.00
Can no longer move about easily (N=1)	2.00	2.00	0.00

1. Values above are the means of 15 responses based on the following scale:
'How likely to occur?': 1 = not at all likely, 2 = somewhat likely, 3 = very likely.

Reasons for not adopting G/C cattle

Fourteen of the households interviewed for the Detailed Survey had never owned G/C animals. Eleven of those said they had wanted to acquire a G/C animal at some time, but had not done so. Thus, many non-adopting households consider ownership of G/C cattle beneficial but were prevented from adopting dairying for some reason. The principal reason for non-adoption was lack of money to purchase the animal, mentioned by eight households. These eight households indicated that lack of credit and inability to participate in a development project (such as NDDP) were 'somewhat important' in their decision not to adopt, given that they had insufficient cash to buy a G/C animal. Other reasons offered by three of the eight households included 'children need schooling', 'insufficient land' and 'disease risk', which indicate that income, access to resources and risk factors also influenced their decision not to adopt. Of the three households who said they had sufficient money, the lack of animals available for purchase was 'somewhat important' as a reason for not owning a G/C animal. No money for cattle housing, and disagreement in the household about the wisdom of owning a G/C animal also played a role in non-adoption by households with sufficient money. Other reasons, such as a lack of information on how to manage animals, insufficient land and shortage of labour were mentioned as less important reasons for not purchasing G/C cattle.

Three households said that they had never wanted to acquire a G/C animal. The three households indicated that they had considered G/C cattle ownership, and thought it profitable and not overly risky. They did not believe that selling the milk would be problematic. The most important reasons for not wanting to acquire G/C cattle were the perception that ownership results in additional work and management complexity. For these households, the need to devote time to other agricultural and non-agricultural enterprises was 'somewhat important' in their lack of interest in G/C cattle ownership.

Econometric analyses of factors affecting adoption

Econometric models are often used to relate the adoption decision to household and technological characteristics. When the outcome to be modelled is a binary choice (e.g. adopt versus do not adopt a technology) standard linear regression models have shortcomings that are typically overcome by using probit or logit models. These models relate household and technological characteristics to the probability that a household will adopt a technology. Typically, factors included in the model are exogenous (i.e. currently taken as given by the household) rather than factors that the household can influence through its current choices. The models provide empirical estimates of how changes in these exogenous variables influence the probability of adoption, and have been widely used to assess the effectiveness of projects to promote technology adoption

(Rahm and Huffman 1984; Nkonya et al 1997). A brief technical discussion of the probit model is given in Appendix 2.

In general, a broad range of factors is hypothesised to influence the adoption of agricultural technologies (Feder et al 1985). The Adoption Survey collected detailed information from 202 households on location, characteristics of the household head and sources of information used by the household farm manager to make decisions about the choice of agricultural technologies (Table 6). The survey also included information about the characteristics of the household, perceptions about the availability of the G/C animals, availability of seeds and planting materials for Napier grass, and access to ECF immunisation. Households were also asked their perceptions about the accessibility of the inputs and services, such as concentrate feeds, artificial insemination and extension and veterinary services associated with the three technologies.

Table 6. *Variables in econometric models of adoption and impact.*

	Mean value of variable		
Variables	Adopters	Non-adopters	Overall
Dependent variables			
Ownership of grade or crossbred cow (1 = Yes, 0 = No)	1	0	0.36
Currently grow Napier grass (1 = Yes, 0 = No)	0.64	0.09	0.28
Have used ECF immunisation (1 = Yes, 0 = No)	0.33	0	0.12
Number of grade or crossbred animals per household	5.06	0	1.8
Acres of Napier grass currently planted	0.93	0.05	0.36
Agricultural income (KSh/month)	10,468	1,534	4,200
Non-agricultural income (KSh/month)	10,353	3,391	5,515
Number of permanent labourers employed per household	1.51	0.22	0.68
Independent variables			
Locational variables			
Kilifi District dummy (Kilifi = 1, Other = 0)	0.29	0.57	0.39
Malindi District dummy (Malindi = 1, Other = 0)	0.23	0.24	0.23
Agro-ecozone dummy (CL3 = 1, Other = 0)	0.75	0.46	0.64
Characteristics of the household head			
Education of household head, years	6.54	4.66	5.34
Ethnic group dummy (Migrants = 1, Coast = 0)	0.24	0.32	0.27
Religion dummy (Organised = 1 , Traditional = 0)	0.93	0.85	0.88
Sex of household head (1 = Male, 0 = Female)	0.75	0.68	0.7
Age of household head (years)	46.42	48.55	47.78
Is farm owner the household head? (1 = Yes, 0 = No)	0.83	0.82	0.83
Is farm owner the farm manager? (1 = Yes, 0 = No)	0.66	0.69	0.68

cont...

Table 6 cont...

Variables	Mean value of variable		
	Adopters	Non-adopters	Overall
Information sources			
Listen to or watch agricultural programmes on radio or TV? (1 = Frequently, 0 = Rarely)	0.72	0.52	0.59
How often sought advice on farming in last month from:			
Friends, relatives, or neighbours (1=Frequently, 0=Rarely)	0.47	0.43	0.45
Other farmers (1 = Frequently, 0 = Rarely)	0.61	0.38	0.47
Farmers' group (1 = Frequently, 0 = Rarely)	0.39	0.25	0.3
Salesmen (1 = Frequently, 0 = Rarely)	0.24	0.08	0.13
How often visit a town, city, or market? (1 = Frequently, 0 = Rarely)	0.83	0.6	0.68
Do you learn about new agricultural practices from:			
Publications (printed material) (1 = Yes, 0 = No)	0.33	0.22	0.26
Seeing neighbours or friends (1 = Yes, 0 = No)	0.64	0.57	0.59
Talking to neighbours (1 = Yes, 0 = No)	0.51	0.62	0.58
Salesmen (1 = Yes, 0 = No)	0.35	0.15	0.22
Own family (1 = Yes, 0 = No)	0.51	0.47	0.49
Attendance at a course (1 = Yes, 0 = No)	0.57	0.34	0.42
Extension agents (1 = Yes, 0 = No)	0.83	0.69	0.74
Educational tours (1 = Yes, 0 = No)	0.54	0.26	0.36
Characteristics of the household			
Number of household members	10.68	9.07	9.65
Land tenure type (1 = Title deed, 0 = Traditional)	0.9	0.83	0.85
Land area farmed (acres)	14.26	11.1	12.23
Distance to an all-weather road (km)	3.59	6.17	5.26
Distance to nearest market or trading centre (km)	7.61	9.98	9.14
Remittance income (KSh/month)	300	463	414
Total number of local cattle owned	2.19	2.64	2.48
Member of NDDP (1 = Yes, 0 = No)	0.51	0.04	0.21
Farmer perceptions of accessibility of inputs, services and technology			
Veterinary services available in your area? (1 = Yes, 0 = No)	0.97	0.95	0.96
Extension services available in your area? (1 = Yes, 0 = No)	0.96	0.88	0.91
Easy to obtain grade or crossbred cows? (1 = Yes, 0 = No)	0.47	0.43	0.45
Easy to obtain fodder seeds or materials (1 = Yes, 0 = No)	0.85	0.85	0.85
Is vaccinating against ECF within your means (1 = Yes, 0 = No)	0.86	0.44	0.6

These variables were used to estimate probit models for the adoption of G/C cattle, Napier grass and ECF immunisation. The results of the probit model estimations (Table 7) are reported as the marginal effects of a change in the exogenous variable, that is, the change in the probability of adoption due to a one unit change in the exogenous variable. In the case of dummy (i.e. 0 or 1) variables such as sex of the household head, the marginal effect is the difference in probability due to belonging to one group rather than another (e.g. female household heads versus male household heads). For continuous variables such as the amount of land farmed, the marginal effect is the change in probability due to an increase of one acre in area farmed. The impact of other discrete and continuous exogenous variables can be interpreted analogously. The magnitude, statistical significance and the signs (i.e. positive or negative influence on probability of adoption) of the marginal effects are typically of most interest in evaluating the factors influencing the probability of adoption. The adequacy of the probit model to explain adoption is evaluated by the Log Ratio Index (LRI), an indicator of how much of the variance in adoption decisions is explained by the model. In addition, the percentage of correct predictions by the model about which households adopt the technology indicates explanatory power (typically, a household is assumed to adopt if the probability predicted by the model is greater than 0.5).

Table 7. *Results of probit models for adoption of grade or crossbred (G/C) cattle, Napier grass, and East Coast fever (ECF) immunisation (marginal effects).*

Independent variable	Dependent variable		
	G/C cattle	Napier grass	ECF immunisation
Locational variables			
Kilifi District dummy (Kilifi = 1, Other = 0)	0.607***	0.248**	0.029
Malindi District dummy (Malindi = 1, Other = 0)	0.594**	0.312**	0.013
Agro-ecozone dummy (CL3 = 1, Other = 0)	–0.343**	0.037	–0.03
Characteristics of the household head			
Education of household head (years)	0.008	–0.01	0
Ethnic group dummy (Migrants = 1, Coast = 0)	0.45**	–0.002	–0.001
Religion dummy (Organised = 1, Traditional = 0)	0.312	0.116	–
Sex of household head (1 = Male, 0 = Female)	–0.018	–0.029	–0.03
Age of household head (years)	–0.014**	–0.008**	–0.001
Is farm owner the household head? (1 = Yes, 0 = No)	0.1	0.106	–
Is farm owner the farm manager? (1 = Yes, 0 = No)	–0.065	–0.007	0.054
Information sources			
Listen to or watch agricultural programmes on radio or TV? (1 = Frequently, 0 = Rarely)	0.222	0.122*	–0.024
How often sought advice on farming in last month from:			
Friends, relatives, or neighbours (1 = Frequently, 0 = Rarely)	–0.052	–0.095	0.022
Other farmers (1 = Frequently, 0 = Rarely)	0.2	–0.027	0.027
Farmers' group (1 = Frequently, 0 = Rarely)	0.198	–0.022	–0.002
Salesmen (1 = Frequently, 0 = Rarely)	–0.031	0.004	0.018
How often visit a town, city, or market? (1 = Frequently, 0 = Rarely)	0.142	0.06	0.016

cont...

Table 7 cont...

Independent variable	Dependent variable		
	G/C cattle	Napier grass	ECF immunisation
Do you learn about new agricultural practices from:			
Publications (printed material) (1 = Yes, 0 = No)	–0.206	–0.006	0.024
Seeing neighbours or friends (1 = Yes, 0 = No)	–0.097	0	–0.045
Talking to neighbours (1 = Yes, 0 = No)	–0.162	–0.041	0.013
Salesmen (1 = Yes, 0 = No)	0.303	0.078	0.023
Own family (1 = Yes, 0 = No)	0.214	0.216**	0.028
Attendance at a course (1 = Yes, 0 = No)	0.171	0.039	–0.011
Extension agents (1 = Yes, 0 = No)	–0.006	0.054	–0.02
Educational tours (1 = Yes, 0 = No)	0.105	0.042	–0.013
Characteristics of the household			
Number of household members	0.019*	–0.027***	0.002
Land tenure type (1 = Title deed, 0 = Traditional)	–0.236	–0.052	–0.019
Land area farmed (acres)	0.012*	0.003	0
Distance to an all-weather road (km)	–0.015	0.001	–0.002
Distance to nearest market or trading centre (km)	0	0.001	0
Total number of local cattle owned	–0.01	0	0
Member of NDDP (1 = Yes, 0 = No)	0.758***	0.449***	0.033
Farmer perceptions of accessibility of inputs, services and technology			
Veterinary services available in your area? (1 = Yes, 0 = No)	–0.519**	–0.231*	–
Extension services available in your area? (1 = Yes, 0 = No)	–0.047	–0.019	–
Easy to obtain G/C cows? (1 = Yes, 0 = No)	–0.243*	–	–
Easy to obtain fodder seeds or materials (1 = Yes, 0 = No)	–	0.038	–
Is vaccinating against ECF within your means (1 = Yes, 0 = No)	–	–	–0.017
Indicators of model performance			
Adjusted R-squared, OLS	0.487	0.477	0.147
Number of observations	170	172	169
Log likelihood, model (LOGLM)	–46.921	–42.43	–34.87
Log likelihood, restricted (LOGLR)	–113.55	–101.837	–57.317
LRI = 1-(LOGLM/LOGLR)	0.587	0.583	0.392
% correct, model (p>0.50 implies value = 1)	87.10	88.40	91.70
% correct, naïve model assuming all non-adopters	61.20	72.10	89.30
% difference between model and naïve model	25.90	16.30	2.40

Statistical significance of regression coefficients is as follows: *** = p>0.01; ** = p>0.05; * = p>0.10.

The factors with a statistically significant influence on the adoption of G/C cattle are location (district and agro-ecozone), ethnic group, age of the household head, number of household members, land area farmed, participation in NDDP, perceived availability of veterinary services in the household's area and perceived availability of G/C cows for purchase (Table 7). Households in Malindi and Kilifi districts were more likely to adopt G/C animals than their counterparts in Kwale District. Households in the higher-rainfall climate zone (Coastal Lowland 3; see Figure 1) are less likely to adopt G/C animals, perhaps because the higher agricultural potential of this zone allows greater flexibility in the choice of agricultural enterprises, of which dairying is but one. Migrants to the coastal region from other areas of Kenya had a higher probability of adopting G/C cattle, probably due to greater exposure to the technology in Kenya's highlands, from where many of the migrants originated. As the age of the household head increased, the probability of adoption decreased. Although the effect is small for one year (about a 1% decrease in probability), a difference of 20 years would imply a decrease in the probability of adoption by more than 28%. The reasons for this decrease with age (which is also a proxy for years of farming experience) are not clear, although some previous studies have reported that older farmers may be more reluctant to adopt new technologies or practices (Feder et al 1985). The total number of household members was used as a proxy for labour availability in the model (this may overstate labour availability if many household members are very young children or elderly people). Labour availability should be positively associated with G/C adoption because G/C animals require more time for care and feeding than local cattle. The total number of household members is significantly and positively associated with G/C adoption. The probability of adoption increased as land farmed increased, although the effect of an additional acre of land was relatively small (1.2%). This seems to indicate that the amount of land does not markedly constrain farmers wishing to adopt G/C animals.

Participation in NDDP considerably increased the probability of adoption, as might be expected. (This is the case although only 51% of G/C adopters in the sample had participated in NDDP.) The strong relationship between adoption and participation in NDDP indicates that the project was effective in involving at least a subset of coastal households in dairying. The availability of veterinary services and perceived availability of G/C animals for purchase should be expected to increase the probability of adoption. However, the signs of these coefficients indicate that increasing availability is associated with a *decrease* in the probability of adoption. This counter-intuitive result is probably due to the fact that adopters were surveyed after the adoption decision, and thus may be more aware of the difficulties of obtaining veterinary services and G/C animals than non-adopters are.

The probit model results also provide information about factors that do not appear strongly associated with adoption of G/C cattle. Among these factors are the household head's years of education, sex of the household head, ownership of the farm, and whether the owner manages the farm. The relatively small and statistically insignificant effects of these variables support the hypothesis that diverse types of households (not just highly educated male-headed households, for example) can adopt G/C cattle. None of the variables representing frequency of use or sources of information significantly affected the adoption of G/C animals, although the reported coefficients for listening to or watching agricultural programmes and seeking advice from other farmers have a positive effect on the probability of adoption greater than 20%. This implies that the design of educational programmes to support adoption of G/C animals could benefit from further study of what types of information are most used and positively regarded by farmers. The lack of a statistically significant relationship between distance to roads and markets and adoption likely indicates the strong demand for milk in local communities in the coast region. As a result, access to more formal marketing channels may not constrain the ability of households to sell milk produced by G/C animals, at least at current levels of production per household.

The results of the probit model for adoption of Napier grass are similar to those for G/C cattle. District of residence, age of the household head, number of household members, participation in NDDP and perceived availability of veterinary services significantly affect both G/C cattle and Napier grass adoption. The magnitudes of the marginal effects tend to be smaller for the adoption of Napier grass than for G/C, and for the number of household members the sign of the coefficient is different. The negative effect of household members on the planting of Napier grass may be related to the labour required for herding cattle. Households in the coastal area often use tethering and grazing as an alternative source of feed for cattle (Swallow 1998). Because grazing and tethering tend to require labour, their use may be more appropriate (and therefore more common) for households with more labour available. Irungu et al (1998) also reported a negative (but statistically insignificant) relationship between family labour and the decision to adopt Napier grass in Kiambu District in the Kenyan highlands.

In contrast to the G/C adoption decision, information from agricultural programmes on radio or TV and learning about new practices from other family members was positively associated with adoption of Napier grass. In addition, the agro-ecozone and land area farmed by the household had no statistically significant influence on planting of Napier grass. For 365 farm households in the Kenyan highlands, Irungu et al (1998) also reported no significant relationship between the probability of Napier grass adoption and land area. The lack of a strong relationship between adoption and location or land area farmed provides evidence that Napier grass is appropriate for various locations or farm types in coastal Kenya. However, because this analysis considers only whether farms planted Napier grass, and not how much was planted or produced; further information would be necessary for a more thorough examination of the appropriate locations and situations for Napier grass use.

The adoption of G/C dairy animals and the planting of Napier grass are likely to be related, in part because of the role that NDDP played in promoting them as complementary technologies. To examine the hypothesis that the adoption of G/C animals and Napier grass are not independent decisions, a bivariate probit model was estimated. The bivariate probit model estimates the correlation between error terms in two probit equations, in this case the equations for adoption of G/C cattle and Napier grass. The two equations use the same variables as those in probit models for the individual technologies (Tables 6 and 7). The magnitude and significance of the correlation term indicate the strength of the association between the adoption for the two technologies. The correlation coefficient between G/C and Napier grass adoption was 0.95, and was statistically significant at the $p<0.001$ level (full model results not shown). Thus, the decision to adopt G/C is strongly related to the decision to adopt Napier grass. Although this result is not surprising, it does indicate the role that NDDP played in dairy development in the region. It also suggests that future efforts to promote dairy adoption should pay attention to the provision of fodder for the higher-producing G/C cows.

The results of the probit models for the use of ECF immunisation indicate that none of the exogenous variables hypothesised to influence adoption behaviour is statistically significant. In contrast to the models of G/C adoption and Napier grass use, the explanatory power of the ECF immunisation model is limited. The LRI is lower, and model predictions of whether a household will adopt are little improvement over the naïve prediction that no households will use the ECF immunisation. This lower predictive power of the model in part reflects the nature of the data: there are relatively few adopters of ECF immunisation, and so there is less information available to the statistical procedure for determination of the factors influencing adoption (Greene 1993). More importantly, the results support the observation that use of the infection and treatment method is limited by institutional factors. The manufacture and distribution of the components of the immunisation has been constrained by uncertainties over the responsibilities of the government institutions involved. The lower predictive ability of the model indicates that factors other than those typically associated with adoption appear to play a major role in determining which producers have access to the immunisation. Further research into current and potential distribution systems to provide smallholders with ECF immunisation is currently underway at ILRI in collaboration with KARI.

In addition to assessing the factors that influence the probability of adoption of a particular technology, an understanding of the factors influencing the extent of adoption (sometimes referred to as 'adoption intensity') is also useful. As in the case of the adoption decision, economists often use econometric models to relate the extent of adoption to various exogenous factors. In the case of G/C cattle, the extent of adoption refers to the number of G/C animals owned. For Napier grass, the number of acres planted is an indicator of the extent of adoption. Future analyses with the data from the Impact Survey will be used to assess the influence of various factors on the extent of adoption.

5 Results of the impact surveys

The study explored both the impacts perceived by adopting households and more measurable impacts based on comparison of adopting and non-adopting households. The Detailed Survey asked households to discuss the impacts of owning G/C cattle and to state which impacts they viewed as most important. The Adoption Survey provides indicators of the impacts of G/C adoption on the income of smallholder households, the number of hired labourers employed and the nutritional status of pre-school aged children. Although these three impacts are but a small subset of the potential impacts that could be examined, they are among the impacts of adoption cited most frequently by households. The impacts are also of interest to organisations involved in dairy development efforts.

Impacts reported by adopting households

The Detailed Survey asked households who had owned a G/C animal at some time to describe the impacts they perceived as a result of adoption. This approach is similar to that taken by most previous studies of the impacts of adoption of dairying in Kenya, such as Price Waterhouse (1990), Ratula (1994) and Mullins et al (1996). The responses provide indications of how households perceive the impacts of dairy adoption, and can complement studies where indicators of impacts are defined by researchers and measured more objectively. The 15 adopting households were asked to specify the impacts of adopting G/C cattle, to discuss them in some detail, and then to rank the impacts according to their importance to the household. Fourteen of the adopting households responded, and 13 of them indicated that the increased milk consumption by some members of the household was an impact of G/C cattle ownership (Table 8). Twelve of the households reported that they sold more milk, that they had higher incomes as a result and that household income was more regular than before adoption. Thus, the most commonly reported impacts relate to the consumption and sale of milk, as might be expected.

Other impacts reported by the households included hiring of more permanent labourers (11 households), substantial changes to routine household activities (10 households) and better health due to increased milk consumption by household members, especially children (10 households). Less than half of the households indicated that adoption of G/C animals resulted in changes in their cropping patterns, in the hiring of more casual labourers or in increased workloads for household members. The households' rankings of impacts by their importance mirror the number of households reporting the impacts: increased milk consumption is most important, followed by increased milk sales and higher incomes.

Table 8. *Impacts of dairy adoption as reported by adopting households.*

Impact	Households reporting this impact (%)	Comments (Number of households indicating)
Some household members consume more milk	93	All household members (7) Children (3) Household head (1) Hired labourers (1)
Household sells more milk	86	'Sell all surplus milk' (1)
Household income is higher	86	'Higher due to milk sales' (1)
Household income is more regular	86	–
Household hires more permanent labourers	79	General dairy work (7) Herding (2) Weeding (1) Cutting grass (1) Cleaning cow shed (1)
Routine household activities have changed a lot	64	Workload increased (3) Work activities are different (2) 'Someone must care for animals'(2) 'Must supervise labourers' (1) 'Must wake up earlier to milk' (1)
Household members are ill less often	64	Consume more milk (5) Nutrition of children improved (3)
Household plants less of some crops	43	Maize (4) Cowpea (2) Cassava (1) Vegetables (1) Citrus (1)
Household plants more of some crops	36	Maize (3) Napier grass (1) Cowpea (1) Banana (1)
Household hires more casual labourers	36	Construction of cattle housing (2) Weeding (1)
Men in the household work more	36	Milking (2) Feeding (2) Herding (1) Selling milk (1)
Women in the household work more	29	Watering (1) Feeding (1) Herding (1) Herding (1) Cutting and carrying grass (1)
Children in the household work more	21	Cattle care (1) Feeding (1) Herding (1)

Values above are for 14 responding households which have owned grade or crossbred dairy cattle at some time.

Impact on household income

The data from 202 households responding to the Adoption Survey allow the impacts of income and hired labour indicated by the households in the Detailed Survey to be examined. One way of comparing outcomes is to examine means and distributions of income and number of hired labourers for adopters and non-adopters. Although this provides a starting point for assessing impacts, a limitation of this approach is controlling for factors other than ownership of G/C cattle that may influence observed outcomes. If factors other than G/C cattle ownership influence the outcomes, attributing differences in variables such as income to adoption alone may prove misleading. If, for example, adopters tend to have more and better land, more off-farm employment and higher incomes than non-adopters do, some of the difference in incomes is undoubtedly due to ownership of more land resources and more income from activities other than agriculture. The impacts of G/C adoption are related to, and confounded with, these other factors. Thus, comparisons of adopting and non-adopting households that do not control for these factors should be viewed as indicative rather than definitive measures of impact. Multivariate econometric analyses (to be discussed subsequently) can help to control for the confounding factors, and thus provide additional insights about the impacts of adoption.

With these caveats in mind, the percentage of households with income from various activities differed for adopters and non-adopters (Table 9). Not surprisingly, 87% of adopting households reported cash income from dairying during the past month. (The remaining adopters did not report cash income from milk sales either because their G/C cows were not lactating during the past month or because all milk produced was consumed at home.) Fourteen per cent of households with local cattle reported cash income from dairying, reflecting shorter lactation lengths and less milk available for sale after household consumption needs are met. About three-quarters of both adopting and non-adopting households received income from crop sales, despite the lack of food self-sufficiency previously reported for households in coastal Kenya (Leegwater et al 1991). Two-thirds of all three groups of households received cash income from non-farm activities (wages, salaries or non-farm enterprises), consistent with the assertions of Waaijenberg (1994) that diversification into non-farm activities is a rational survival strategy for smallholder households in the region. Other sources of cash income, such as poultry production, remittances or 'other' were received by less than half of all households.

Average cash income per month received from dairying was much higher for adopting households than non-adopting households (Table 9), although some non-adopting households have some income from sales of milk produced by local cows. Differences in cash income from dairying accounted for more than 40% of the difference in total mean cash income between adopters and non-adopters. The largest number of adopting households earned between KSh 1000 and KSh 5000 per month from dairying, and nearly one-quarter of adopters had cash income from dairying

Table 9. *Reported cash income by type of income and adoption status.*

Income type	No cattle	Local cattle only	Own grade or crossbred	Percentage of the difference between adopters and non-adopters[2]
Percentage of households with cash income from:				
Dairying	0	14	87	
Poultry or eggs	9	8	14	
Crops	75	80	73	
Wages, salaries, or non-farm activities	65	66	65	
Remittances	39	35	22	
Other income	13	25	18	
Cash income from:				
Dairying (KSh/mo)[1]				
Mean	0[ac]	321[ab]	6,809[bc]	
(s.d.)	–	(1,211)	(7,836)	42
Poultry or eggs (KSh/mo)[1]				
Mean	651	267	1,964	9
(s.d.)	(3,261)	(1,682)	(8,687)	
Crops (KSh/mo)[1]				
Mean	744[c]	1,236	1,628[c]	4
(s.d.)	(991)	(2,242)	(2,967)	
Wages, salaries, or non-farm activities (KSh/mo)[1]				
Mean	2,645[c]	3,018[b]	9,258[bc]	41
(s.d.)	(5,585)	(4,169)	(17,079)	
Remittances (KSh/mo)[1]				
Mean	452	482	300	−1
(s.d.)	(965)	(902)	(852)	
Other income (KSh/mo)[1]				
Mean	141	146	795	4
(s.d.)	(823)	(350)	(4,115)	
Total income (KSh/mo)[1]				
Mean	4,667[c]	5,439[b]	20,912[bc]	100
(s.d.)	(7,280)	(4,444)	(23,761)	

1. In early 1998, KSh 62 = US$ 1.00.
2. Percentage of the difference in mean total income between adopters (households with at least one G/C animal) and non-adopters (households owning no G/C animals) due to a difference in a particular income source.

The use of 'a', 'b', and 'c' indicates that the means for the two adoption categories with the same letter are statistically significantly different at the 95% confidence level.

greater than KSh 10,000 per month (Figure 3). Adopting households' perceptions of increases in income due to adoption of G/C animals are thus supported by the large differences in cash incomes from dairying reported by adopters and non-adopters. For adopting households, dairy income constitutes more than one-third of total cash income, whereas for non-adopting households dairy income is less than 3% of total cash income.

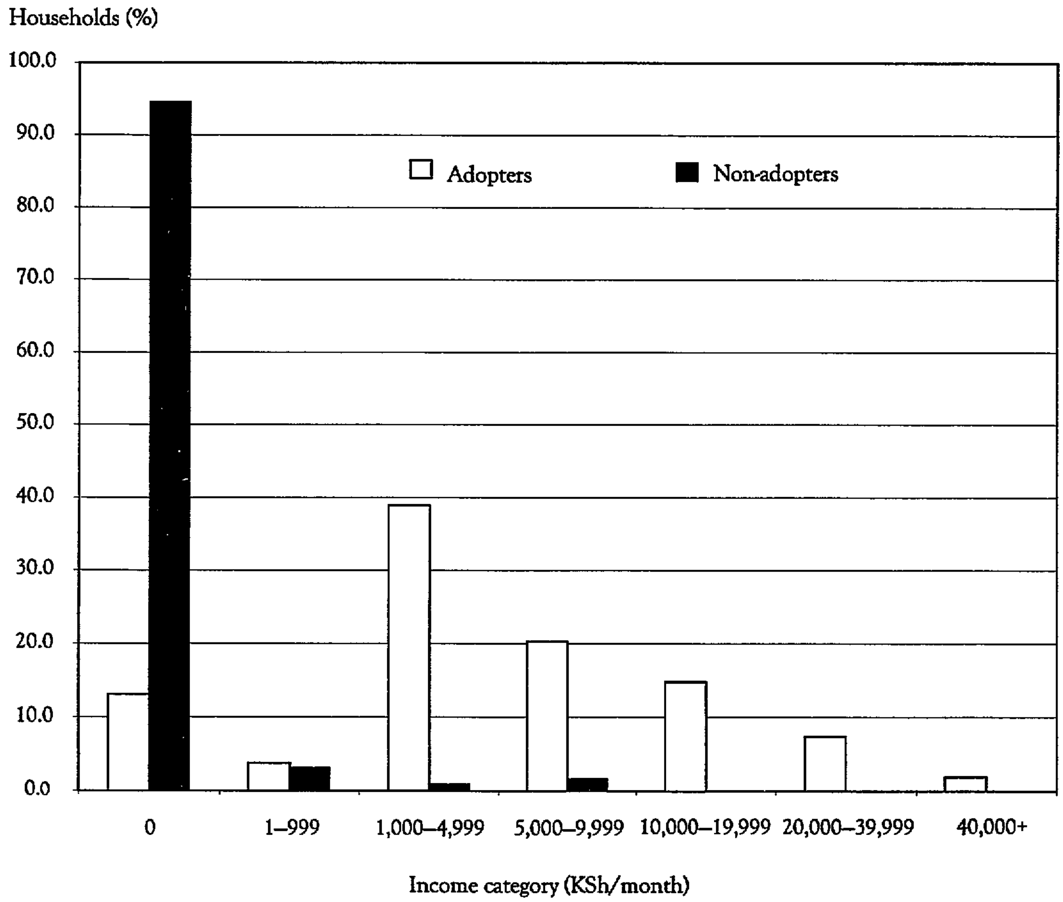

Figure 3. *Dairy income distribution by adoption status.*

Adopting households had higher mean cash incomes from all other sources except remittances, although the differences were statistically significant only for wages, salaries and other non-farm activities. Total incomes were four times as high for adopters than for non-adopters, and the differences between adoption categories were statistically significant at the 95% confidence level (Table 9). Non-farm income was important for all three groups: wages, salaries and non-farm businesses accounted for 44% of total cash income for adopting households, and about 56% of total cash income for households with no cattle or only local cattle. Differences in cash income from wages and salaries accounted for about 40% of the difference in total mean cash income between adopters and non-adopters. The magnitude of wage and salary income indicates the reliance of households in coastal Kenya on non-farm activities. The importance of activities other than farming may make the adoption of agricultural technologies less attractive to the region's households (Waaijenberg 1994). However, additional sources of income may also allow investments in agricultural technologies (such as G/C cows) when these provide sufficient demonstrable benefits to the household or complement the household's current choices of farm and non-farm activities.

The observation that adopting households have higher incomes than non-adopters, and higher income from non-farm employment in particular, has been used to argue that adoption of G/C dairy cattle is accessible only to the relatively wealthy or those with non-farm income sources (Leegwater et al 1991). In contrast, the results from the Adoption Survey indicate that the percentage of adopters is fairly evenly spread across income categories, although a larger proportion of adopting households have incomes that fall into the higher income categories (Figure 4). To examine the importance of income from non-farm sources for the adoption decision, a bivariate probit model for G/C cattle ownership and involvement of the household head in non-farm activities was estimated (results not shown). The correlation coefficient between G/C ownership and non-farm activities was negative and statistically insignificant. This provides evidence that non-farm activities— although undoubtedly important for some households—are not systematically associated with (or are a necessity for) adoption of G/C cattle.

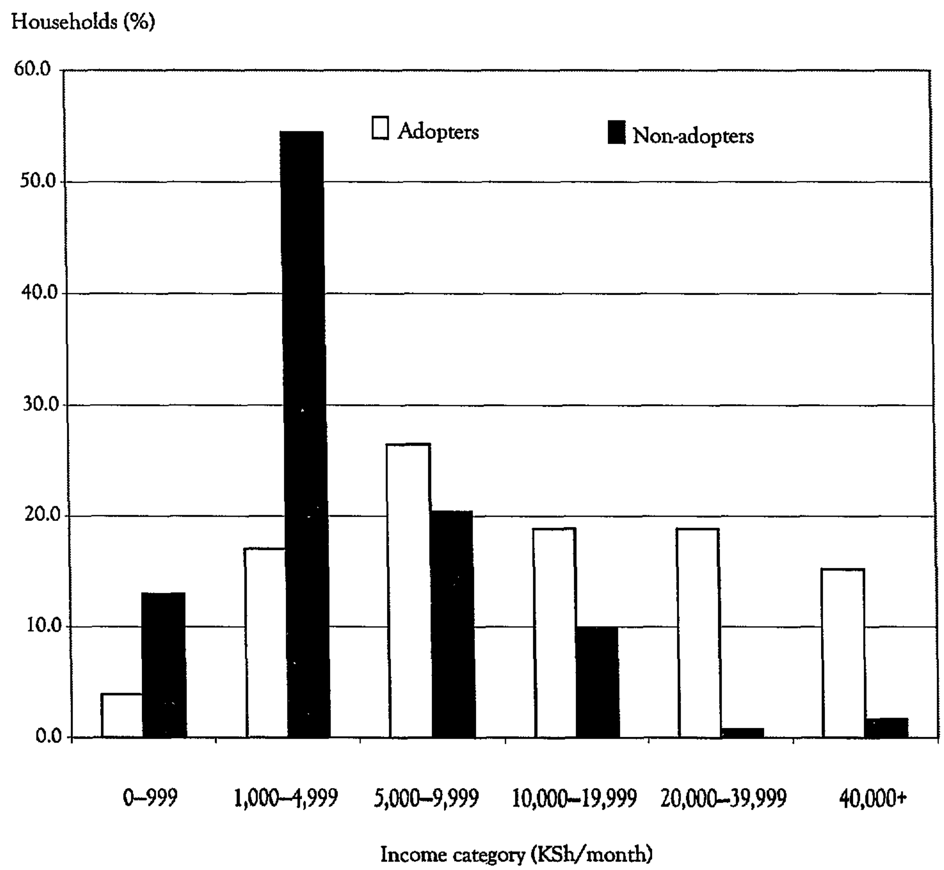

Figure 4. *Total income distribution by adoption status.*

Impacts on the number of hired labourers

Employment generation is another potential impact of adoption, in part because the care and feeding of G/C animals requires more labour. It is common for G/C owners to hire labourers to help with the increased workload; more than three-quarters of households responding to the Detailed Survey indicated that they hired more permanent labour as a result of adopting G/C animals. Hired labourers generally come from the areas surrounding the adopters' farms, and the financial benefits of dairying are thus shared among both owners of G/C animals and others in the local community.

Sixty per cent of the adopting households reported employing at least one permanent labourer compared with 15% of non-adopting households (Table 10). Thus, although only slightly more than half the adopters employed a permanent labourer, they did so much more often than households with no cattle or only local cattle. In contrast, roughly equal numbers of adopting and non-adopting households employed casual labourers. Households with G/C cattle employed between one and two permanent labourers on average, compared with one permanent labourer hired for every five households without G/C cattle. In addition to the number of labourers employed, permanent labourers working for adopting households were paid more per month than permanent labourers employed by households with only local cattle. This may be due in part to more hours worked, but the end result is higher income received by hired labourers employed by adopters. Not all of the employment on adopting household's farms can be attributed to the presence of G/C animals. As noted with income, other factors will influence the number of hired labourers employed; subsequent econometric analyses will examine the influence of the number of G/C animals owned by the household on the number of permanent labourers employed.

Table 10. *Hired labourers by adoption status.*

Hired labour characteristic	No cattle	Local cattle only	Own grade or crossbred cattle
Households with permanent hired labour (%)	9	23	60
Households with casual hired labour (%)	44	37	48
Number of permanent hired labourers per household			
Mean	0.2[c]	0.3[b]	1.5[bc]
(Standard deviation)	(0.6)	(0.7)	(2.3)
Valid observations	78		72
Number of casual hired labourers per household			
Mean	1.6	1	1.9
(Standard deviation)	(2.8)	(1.8)	(4.3)
Valid observations	78	51	71
Pay per month for permanent hired labourers (KSh)[1]			
Mean	1,067	730[b]	1,335[b]
(Standard deviation)	(459)	(377)	(674)
Valid observations	6	10	43
Pay per day for casual hired labourer (KSh)[1]			
Mean	92	96	88
(Standard deviation)	(59)	(51)	(54)
Valid observations	35	18	36

1. In early 1998, KSh 62 = US$ 1.00.

The use of 'a', 'b', and 'c' indicates that the means for the two adoption categories with the same letter are statistically significantly different at the 95% confidence level.

Impacts on household nutritional status

Dairy development efforts are often justified using the assumption that higher milk production will increase household milk consumption. Milk is a significant source of both energy and protein, including many essential amino acids lacking in carbohydrate-based diets (Huss-Ashmore 1992). Milk also contains many essential micronutrients, such as vitamins A and D. Increased milk consumption is therefore assumed to improve nutritional outcomes for households. In addition, to the extent that dairy production increases incomes, households with dairy cattle can afford to purchase more food and a wider variety of foods. This 'income effect' is also expected to contribute to improving the nutritional status in households with G/C cattle. Most studies have long recognised the complexity of the relationship among agricultural production systems, alternative means of generating household income, household food consumption patterns and nutritional status (Low 1991). Because the mechanisms and pathways between production, income and nutritional status are complicated, studies of nutritional outcomes by social scientists have come to rely upon summary indicators of nutritional status rather than direct measures of nutritional status itself (Randolph 1992). These summary measures do not, in and of themselves, elucidate the ways in which nutritional outcomes are determined—this requires additional information on the households' production, consumption, time allocation and morbidity—but they provide a reliable proxy for assessing nutritional status.

Anthropometric measures for children 0 to 59 months of age often are used as indicators of nutritional status for households in societies with significant levels of protein-energy malnutrition (Low 1991; Quinn 1992). Children are measured because they are presumed to be the most vulnerable members of the household, and thus provide a sensitive indicator for the household as a whole. The interpretation of anthropometric measurements is also easier for children than for older members of the household because there are fewer genetic differences among children in different ethnic groups and reproductive status of females can be ignored. The measures typically used include 'weight-for-height' and 'height-for-age'. A low value of weight-for-height indicates that the child is very thin for his or her stature, and thus provides a measure of acute malnutrition (often referred to as 'wasting'). A low value of height-for-age indicates that the child is shorter than one would typically expect for a child of the same age because of the accumulated effect of periods of morbidity and inadequate food intake (often referred to as 'stunting'). The measures are typically converted to z-scores (the number of standard deviations from the mean of a reference population) using the US National Center for Health Statistics (NCHS) growth percentiles as a reference (WHO 1983). Because they are standardised measures, the z-scores can be compared for different age groups and for the two indicators of nutritional status (Quinn 1992).

As a part of the Impact Survey, height and weight measurements for 112 children under the age of five years were collected from the 202 households surveyed. Comparison of the weight-for-height and height-for-age z-scores provides an indicator of the impacts of adoption on the nutritional status of households. As with the income and employment impacts, differences in nutritional status cannot be entirely attributed to the adoption of G/C animals; subsequent econometric analyses (to be reported in a separate document) will assess nutritional outcomes controlling for other variables in addition to G/C cattle ownership.

The mean weight-for-height z-scores do not differ significantly for children in households with no cattle, only local cattle or G/C cattle (Table 11). This indicates that the prevalence of acute malnutrition appears to be little affected by adoption status, consistent with previous studies of the adoption of G/C animals in Ethiopia (Shapiro et al 1998). Consistent with previous studies of nutritional status in coastal Kenya (Leegwater et al 1991) over one-quarter of children measured were at least somewhat acutely malnourished. The percentages of children suffering from different degrees of wasting differed only in that somewhat fewer children were severely malnourished in adopting households (χ^2 test for differences between the distributions for adopters and non-adopters was not significant at the $p = 0.10$ level).

Table 11. *Nutritional status of pre-school children and adoption status.*[1]

Nutritional indicator	No cattle	Local cattle only	Own grade or crossbred
Weight-for-height (indicates wasting)			
Mean z-score	−0.29	−0.52	−0.34
(standard deviation)	(1.01)	(1.4)	(1.17)
Number of children	51	17	40
Percentage of children[2]			
Normal	71	77	80
Mild wasting	28	12	13
Moderate wasting	2	6	0
Severe wasting	0	6	8
Height-for-age (indicates stunting)			
Mean z-score	−2.12[ac]	−1.29[a]	−1.58[c]
(standard deviation)	(1.36)	(1.84)	(1.31)
Number of children	51	25	42
Percentage of children[2]			
Normal	22	28	31
Mild stunting	24	32	33
Moderate stunting	31	32	21
Severe stunting	24	8	14

1. Pre-school children are those 0–59 months of age.
2. Categories of wasting and stunting are based on z-scores, where $z > -1.00$ is normal, $-1.00 > z > -2.00$ is mild malnutrition, $-2.00 > z > -3.00$ is moderate malnutrition, and $z < -3.00$ is severe malnutrition (WHO/Brazzaville, n.d., as cited in Quinn (1992)).

The use of 'a', 'b', and 'c' indicates that the means for the two adoption categories with the same letter are statistically significantly different at the 95% confidence level.

The mean z-score for height-for-age was statistically significantly higher for children in households with cattle than for households with no cattle (Table 11). The mean height-for-age z-score for children in households with only local cattle was higher than for children in households with G/C cattle, but the difference was not statistically significant. The difference between children in households with cattle and those in households without indicates that ownership of cattle—or other factors associated with cattle ownership—may have some impact on chronic malnutrition. Despite the potential nutritional benefits of cattle ownership, more than two-thirds of children in adopting and non-adopting households showed some degree of stunting. Leegwater et al (1991) also observed that stunting was much more common than wasting among households in coastal Kenya. Moderate and severe stunting was more common for children in households without G/C cattle, but χ^2 test for differences between the distributions for adoption categories was not significant at the $p = 0.10$ level. The foregoing descriptive evidence suggests that the ownership of G/C cattle *per se* has limited impact on average household nutritional status.

Econometric analyses of impacts with adoption data

The adoption data can also be used in econometric models to assess selected impacts of the adoption of G/C cattle. As noted previously, households with G/C cattle have higher cash incomes and hire labourers more frequently. Although this descriptive analysis provides an indication of the impacts of adoption, it does not control for other factors that influence the observed outcomes. Econometric models can control for these other factors and thus provide a better indication of the changes in household income and number of hired labourers that can be directly attributed to the number of G/C animals owned. The econometric models used to explore the determinants of household income and the number of hired labourers include the factors that can be considered 'exogenous' by the household (i.e. given for the current time period). Because a substantial proportion of the households report neither cash income nor hired labourers, a censored regression, or Tobit model is appropriate.[1]

In addition to the exogenous variables affecting household income or hired labourers, we wish to examine the effect of an 'endogenous' variable (a variable that the household makes current decisions about), the number of G/C cattle owned. Because the number of G/C cattle owned is endogenous, it is assumed to be determined simultaneously with household income and the number of hired labourers. Thus, to examine the impacts of number of G/C cattle owned on income and labourers in the econometric models, a two-step procedure is used. First, a Tobit model is used to estimate the impact of exogenous' variables on the number of G/C cattle owned.[2] This model assumes that:

G/C cattle owned = f(Household characteristics, Characteristics of the household head, and Information sources used)

Given the exogenous variables for each household and the estimated parameters from the model, the number of G/C animals a household is predicted to own given its characteristics can be calculated. In the second step, this predicted value of the number of G/C cattle owned by the household from this model is used as an independent variable in the

1. The Tobit model accounts for the censored distribution of the error terms due to the zero observations of households without cash income or hired labourers (see Appendix 2 for a brief technical discussion of Tobit models).
2. A Tobit model is appropriate here due to the number of non-adopters, who own no G/C cattle.

Tobit models for household income and hired labourers, which assume that:

Household cash income = f(Household characteristics, Characteristics of the household head, Information sources used, and Predicted number of G/C cattle owned)

and

Hired labourers = f(Household characteristics, Characteristics of the household head, Information sources used, and Predicted number of G/C cattle owned)

The use of the predicted values of G/C cattle owned addresses simultaneity bias, and allows the models to examine questions such as 'What is the effect of an additional G/C cow on household cash income?' or 'How many permanent labourers are hired for each additional G/C cow owned?'

Three econometric models were estimated to examine the impacts of G/C cows on household cash income and hired labourers (Table 12). The number of G/C cows owned by the households was chosen rather than the number of cattle, because cow ownership should be more closely related to income (via increased milk production and sales) and increased demand for labour for cattle care and feeding. In contrast to the models of adoption, the emphasis in these models is on the coefficients for the predicted number of G/C cattle. These coefficients indicate the effect of an additional G/C cow on household income or hired labourers controlling for the other factors exogenous to the household.

Table 12. *Results of Tobit models to assess the impact of grade or crossbred (G/C) animals on household income and hired labourers (marginal effects for adopting households).*

Independent variable	Dependent variables		
	Total cash income	Total hired labourers	Total full-time labourers
Simultaneous variables (predicted value)			
Number of grade or crossbred cows per household	4,046.0***	-0.01	0.08
Locational variables			
Kilifi District dummy (Kilifi = 1, Other = 0)	5,066.1*	1.21**	0.31*
Malindi District dummy (Malindi = 1, Other = 0)	6,106.5*	-	-
Agro-ecozone dummy (CL3 = 1, Other = 0)	3,830.6	1.32	-
Characteristics of the household head			
Education of household head (years)	100.1	–	< 0.01
Ethnic group dummy (Migrants = 1, Coast = 0)	4,564.8*	0.83	0.45***
Religion dummy (Organised = 1, Traditional = 0)	2,055.3	1.45**	0.42
Sex of household head (1 = Male, 0 = Female)	3,557.5	–	0.33**
Age of household head (years)	–110.6	–	< 0.01
Is farm owner the household head? (1 = Yes, 0 = No)	1,013.6	–	0.29
Is farm owner the farm manager? (1 = Yes, 0 = No)	–1,202.4	0.46	–0.38**

cont...

Table 12 cont...

Independent variable	Total cash income	Total hired labourers	Total full-time labourers
	Dependent variables		
Information sources			
Listen to or watch agricultural programmes on radio or TV? (1 = Frequently, 0 = Rarely)	–	1.16***	0.18
How often sought advice on farming in last month from:			
Friends, relatives, or neighbours (1 = Frequently, 0 = Rarely)	–	–	0.04
Other farmers (1 = Frequently, 0 = Rarely)	–	1.04**	0.27*
Farmers' group (1 = Frequently, 0 = Rarely)	–	–	–0.03
Salesmen (1 = Frequently, 0 = Rarely)	–	–	0.24
How often visit a town, city, or market? (1 = Frequently, 0 = Rarely)	–	–	0.38**
Do you learn about new agricultural practices from:			
Publications (printed material) (1 = Yes, 0 = No)	–	–	0.05
Seeing neighbours or friends (1 = Yes, 0 = No)	–	–	0.13
Talking to neighbours (1 = Yes, 0 = No)	–	–	–0.12
Salesmen (1 = Yes, 0 = No)	–	–	–0.29
Own family (1 = Yes, 0 = No)	–	–	–0.21
Attendance at a course (1 = Yes, 0 = No)	–	–	–0.76
Extension agents (1 = Yes, 0 = No)	–	–	–0.55
Educational tours (1 = Yes, 0 = No)	–	–	–0.03
Characteristics of the household			
Number of household members	–161.4	0.05*	0.03***
Land tenure type (1 = Title deed, 0 = Traditional)	3,319.1	–	–0.31*
Land area farmed (acres)	–204.8.4*	0.05**	0.01*
Distance to an all-weather road (km)	–5.9	–0.07	–0.02**
Total number of local cattle owned	59.7	–	–
Member of NDDP (1 = Yes, 0 = No)	–	–0.47	0.10
Model generated parameters			
σ	17.5***	13.4***	9.54***
Indicators of model performance			
Adjusted R-squared, OLS	0.22	0.16	0.32
Number of observations	153	174	167
Log likelihood, model (LOGLM)	–1674.6	–331.5	–156.1

Statistical significance of regression coefficients is as follows: *** = p>0.01; ** = p>0.05; * = p>0.10.

The addition of a G/C cow for the average adopting household in the sample results in an increase in household cash income of over KSh 4000 per month (Table 12). This effect is statistically significant at the 1% level, and its magnitude is nearly equal to the total mean monthly income for households that currently own no G/C cattle (Table 9). Thus, the adoption data provide evidence that adoption increases household incomes by a statistically and practically significant amount in coastal Kenya.

Two models were estimated to examine the impact of the number of G/C cattle owned on the number of total labourers and the number of full-time labourers hired by the household. In both cases, the coefficient for the predicted value of G/C cows owned was small and statistically insignificant. Thus, the number of G/C cows owned by the household appears to have relatively little consistent impact on either total labourers hired or permanent labourers hired. An alternative question is whether ownership of any G/C cows affects the hiring of any labourers. To examine the probability of this, bivariate probit models relating ownership to hired labourers or permanent labourers were estimated (results not shown). These models indicated that the correlation coefficients between ownership and hiring labourers, although positive, were not statistically significant at the 10% level. The limited impact of G/C animals on the number of hired labourers is consistent with the observation that only 60% of adopting households have hired permanent labourers (Table 10). Leegwater et al (1991) found that only half of the households participating in NDDP (and therefore owning G/C cows) had hired labour. Thus, there may be subsets of adopters for whom hired labour is essential, whereas other adopters are able to handle the increased workload without hired assistance. The larger mean number of hired labourers observed for adopting households (Table 10) is due in part to factors other than G/C cow ownership.

6 Summary and conclusions

This study examined the factors associated with adoption of three dairy-related technologies and practices in Coast Province, Kenya: grade or crossbred (G/C) dairy cows, Napier grass production and the infection and treatment method for protection of cattle against East Coast fever. As G/C dairy cattle have higher feed requirements and lower disease resistance than local cattle, these three technologies should be highly complementary. The principal conclusions of the analyses to date are summarised as follows:

- *Adoption of a G/C animal is not a simple one-off binary decision.* Households adopt and de-adopt G/C dairy cattle primarily because of the expense of replacing an old or diseased animal. Grade and crossbred dairy cattle are adopted in the first place primarily because the sale of milk increases and stabilises household income, while allowing household milk consumption to increase. This is in spite of perceived disease, feed supply and milk marketing risks.
- *The probability that a household will adopt a G/C animal depends on location, characteristics of the household head, sources of information and characteristics of the farm.* The probability increases if the household is located in Malindi and Kilifi rather than in Kwale. Migrants to the coast from other areas of Kenya are also more likely to adopt G/C cattle, probably because of previous experience with smallholder dairying in the highland regions of the country. Probability of adoption decreases with increasing age of the household head, but increases with increasing number of household members, presumably related to the increased size of the labour for dairy-related activities. The amount of land available to the household does not apparently constrain adoption of G/C animals. Participation in the National Dairy Development Project (NDDP) increased the probability of adoption, indicating that the project was effective in involving coastal households in dairying. This was at least partially because smallholders in coastal Kenya may experience difficulty in gaining access to money with which to purchase a G/C animal. This problem was reduced at least partially in the past through participation in dairy development projects such as NDDP. Such involvement is clearly reflected in survey analyses, where it is shown that the decision to adopt a G/C animal is strongly associated with the decision to adopt Napier grass, a technology strongly supported by NDDP.
- *Survey results support the notion of the basic substitutability of dairying and other economic activities.* This is consistent with the continuous nature of the adoption decision, the diversity of households that have adopted G/C animals and the fact that households adopt despite perceived disease risks. This substitutability means that keeping a G/C animal is just one activity of many that the household might engage in, as and when conditions within the household are conducive to it. For some households, purchase of a G/C animal does not necessarily involve a long-term commitment to dairy production. If the household has sufficient cash, then dairying clearly can be profitable, even on the Kenyan coast, but it takes management input.

- *Adoption of dairy increases household incomes.* Adopting households' perceptions of increases in income due to adoption of G/C cattle are supported by the large differences in cash incomes from dairying reported by adopters and non-adopters (one-third of total cash income for adopters versus less than 3% for non-adopting households). Dairy income comprised the largest part of the difference in total cash incomes between adopting and non-adopting households. The observed differences in total incomes between adopting and non-adopting households are supported by econometric evidence that each G/C animal owned by an adopting household increases income by KSh 4000 per month—an amount nearly equal to mean total incomes reported by non-adopting households. Thus, the adoption of G/C cattle has the potential to markedly increase total household incomes for smallholder households in coastal Kenya. This finding focuses attention on the reasons why more households in coastal Kenya have not adopted G/C cattle.
- *Adoption of G/C cattle is not limited to wealthy farmers.* Both the descriptive and econometric evidence support the idea that non-agricultural activities are not a key determinant of dairy adoption. The descriptive results indicate that the percentage of adopters is fairly evenly spread across all income categories, implying that adoption of G/C dairy cattle is accessible to many households, not just the wealthier ones. The econometric evidence suggests that involvement of the household head in non-farm activities does not have a systematic effect on the probability that a household will adopt G/C cattle.
- *Adoption of dairy can generate paid (secondary) employment.* Although only slightly more than half of the adopters employed a permanent labourer, they did so much more often than their non-adopting counterparts. Households with G/C cattle employed between one and two permanent labourers on average, compared with one permanent labourer hired for every five households without G/C cattle. The econometric evidence suggests that the linkage between the number of total or permanent hired labourers and the number of G/C cattle is not particularly strong. Further, ownership of G/C cattle appears to have little impact on the probability that a household has hired labourers. However, these results may have occurred because our survey did not distinguish between labour hired for cattle care and labour hired for other agricultural and non-agricultural tasks.
- *Adoption of dairy may have a positive impact on the nutritional status of pre-school children.* The incidence of chronic malnutrition (stunting) was statistically lower for children in households with cattle (G/C or local) than for those in households with no cattle. Although not all this observed difference can be attributed to milk consumption or dairy income, this result provides a starting point for future multivariate analyses that will control for other factors influencing nutritional status. Despite the potential benefits of G/C adoption, more than two-thirds of children in adopting and non-adopting households showed some degree of stunting. The prevalence of acute malnutrition seems to be little affected by adoption status: over one-quarter of children measured were at least somewhat acutely malnourished.

The milieu for smallholder dairy production at the coast is highly complex. Dairying in coastal Kenya provides benefits for adopters. For some households, adoption of a G/C dairy animal can lead to substantial increases in household income, can generate employment and can improve the nutritional status of pre-school-age children in the household. Households have various non-farm options for generating income that may serve the same purposes, however, and dairying seems to be treated as one of these options—to be engaged in from time to time as the opportunity arises. Previous dairy-related research has identified management options and practices that are viable and can be profitable for smallholders wanting to adopt or increase dairy production. Taken in the context of a risky production environment and competing opportunities for investment, the results of this study would suggest that neither the adoption nor productivity of dairying are constrained by poor availability of technology options. In terms of dairy development activities on the coast, there would seem to be two areas in particular that merit attention: mechanisms for easing access to grade and crossbred dairy cattle, either through credit schemes or through self-help smallholder co-operatives, and reducing the disease risks associated with G/C animals. Developments in both these areas would increase the propensity of smallholders to go into dairying. Whether or not such activities are viewed as worthwhile by development agencies is a question that requires a full appreciation of the opportunity costs involved and the policy goals of government.

In conclusion, the medium rainfall coastal lowlands of East Africa represent a difficult and risky environment for smallholder dairy production, yet one with access to two principal and rapidly growing urban markets, Mombasa and Dar-es-Salaam. These markets offer smallholder dairy producers, actual or potential, large margins for their milk. However, these markets and their environs also offer many other opportunities for the investment of smallholders' scarce capital. Many of these investment opportunities require smaller initial investment than dairy cattle, are less constantly demanding of family labour, require fewer specialist skills and are less risky. Of particular importance to increasing the adoption of dairy amongst smallholders will be ensuring the effective delivery of the infection and treatment method of immunisation against East Coast fever, or the delivery of the next-generation technology. Notwithstanding these reservations, dairy production and marketing has large potential for direct financial returns and indirect benefits for crop production. It is therefore likely that as smallholder agriculture in the coastal lowlands intensifies in response to human population pressure, dairying will become an important enterprise for a significant number of resource-poor families. In turn, the success of these families will depend in no small part on the products arising from the publicly funded research and development investments made during the 1980s and 1990s.

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Appendix 1. Summary of selected previous adoption and impact studies of smallholder dairying in Kenya

Various previous studies have examined the adoption of dairy technologies and their impacts on smallholders in Kenya. These studies are summarised in Table A1. Although the objectives of the studies differ, many of them share common approaches to assessment of impacts. Most of the studies relied on single-visit surveys with random (or semi-random) samples of households involved in dairy production. That is, only households with dairy cattle were included in the sample, and thus there typically was no 'control' group of households with similar characteristics but not involved in dairy production. The survey methods often relied on comparisons of the situation 'before and after' adoption of the dairying, based on recall of past events by households. Such studies provide indicators of how households perceive the impacts of dairying, but are probably less insightful than studies that use longitudinal monitoring techniques or include a control group in the study design.

The technology adoption and diffusion studies emphasise the high variation in adoption rates and factors apparently influencing the adoption of dairy-related technologies and practices. Whereas Irungu et al (1998) reported that 70% of farmers surveyed in Kiambu District planted Napier grass, adoption of Napier grass ranged from 22% to 76% of households in six other districts (Metz et al 1995). The technologies were most often adopted individually, even though the National Dairy Development Project (NDDP) promoted the related technologies as an integrated package (Metz et al 1995). Even when the technologies promoted by NDDP were adopted, some farmers abandoned them after a few years. Maarse (1997) asserted that in Coast Province, the number of farms with pure stands of Napier grass and the amount of Napier grass planted per cow declined by nearly 50% from 1988 to 1993. The number of 'dormant' NDDP farmers (i.e. farmers who did not own a cow, have milking or feeding facilities, produce fodder on farm or practice zero grazing at least 25% of the time, despite previously being registered in NDDP) also varied by district. This indicated that the accessibility and appropriateness of the NDDP 'zero grazing' recommendations vary depending on local conditions. Dormancy was highest in Coast Province compared with other regions of Kenya. Nearly 9% of registered farmers at the coast were dormant in 1993, mostly due to loss of animals due to disease or the 'lack of management input' (Metz 1993).

A potentially large number of impacts could be examined after households decide to undertake dairy production. Impacts assessed in the different studies cited above focus on who performs the tasks associated with more intensive dairying and the perceived benefits to the household. The studies confirm the importance of female household members in dairy production and marketing. Mullins et al (1996) found that in Kilifi District women are frequently responsible for dairy-related tasks other than herding and spraying for ticks. Women in the same district were 'involved' in 30% of the dairy-related tasks performed, more than children (26%) or hired labour (19%) (Price Waterhouse 1990). The

MoALDM/NDDP studies (Mugo 1994) found that women contributed between 25% and 41% of the 'relative labour contribution' in the 'main dairy management areas'.

The impacts of dairy adoption, like the prevalence of adoption itself, varied by location in Kenya. The impact of dairying on household labour requirements, perceived responsibilities and the health of household members were outcomes that differed most by district. The percentage of households reporting that the adoption of dairy increased the amount of time devoted to farm work varied from 25% to 75%. (In Kilifi District, however, time devoted to 'other family activities' was not affected by the adoption of dairy, although the amount of work increased; Price Waterhouse 1990.) Households reporting 'more responsibilities' varied from 0% to 72% of respondents in the six districts where the MoALDM/NDDP study was carried out. Between 10% and 78% of households reported that adoption of dairying had improved the health status of the family (Mugo 1994; Mullins et al 1996). Thus, some key effects of adopting dairying appear to be highly variable; this suggests that additional analyses may help to elucidate the underlying reasons for this variability.

The promotion of dairy production is often justified by the assumption that adopting households will consume more milk, but the results of the studies suggest this outcome is not universal. Less than 10% of the households in the MoALDM/NDDP studies for Migori and Nandi districts indicated that more milk was available for consumption. None of the female respondents in those studies indicated that 'more milk for home consumption' was an 'effect of zero grazing', whereas 8% and 17% of male respondents in those districts indicated that milk consumption by the household had increased after adoption. In contrast, Price Waterhouse (1990) and Mullins et al (1996) both found that more than 90% of households reported greater milk consumption after adoption. Launonon et al (1985) reported that over 70% of households in a Meru District survey reported increased milk consumption after the adoption of dairying.

Household perceptions of the impacts of dairying on income and financial status varied less than other impacts assessed by the studies. Fifty-five to ninety per cent of the households reported more income after adoption, and 78% to 100% of households reported improved 'financial status' as a result of dairying (Mugo 1994). Mullins et al (1996) reported that 97% of households said that income had increased after adoption of grade and crossbred animals.

Another hypothesis concerning adoption of more intensive dairying is that it generates employment, because more labour is required to care for Napier grass and grade or crossbred animals. In the MoALDM/NDDP studies, respondents reported that hired labour provided between 28% and 39% of the 'relative labour contribution' for tasks related to zero grazing. Often, hired labourers performed much of the work of weeding Napier grass plots and cutting grass for confined cattle. The results for Kilifi District suggest lower levels of employment generation, but vary depending on the study. Price Waterhouse (1990) found that only 12% of households hired more labour after adoption of dairy production—yet hired labour accounted for nearly one-fifth of dairy-related tasks. This suggests that the households adopting dairying may have already employed hired labour, and some of the additional work was taken up by existing labourers rather than new hires. The study did not examine the total payments to labourers or the amount of time they worked, so the impact on total payments to hired labour is unknown. In contrast, Leegwater et al (1991) found that about half of the NDDP farmers in Kilifi District employed labourers, particularly when the farm owner had off-farm employment. The extent to which dairy cattle *per se* are responsible for the increase in hired labour was not examined in detail in either of the two studies.

Leegwater et al (1991) was one of the only studies to explore impacts of dairy adoption through examination of adopters and non-adopters. The study examined five groups: NDDP dairy producers, 'independent' dairy producers, extensive livestock producers, households that purchased dairy products from NDDP farmers, and the general rural population in Kilifi District. This study also examined factors in greater detail and more quantitative measurement than most of the other studies. Leegwater et al (1991) found that NDDP farms produced more milk than their 'independent' dairy counterparts, consumed more milk than the other four groups, and purchased a smaller percentage of calories consumed by the household. NDDP households also engaged more frequently in off-farm employment, earned higher total incomes, and enjoyed better nutritional status for pre-school age children.

A limitation of the Leegwater et al (1991) study is that the results rely on tabular summaries for the five groups, and thus do not control for factors other than dairy production, such as land availability or other income, that will influence the reported outcomes. The authors assert, for example, that off-farm income allowed the farmers in NDDP to afford the investments required by the project, yet only one-quarter of the sampled NDDP farmers are reported to have off-farm income. Similarly, the study concludes that the nutritional outcomes, while better for dairy producing and consuming households, are due to 'better child care in general' and thus cannot be attributed specifically to dairy production.

Table A1. *Previous studies of adoption and impact of smallholder dairying in Kenya.*

Author(s)	Focus of the research	Location	Methods	Findings
Studies related to adoption				
Metz (1993)	'Dormancy' of NDDP farmers	All districts in which NDDP operates	• Survey of NDDP field staff • Survey of all 'dormant' NDDP farmers, defined as not meeting one of the following conditions: - ownership of at least one diary cow or heifer - farm has both milking and feeding facilities - on-farm fodder production - zero grazing practised at least 25% of the time	• The use of NDDP-promoted technologies varies by district for 'registered' farmers; thus, the definition of 'dormancy' needs to account for regional variation • In Kilifi District, 8.8% of farmers were 'dormant' (highest dormancy rate of the NDDP districts) • Dormancy was not closely related to household characteristics • Reasons for dormancy in Kilifi District: - disease or mortality, 24% - lack of management input, 18%
Waaijenberg (1994)	Farming systems of Mijikenda agriculture; factors constraining performance and pathways for future development	Four villages in Kaloleni Division, Kilifi District	• Literature review, formal and informal interviews, qualitative and quantitative observations in farmers' fields, and researcher-managed experiments in farmers' fields. • Data collection during 1981–85	• Rural households rely on diverse activities to meet basic needs due to the relatively low productivity of the land base and proximity to off-farm employment opportunities • Technologies suited to the current household strategies and objectives are lacking; the availability of off-farm employment limits interest in new technologies • Few farmers own cattle; goats are more common • About one-half of the adopters of dairy cattle were relatively wealthy and able to employ hired labour
Metz et al (1995)	Diffusion of dairy technologies to non-NDDP farms	Six districts: Kakamega Nandi Nakuru Uasin Gishu Kiambu Nyeri	• Survey of 200 households per district, randomly sampled from clusters used by national population survey in 1989 • Data collected mid-1995. • Assessed whether 20 'practices' promoted by NDDP were currently used or had been used in the past • Constructed 'adoption curves' assuming continuous use since the first year the practice was used • Compared rates of adoption over time in districts with different starting dates for NDDP activities	• Wide variation by district in the percentage of households currently using of NDDP-promoted practices: - Napier grass planted, 22–76% - grade or crossbred ownership, 11–77% - cattle grazed (i.e. not zero grazing), 17–89% • Practices not adopted as a 'package', rather as individual components • Impact of NDDP on adoption varies by district, based on different starting dates • NDDP may not have been the main factor explaining diffusion in some districts, given the dates practices were adopted relative to intensity of NDDP efforts

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Table A1 cont...

Author(s)	Focus of the research	Location	Methods	Findings
Maarse (1997)	Processes of change in agricultural extension	Coast Province	• Review of project documents and personal experiences (no primary data collection).	• Claims that adoption of crossbred cows and Napier grass was slower than expected (uses the term 'disappointing') • The longer farmers owned dairy animals, the less Napier grass per cow was maintained—yet milk production increased: % of farms with pure stands of Napier grass fell from 94% in 1988 to 53% in 1993; Napier grass planted per cow fell from 0.72 acres in 1988 to 0.45 in 1993 • Stresses the need for exploration of alternatives to Napier grass production and zero grazing.
Irungu et al (1998)	Factors affecting adoption of Napier grass	Kiambu District	• Survey of 365 households, stratified by sublocation • Data collected June–July 1996 • Households located in tea/dairy, coffee/dairy, and horticulture/dairy zones • Tobit, probit and truncated regression models used to assess factors influencing Napier grass adoption	• 70% of households had adopted Napier grass • Factors affecting adoption depended on the model used: – probit: income, co-operative membership – Tobit: education, land owned, co-operative membership, years of farm experience – truncated: TLU, years of farming experience, milk price, and land owned • Napier grass planting is not affected by 'technical' factors, so efforts to promote it should focus on increasing human capital
Swallow (1998)	Intensification of cattle feeding in Coast Province	Representative village in coconut-cassava zone, Kaloleni Division	• Open-ended interviews and observation • Surveys of households for background data collection (N=132; N=37), longitudinal monitoring (N=8) and herd following (N=2) • Data collected July 1992 to July 1994	• Cattle keepers major problems were shortages of feeds and poor animal health services • 8% of households operated dairy enterprises with grade or crossbred cattle • Cattle keepers use feed resources belonging to neighbours without cattle • At intermediate stages of land use, cattle owners will make marginal adjustments in feed management to effect a gradual change in intensification (rather than moving directly from grazing to stall-feeding based on purchased feeds) • Cattle keepers will blend types of enterprises, cattle feeding techniques, feeds and feed sources to achieve a gradual increase in the intensity of their operations

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Author(s)	Focus of the research	Location	Methods	Findings
Studies on impacts				
Launonon et al (1985)	Smallholder milk production, consumption and marketing in Meru District	North Imenti and South Imenti divisions, Meru District	• Survey of 254 households who were members of 10 Dairy Societies; strata were DS and household participation status (active or inactive); 46 non-member households were a semi-random sample • Survey was to provide a 'baseline' for future impact assessments • Data collection January–March 1984 • Socio-economic information collected • Weight-for-age of children less than 5 years old collected	• More than 98% of households surveyed owned milking cows • 55% of the households planted fodder crops • 77% of all households said milk consumption had increased after the adoption of dairying • Dairy income as a percentage of total household income varied from 5% for non-members to 37% for Dairy Society members • Mean milk consumption per person was 0.7 litres per day regardless of DS participation status • 25% of children were below 90% of reference weight-for-age; [WFA is a measure that combines both stunting (height-for-age) and wasting (weight-for-height), and as such is more difficult to interpret than either HFA or WFH]; no comparisons by DS participation were presented for nutritional status
Price Waterhouse (1990)	Role of women in NDDP	Six districts: Kilifi Meru Kiambu Nandi South Nyanza/ Kisii Kakamega	• Survey of 420 'full time family farms' sampled from farmers registered more than 6 months with NDDP • Data collection in December 1989 • Examined 18 activities and reported the number of times individuals in the household 'were involved' in the activity (neither the time frame for involvement nor the amount of time spent was specified) • Before and after comparisons based on recall of outcomes such as: Who did the work regarding cows? Do more people work on the farm?	• Results for Kilifi District • Percentage of households that: - owned cattle before NDDP, 43% - hired more labour after adoption, 12% - say more milk is available for consumption, 90% - say they are 'delighted' with zero grazing, 95% • Contribution to performance of 'dairy work': wives, 30%; children, 26%; hired labour, 19% • Adoption had no major influence on time spent in other 'family activities'

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Author(s)	Focus of the research	Location	Methods	Findings
Leegwater et al (1991)	• To assess the importance of NDDP dairy with other small-scale dairy farming • To assess the importance of intensive dairy farming for the 'household economy' and nutrition of smallholders • To assess the importance of intensive dairy for nutrition of local community	Kilifi District	• Surveys of households in five study groups: – NDDP farmers (N=30) – Independent dairy farmers (N=25) – Livestock farmers (N=11) – Households buying milk from NDDP farmers (N=24) – Comparison group from the general population of farming households (N=90) [NDDP farmers were contacted through local NDDP staff, and then they identified 'independent' farmers and households to whom they sell milk; it is not clear whether this is a random sample] • Data collection from May–July 1987 of: – household characteristics – dairy farming and milk production – milk sales – household food consumption (24-hour food preparation recall) – nutritional status of pre-school aged children (height, weight and mid-upper arm circumference) • Tabular comparisons of outcomes for the five groups	• NDDP farms are more capital and labour intensive, and rely more on purchased inputs and services than 'independent' dairy farms • Milk production per cow is higher on NDDP farms than on 'independent' farms • Nearly all NDDP farmers have 'high' and 'middle' incomes, in part due to off-farm employment: NDDP households and NDDP customers had higher incomes than other groups, 31% of household income for NDDP farmers came from 'livestock' production [dairy income was estimated as a certain amount per cow in each of the divisions where the study collected data] • 57% of NDDP farmers were classified as 'rich' (earning more than KSh 4000 per consumer unit per year); 52% of the general population was below the 'food poverty line' (KSh 1000 per consumer unit per year). • The percentage of households with off-farm employment of adults ranges from 17% to 31%; fewer than one-quarter of the NDDP households have off-farm employment • Two groups of NDDP farmers exist: farms hiring labour and farms using only family labour; farms hiring labour had more dairy cows and higher incomes from off-farm employment than farms not hiring labour • Milk consumption was higher for dairy farmers than for livestock keepers and customers of NDDP farmers • Milk consumption among the general populace is rare and irregular • The nutritional status of pre-school age children is better in NDDP households and among NDDP customers than among children from the general population, although this is not due to milk consumption alone • Mean food 'self-sufficiency' (estimated staple food caloric production divided by estimated caloric requirements from staple foods) ranged from 32% to 50%, and was highest for NDDP farmers

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Author(s)	Focus of the research	Location	Methods	Findings
Huss-Ashmore (1992)	Nutritional impacts of intensified dairy production	Coast Province	• Discusses results of previous nutrition studies (particularly Leegwater et al 1991) • Assesses the potential contribution of an additional dairy cow to household calorie and protein supplies, assuming mean observed milk production and retention levels: – when milk is consumed – when milk is sold and all income is used to purchase other foods	• The Leegwater et al (1991) study used generally appropriate methods and sample sizes, but could have been improved by a more consistent approach to sampling, and better explanation of the analytical methods used • At current rates of milk 'retention', the direct impact of an additional dairy cow is to provide 38–56 kcal per consumer unit per day, or less than 2% of estimated energy requirements • If additional milk produced was given only to children, and a higher proportion retained, the nutritional impacts would be greater • Where food energy is limiting, the income effects of dairy production may be more important than the direct consumption effects • Milk is a good supplement in a maize-based diet, particularly for micronutrients and essential amino acids
Mugo (1994)	Impact of intensive dairy farming on gender-differentiated socio-economic position of smallholder households	Five districts: Kiambu Meru Migori Nandi Vihiga	• Survey of 120 households per district using Dairy Evaluation and Advice Form of NDDP as sample frame • Stratified 'random purposive' survey; sex of 'recruited' farmer and 'type of household' (defined by dependence on agriculture for livelihood) used as strata • Data collection December 1993 to January 1994 • Recall of before and after adoption from male and female respondents • Questions such as: Main crops before and after adoption? Who does the work now (all, most, some)? 'Financial' and 'Family' status?	• Few changes in 'main' enterprises before and after adoption of dairying in all districts except Nandi • Percentage of households reporting: – 'more work' after adoption, 25–45% – 'less leisure' after adoption, 8–43% – 'improved health' after adoption, 10–78% – 'more income' after adoption, 55–90% – 'more milk for consumption', 4–9% – 'improved family financial status' after adoption, 78–100%

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Author(s)	Focus of the research	Location	Methods	Findings
Mullins et al (1996)	Impacts of intensive dairy production on smallholder farm women in coastal Kenya	Kilifi District	• Survey of 32 households participating in NDDP, stratified by sex of 'extension contact' • Data collected February 1993 • Before and after recall for questions such as: Who performs tasks 'all or most' of the time? Who controls income? • Tabular comparisons by sex of farm owner, farm operator and extension contact	• 84% of dairy 'operators' were female • One-third of farm owners had salaried employment as their 'main occupation' • Adding dairying did not reduce other farm activities • Wife does dairy tasks most often, except for spraying and herding • Women's responsibility for livestock tasks and financial payments increased after adoption of dairying • % of households saying that dairy: - increased income, 97% - increased milk consumption, 91% - increased work, 75% - improved family's health, 25%

Appendix 2. Econometric models of adoption and impact

Probit models

The probit model is most often derived using the assumption that farm households maximise a utility function that ranks the household's preferences of available technological choices. The utility function U depends on attributes of the household and sources of information about the characteristics of the technologies that the household could adopt. Thus, the utility of technology t for household h is defined by:

$$U_{th} = U_{th}(Z_h, I_h)$$

where Z_h are household characteristics variables and I_h are variables indicating the household's sources of information about technologies. The Z variables are often selected based on the theory of the agricultural household (Singh et al 1986), and thus include household characteristics that are exogenous, such as land area, number of household members and location. The relationship between utility and the variables Z and I is often assumed to be linear, so that:

$$U_{th} = X_h \alpha_t + e_{th}$$

where the X_h is a vector containing all the variables included in Z_h and I_h, α is a vector of parameters relating the variables X to the household's utility, and e_{th} is a zero-mean random error term.

Households are assumed to choose the technology that maximises their utility. Thus, a household will in theory adopt a technology if the utility provided by the new technology exceeds the utility provided by a previously used technology. Mathematically, this implies that adoption occurs when:

$$U_h^{New} > U_h^{Old}$$

If a variable D is defined as:

$$D_h = \begin{cases} 1, \text{if } U_h^{New} > U_h^{Old} & \text{(the new technology is adopted and replaces the old)} \\ 0, \text{if } U_h^{New} \le U_h^{Old} & \text{(the new technology is not adopted)} \end{cases}$$

then the probability that $D_h = 1$ can be expressed as a function of the variables X as follows:

$$
\begin{aligned}
\Pr[D_h = 1] & \\
&= \Pr[U_h^{Old} < U_h^{New}] \\
&= \Pr[X_h \alpha^{Old}{}_t + e_h^{Old} < X_h \alpha^{New} + e_h^{New}] \\
&= \Pr[e_h^{Old} - e_h^{New} > X_h (\alpha^{New} - \alpha^{Old})] \\
&= \Pr[\mu_h < X_h \beta] \\
&= F(X_h \beta)
\end{aligned}
$$

here, Pr[•] is a probability function, μ_h is a random error term, and $F(X_h\beta)$ is a cumulative distribution function for μ_h evaluated at $X\beta$. Thus, the probability of adoption of the technology can be expressed as a function of the variables X and parameters β. The choice of the cumulative normal distribution for F(•) defines the model as a probit model. The estimates of the parameters β are typically obtained using maximum likelihood methods, which use optimisation methods to choose the values of β that maximise a likelihood function (Greene 1993). When the parameters β are estimated, the marginal effect of a change in the jth variable in X, Xj, is defined by:

$$\frac{\partial \Pr(D=1)}{\partial X_j} = f(X_h \beta_j) \cdot \beta_j$$

The marginal effects thus depend on the value of X_h used. Typically, the overall mean value of X_h in the sample is used to calculate $f(X_h\beta_j)$. The signs and magnitude of the marginal effects indicate the effect of the variable X_j on the probability that the household will adopt the technology. To assess the adequacy of the model, model predictions of which households adopt are compared to the actual number of households adopting the technology. (Typically if the probability predicted by the model is greater than 0.5, the household is assumed to adopt the technology.) The percentage of correct predictions by the model is an indicator of model predictive ability. As Greene (1993) noted, it is also useful to compare the model's percentage of correct predictions to a 'naïve' model that predicts that no households adopt.

Bivariate probit models

The bivariate probit model is what Greene (1993) calls a 'natural extension' of the individual probit model discussed above. In the case of the bivariate probit model, there are two equations relating choices of technology to variables X, and the random error terms e in the equations are assumed to be correlated. In statistical terms, this implies that the covariance of $[e^1, e^2]$ equals a constant ρ, rather than zero as is assumed in the case of the individual probit models. In practical terms, this implies that the decisions to adopt one technology are related to the decision to adopt another. The statistical test for $\rho = 0$ provides an indication of the interdependence of the two adoption decisions.

Tobit models

A basic assumption of the linear regression model is that a random variable (such as the number of grade or dairy (G/C) cattle owned) can be modelled as a linear function of independent variables with a normally distributed error term with a mean value of zero. However, it is common in economic studies to encounter situations in which a significant proportion of the observations have the value 0; this is the case for the number of G/C owned by households who responded to the Adoption Survey. When the observed value is zero, this implies that the error term no longer has the assumed properties, and so a linear regression will provide misleading estimates of the statistical relationship between the independent variables and the outcome(s) of interest. (For this study, these outcomes are the number of G/C animals, the amount of Napier grass planted etc.) To adjust for the problems with the error term, a censored regression, or Tobit model, is appropriate. The development of the Tobit model hypothesises the existence of a latent variable, y* (sometimes called an 'index function'), which is not actually observed. y* is assumed to be a linear function of the independent variables in the model, such as the X above, so that:

$$y_h{}^* = \beta' X_h + e_h$$

What is observed is an 'actual' variable, y (the actual extent of adoption, such as the number of G/C cattle), and the relationship between y* and y is given by:

$$y_h = \begin{cases} y_h^*, \text{if } y_h^* > 0 \\ 0, \ \text{if } y_h^* \le 0 \end{cases}$$

This relationship is used to develop a regression model relating the observed variable to the variables assumed to influence the extent of adoption, X. In the standard linear regression model, the expected value of the observed variable y_h is given as:

$$E[y_h] = \beta' X_h$$

because the error term e_h has an expected value of zero. When the latent variable y* is of interest, the error term in a regression of y on X no longer has zero mean because the values of y_h must all be greater than or equal to zero (i.e. no negative values are allowed for the number of G/C cattle owned). In this case, it was shown that the expected value of the observed value y_h is given by:

$$E[yh] = \beta 'X + \sigma\lambda(\alpha)$$

The parameters β and the variables X are as previously defined, σ is the standard error of the error term e_h, λ is a non-linear function of the standard normal distribution, $\alpha = (-\mu/\sigma)$ and μ is the overall mean of y_h. A Tobit model essentially allows for the influence of the $\sigma\lambda(\alpha)$ term in the regression, and thus avoids the bias in the parameters that would exist if the model were estimated as an ordinary linear regression. As a result, the marginal effect of a change in the jth independent variable in X, Xj, for the adopting households is the coefficient β multiplied by a scale factor, or:

$$\frac{\partial y_h}{dX_j} = \beta_j \cdot (1 - \lambda_h^2 + \alpha\lambda_h)$$

Greene (1993) showed that this scale factor is always greater than zero and less than one, so that the marginal effect of a variable X_j for adopting households is always less than the value of β.