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Returns to smallholder dairying in the Kilimanjaro region, Tanzania

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Abstract

Tanzania is a net importer of dairy products despite its large cattle herd and successive government efforts to promote dairying. This paper draws on survey data to examine the financial attractiveness of dairying to smallholders in an area of high dairy potential on the slopes of Mount Kilimanjaro. On mixed farms in which coffee and bananas are the other main enterprises, producers keep small herds of mainly crossbred and grade cattle, mostly fed in stalls on cut forage and crop residues. Using a herd model, a benefit-cost analysis of dairying was carried out. This showed that at prevailing prices, returns to dairying were around 20%. There was, however, no difference in the returns gained by the larger scale farmers who had more of the grade cows and managed them intensively, compared to those using a less intensive system with lower potential stock. Moreover, the profitability of dairying for the former was underwritten by subsidies on inputs and fuel which are difficult to justify. Policy has apparently over-emphasised improving yields and the development of intensive dairying, and has not been sufficiently concerned with keeping down the costs of dairying. © 1997 Elsevier Science B.V.

1. Introduction

In common with many other African countries (see Walshe et al., 1991), Tanzania is a net importer of dairy products, largely of skimmed milk powder (SMP). When reconstituted this provides about 10% of the country's milk supplies (MALD, 1990b) in total, and a much higher share of the supplies for the largest cities (as much as 85% in the late 1970s according to Raikes, 1981). Although the imported dairy products have been relatively cheap, the bulk having been supplied under commodity aid agreements with the World Food Programme and the European Community, they are not free and drain away foreign exchange – Tanzania spent more than US$ 4 million on imported dairy products in 1990 (FAO Agrostat). Moreover, they leave the country dependent on the agreements reached.

Yet Tanzania is well endowed with good land and has a large cattle herd which reached more than 13 million heads by the early 1990s (FAO Agrostat data). Milk production has, however, been growing only slowly: Ministry of Agriculture estimates (MALD, 1990a) show production rising from 364 million litres in 1981 to 447 millions in 1989, an increase equivalent to just 2.6% a yr. This is significantly below total population growth in the 1980s of 3.4% a year, and well behind the annual growth of urban population of 10.5% (World Bank, 1992).

Since before Independence in 1961 and with greater emphasis since, the governments of Tanzania

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have tried to encourage more domestic milk production to achieve self-sufficiency. During the 1970s large-scale milk production on farms run by a parastatal (DAFCO) using relatively intensive production systems was encouraged. Another state enterprise, Tanzania Dairies Ltd. (TDL), was set up to collect, process, and market dairy products. The outcomes were disappointing: DAFCO farms were often poorly managed and ran at high costs; whilst TDL built large, modern processing plants close to the consumers which produced good quality pasteurised products, but at relatively high cost. This in turn made it difficult for TDL to offer attractive prices to local farmers for their milk, and so capacity could only be maintained by using imported SMP. When SMP imports declined in the 1980s, owing largely to national economic problems and the loss of ability to import, the plants found themselves operating substantially below capacity, with correspondingly high overheads per litre of milk processed.

As DAFCO's problems became clear, a new approach was adopted in 1983 (MLD, 1983), switching attention to the promotion of smallholder dairying. It was decided to supply improved cattle, animal feeds, veterinary medicines, extension services, etc. to smallholders, and to improve price incentives to them. For example, in Hai District (the focus of this study), dairy projects were set up in the 1980s by Heifer Project International, FAO/UNDP, the World Food Programme, and Canada's International Development Research Centre (IDRC) to provide and encourage the use of better breeding stock, artificial insemination, forage planting, and molasses and urea feed supplements. Nationally, resources for input supplies have been scarce, whilst increases in the price paid by TDL for milk have been unattractive in many areas since there were better prices on offer for milk passing through other, less formal channels (which handled the majority of milk in the Kilimanjaro area, see Mdoe and Wiggins, 1996).

Despite these problems, Tanzania has some promising dairy areas, especially in its highlands where tsetse flies are absent, heat stress on cows is limited, and ample rainfall provides the potential for abundant fodder production. This study looks at one such district, Hai, where for more than twenty years smallholders have specialised in dairying supported by a series of dairy development projects.

This paper explores the economics of smallholder dairying. The heart of the analysis is an examination of financial returns to smallholder dairy farmers, differentiated by scale and correspondingly by intensity of production. It also looks at whether government programmes to encourage increased use of feed, veterinary attention and upgraded cows make economic sense.

2. Description of the study area and the investigation methods

The area studied is part of Hai District, Kilimanjaro Region, in northern Tanzania. The District, some 2169 km^2 in area, covers the western part of the Kilimanjaro massif, and includes land at over 5000 m at the top of the mountain, down to the lowlands at the foot of the mountain which lie at under 800 m. (See Aminu-Kano et al., 1992 for a description of Hai District.)

Although quite close to the Equator, altitude cools the local climate, producing mild temperatures in the highlands. Rainfall is bimodal, falling in the long rains of March-May and the short rains of September–November, with amounts varying from 1000-1500 mm in the highlands and 500-900 mm a year in the lowlands. The soils are of volcanic origin, fertile dark brown and brownish-red clays in the highlands, and less fertile light clays in the lowlands.

In 1988, Hai District had a population estimated at 200 136, which had grown at 2.1% a year over the previous ten years. Average population density was 92 persons/km^2, but given that the majority of the population lives in the highland zone studied, densities there exceeded 190 persons/km^2. Most people live in rural areas. The district has only a handful of market centres; the main town serving the area being the regional capital, Moshi, located less than 25 km beyond the eastern edge of the district.

The study area comprises the densely-settled farming land between 1000 and 1600 m on the southwestern slopes of Kilimanjaro, the highlands where most smallholder dairy farms are located, and the immediate fringe of adjacent lowland at 800–1000 m (see Fig. 1).

Data on dairying and other aspects of farming were collected during 1990 and 1991. In each of the four divisions of Hai district, three villages were randomly selected. In each of these, ten households (typically out of a total of 250 or so) were picked randomly from the lists kept by village chairmen, to give a sample of 120 households in all. Following pre-testing, a questionnaire was used to interview the families during a single visit. Interviews lasted about

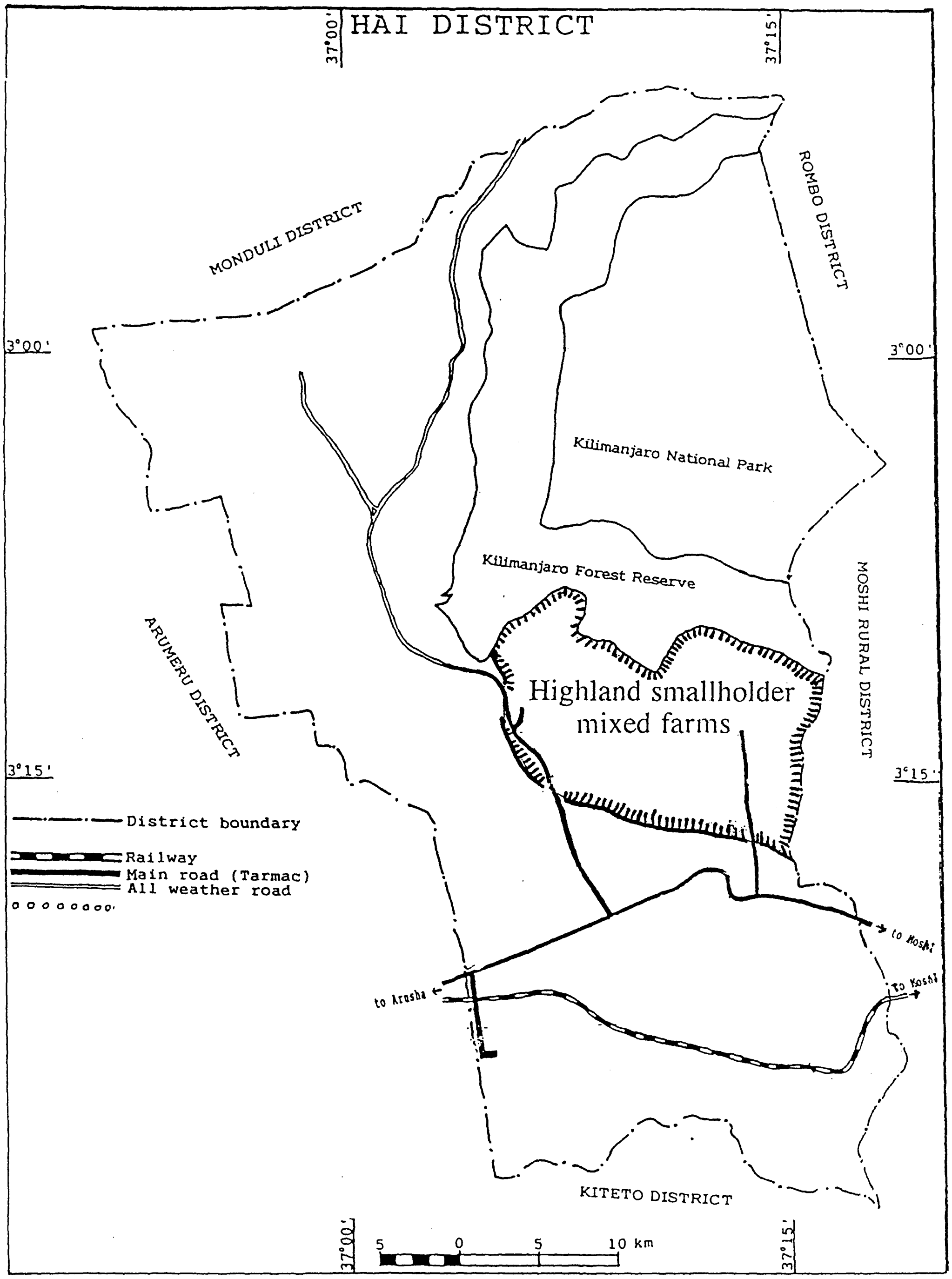

Fig. 1. Hai district, showing the highland dairy farming zone. Source: Land use planning office, Hai district.

1 h and included questions about the farm household in general, but focused mainly on cattle, their management, production, and use of milk.

In addition, another two households from each of the dozen villages were selected and interviewed to collect histories of the progeny of their cows, to corroborate and improve estimates of cattle production parameters.

Although there were no abrupt or obvious social differences amongst the people of Hai district [1], households were not homogeneous. Previous studies show ample evidence of income differences amongst households in rural Tanzania (for example, Collier et al., 1986 nationally, and Zalla, 1974 in Hai itself). Hence the data were scrutinised to establish differences within the sample. This resulted in farms being divided into four groups by an aggregate measure of scale of the two main farm enterprises, dairy cattle and coffee. To do this the number of livestock units in cattle and the area under coffee–banana plants were multiplied by constants representing discounted expected flows of gross income from each of these enterprises [2]. This gave an estimate of the present capital value of the two enterprises, and was taken as a proxy for scale [3].

[1] Ethnically and linguistically, the farm households are composed of Chagga people. The large mojority have access to land, without payment of tribute. Social hierarchy is weak and leadership is by age, respect, and consent. The most obvious social cleavage is by gender, with different tasks being allocated to the sexes within the household. Female-headed households, about 16% of the sample, tended to be disadvantaged.

[2] For livestock units the figure used was T.shs 978470, whilst for each hectare of coffee–banana land T.shs 891130 was used; figures representing the sum of present values of benefits to the 'average' cow and hectare under coffee and bananas over 15 yr, discounted at 7%.

[3] Since the bulk of farm income came from coffee and cows – remittances, although present in the Hai rural economy, proved to be far less important – this measure is a also a proxy for farm income. Examination of the distribution of these values allowed four scale groups to be defined, as follows: smallest, less than Tanzanian shillings (T.shs) 2.79 m of gross present value of cattle and coffee–banana land, average T.shs 2.64 m; lower middle, T.shs 2.79 to 3.85 m, average T.shs 3.08 m; upper middle, T.shs 3.85 to 4.98 m, average T.shs 3.96 m; largest, more than T.shs 4.98 m, average T.shs 6.96 m. At the time of the survey in 1990–91, the Tanzanian shilling exchanged at T.shs 190 to the US dollar, although the World Bank reported a parallel market rate of T.shs 290 to the dollar in 1990.

The four groups were dubbed smallest, lower middle, upper middle and largest scale farms. Average values diverged by little more than two-and-one-half times between the largest and smallest scale groups, a relatively small spread when considering farm scales. Despite the narrowness of the scale bands, differentiating the farm households revealed significant differences between the groups.

3. Survey findings

3.1. The farming system

Table 1 shows the resources available to the surveyed households and their use. Farming is the backbone of the highland economy. Production is organised at the level of the household, typically a nuclear family with an average of seven members.

Table 1
General characteristics of the sample households by scale

Item	Scale group				
	Smallest	Lower middle	Upper middle	Largest	All
Land owned per household (ha):					
Highland	0.77	1.10	1.68	3.08	1.72
Lowland	1.51	1.76	1.97	3.22	2.15
Total	2.28	2.86	3.65	6.3	3.87
Average household size (persons):					
Adults	3.1	2.8	3.1	3.5	3.1
Children	3	4.3	3.8	4.2	3.8
Total	6.1	7.1	6.9	7.7	6.9
Average areas under major crops (ha per household):					
Highland zone:					
Coffee–banana	0.51	0.81	1.16	2.54	1.29
Forage	0.12	0.13	0.31	0.31	0.24
Other	0.14	0.16	0.21	0.23	0.19
Lowland zone:					
Maize–beans	0.67	0.99	0.86	1.00	0.88
Maize	0.80	0.75	0.96	2.10	1.27
Beans	0.36	0.21	0.35	0.48	0.36
Others	0.06	0.06	0.08	0.07	0.07
Average livestock holding (head):					
Cattle	3.1	3.5	3.7	6.8	4.4
Goats	1.4	1.2	0.5	1.0	1.0
Sheep	0.8	1.2	1	0.7	0.9
Pigs	0	1.2	2.5	4.6	0.4
Poultry	5.4	7.6	8.5	10.2	8.9

Source: Survey data, 1990

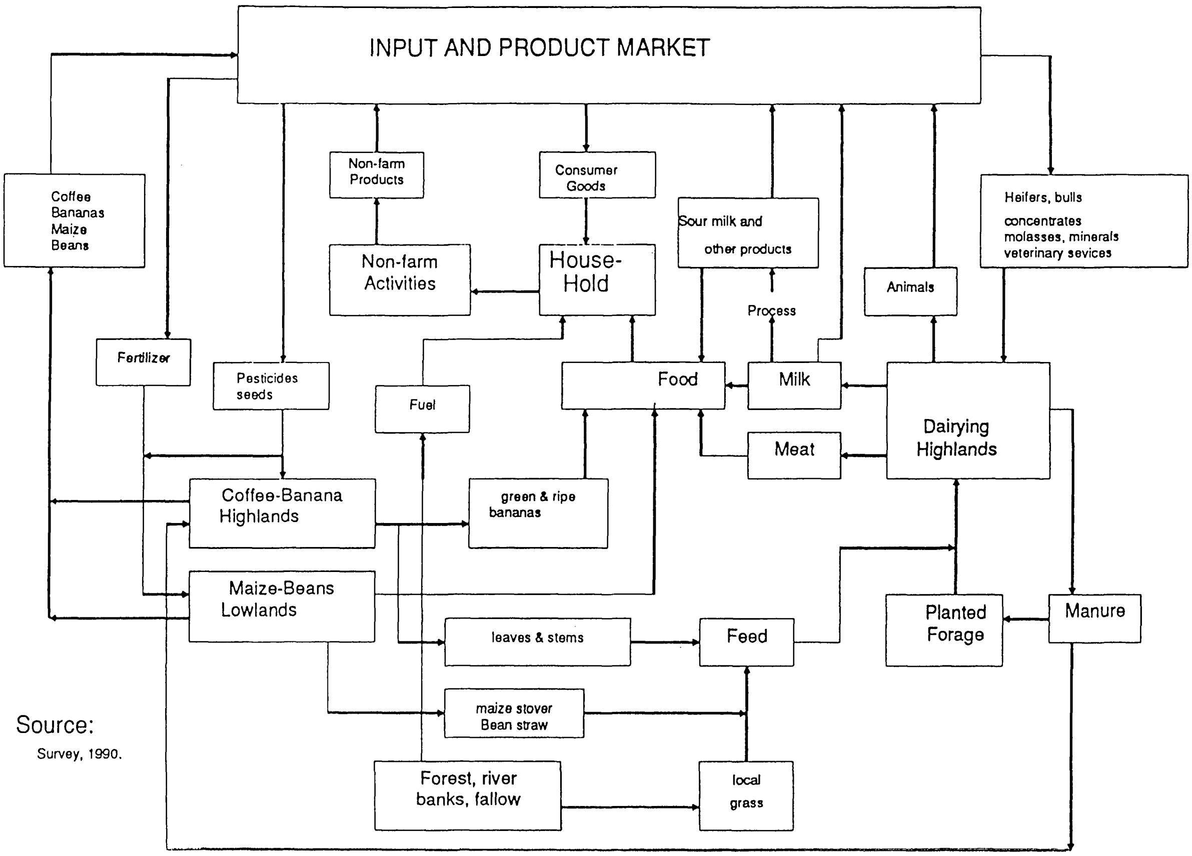

Fig. 2. Smallholder dairy farming systems in Hai district.

On average, about 16% of households are headed by women, slightly more amongst the less well-off families. Household labour is central to successful farming. Although the largest scale group had significantly [4] more persons per household than the smallest scale group, there was no significant difference in the number of adults, the main source of labour. More than half of the household members in each scale group were children, and about half of them were schooling, only available for farm work during weekends and school holidays.

Hired and traditional exchange labour, the latter rewarded partly in kind through provision of food and refreshments (e.g. local brew) by the owner of the plot being worked, were used especially during peak periods when labour demand for farm operations exceeded the available family labour. On average about 35 days of additional labour were deployed on the plots. Whilst the proportion of sample households which hired labour increased with scale, the proportion using exchange labour declined with increases in scale.

Given the relatively dense settlement of the study area, all arable land was under cultivation and it was impossible to open virgin land. On average, households had access to a little less than 4 ha of land, divided between the highland area ('kihamba' land) with an average of 1.7 ha, where they lived, and the lowlands ('shamba' land) with an average of 2.2 ha, anything from 6 to 27 km distant from the house. Available land per household in both farming zones

[4] 'Significant' or 'significantly' in this paper means that statistical tests on observed differences show that there was less than a 5% probability that the true means were equal.

had been declining over time due to land fragmentation resulting from increased population pressure. Table 1 shows that the richer farms had larger areas, and that land inequality was more pronounced for 'kihamba' than for 'shamba' land.

The farming system, see the illustration in Fig. 2, used land in the two zones to produce both livestock products and crops. The highland farms were largely under a permanent coffee–banana intercrop, fertilised by cattle manure, covering an average of 1.3 ha or 75% of the arable highland. Coffee is sold for cash, bananas are an important staple food. Small areas (average 0.2 ha) were also planted as household gardens with vegetables. Of increasing importance, there were plots (average 0.24 ha) of planted forage – elephant (*Pennisetum purpureum*), *Setaria anceps*, and Guatemala (*Tripsacum laxum*) grasses – usually irrigated by water from furrows taken off the frequent streams in the uplands. Better-off households had significantly more land under coffee–bananas and forage crops than their less well-off neighbours. Cultivation and other farm operations were by hand tools: hoes, machetes ('pangas'), axes, and knives.

Lowland plots were devoted to grain production, either maize–bean intercrops or sole stands of these two crops. Maize was grown during the long rains as a single annual crop, whilst beans were planted during both long and short rains to give two crops a year. The largest scale group planted significantly more land to pure stands of maize than the other groups. Mineral fertiliser (ammonium sulphate) was used to fertilise the lowland shambas, an average of 125 kg/ha being applied. Fields were prepared by hired tractors (71%), by ox-plough teams hired from neighbouring agro-pastoralists (9%), and by hand hoes (20%). Shamba crops and stover had to be taken up the mountain to residences and the highland farms, the main forms of transport being pick-up trucks and head-loading.

All the surveyed households owned cattle, typically in small herds of three to six improved dairy stock. The largest scale farms had significantly more cattle than the other groups.

Most farms also had a few poultry, but less than half had sheep or goats and even then the numbers were usually only one or two. A small minority of farmers kept a few pigs.

The farming system described has intensified notably over the last fifty years or so. Fallowing is now unknown, and fertility is maintained by use of animal manures and mulching in the highlands, and by applying mineral fertiliser in the lowlands. Coffee planting was introduced in the 1920s by German missionaries and for long was the main cash earner. However, during the 1970s the combination of falling coffee prices and outbreaks of coffee berry disease led to a decline in the relative importance of coffee and an upsurge in dairying which has now become a more important source of cash for the majority of households.

3.2. Dairy cattle and their production parameters

Most of the cattle in the study area were stock improved for dairying with at least some European blood. The major cattle breeds are Friesians, Jersey, Ayrshire and crosses of these breeds with the local Zebu cattle. Only 7% of the sample cattle herd in 1990 were local Zebu. Table 2 shows estimates of production parameters by cattle breed and scale group.

Calving intervals varied between 16 and 22 months for the different kinds of cattle [5]. There were significant differences between the unimproved Zebu stock and the improved types, but not between scale groups.

Mortality rates averaged between 4 and 5% a year for adults, and between 9 and 10% for calves [6]. The cattle kept by richer households tended to have lower mortality for both adults and calves: differences between breeds were insignificant.

[5] The calving intervals found in this study for improved cattle breeds (crossbreeds, Jersey, Ayrshire and Friesian) were shorter than those reported by Zalla (1982) for Hai, but slightly longer than those reported by Biwi (1990), Kifaro (1984), Mchau (1991), Mpiri (1987), Shekimweri (1982), and Wolf (1987) for other parts of Tanzania.

[6] The average annual calf mortalities in Table 2 are slightly higher than that reported by Swai et al. (1992) but significantly lower than those reported by Mchau (1991), Wolf (1987), and Zalla (1982) for similar cattle breeds in similar farming systems. The adult mortality found for crossbreeds in this study is significantly higher than the figure reported by Wolf (1987). Comparisons of mortality rates between studies, however, need to be made cautiously because of their great variation with changes in climate, mortality rates being high during drought periods.

Lactation lengths varied according to cattle breed, between 9 and 11 months [7]. Irrespective of scale group, improved cattle appeared to lactate for longer than Zebu cattle. Milk yields varied considerably between cattle breeds [8] and scale groups. Improved cattle produced significantly more milk per cow per day than local Zebu, regardless of scale group. Amongst the improved cattle, Friesians produced more milk than Jerseys, Ayrshires and crossbreeds, probably reflecting differences in milk yield potential between these cattle breeds. Better-off households had higher milk yields per cow.

3.3. Cattle feeding and management

Since only one-third of households had access to grazing land, most cattle were stall-fed. Their basic diet consisted of banana leaves and stems, the stover and haulm from the lowland cereals crops, and grasses either harvested from the cultivated forage plots or collected from the forest and river banks (with some brought from the lowlands when weeding). Crop residues made up the bulk of the diet in the long dry season of December–February, whilst planted forages, wild grasses, cut fodder and banana trash were more abundant during the rains. They were fed ad libitum in the stalls. These feeds were supplemented by concentrates, above all by maize bran from local milling, bought-in minerals, and, for about half of households, the use of molasses and molasses/urea bought at subsidised prices from a dairy development project. Supplements such as concentrates and molasses were used sparingly, and given to lactating cows at milking time. Most cattle operations were carried out manually, mainly by the women of the household.

The use of bulls was more widespread than use of artificial insemination (AI) in the study area. AI was not readily available and was also constrained by lack of semen storage facilities, rendering it less reliable than use of bulls. Only 24% of the sample households used AI in 1990, and most of these also used bulls. About 20% of the sample households using bulls owned one or more and these bulls were shared with neighbours.

All surveyed households took advantage of the free rinderpest vaccines, subsidized anthrax vaccines and free veterinarian services provided by the government. Most sample households sprayed their animals against tick-borne diseases. The use of other vaccines and conventional medicines was limited by

Table 2
Sample households: cattle production parameters by breed and scale

Item	Scale group				
	Smallest	Lower middle	Upper middle	Largest	All
Calving interval (months):					
Zebu	22.3	22.0	20.0	na	21.2
Cross	18.2	17.8	17.3	16.4	17.5
Jersey	17.3	17.0	16.9	16.2	16.8
Ayrshire	16.7	16.5	15.8	15.3	16.0
Friesian	16.3	16.0	15.3	14.5	15.9
Adult mortality (%):					
Zebu	5.0	5.0	4.0	na	4.7
Cross	5.4	5.0	4.3	3.8	4.4
Jersey	5.0	4.7	4.0	4.1	4.3
Ayrshire	5.8	5.2	4.4	4.0	4.6
Friesian	5.6	5.2	4.5	4.0	4.4
Calf mortality (%):					
Zebu	10.0	9.0	8.4	na	9.2
Cross	10.3	9.6	9.1	7.4	9.1
Jersey	11.0	9.6	9.0	9.0	9.4
Ayrshire	10.7	10.0	9.0	9.0	9.5
Friesian	11.0	9.5	9.5	9.0	9.3
Lactation length (months):					
Zebu	9.3	9.0	9.5	na	9.3
Cross	11.3	11.2	11.2	10.7	11.1
Jersey	11.5	11.0	11.0	10.7	10.9
Ayrshire	11.5	11.0	10.8	10.3	10.9
Friesian	11.3	11.2	11.0	10.5	10.6
Milk yield (litres per cow per day):					
Zebu	2.2	2.4	2.3	na	2.3
Cross	4.9	5.2	5.4	6.6	5.4
Jersey	5.4	5.7	6.4	6.8	6.2
Ayrshire	5.4	5.9	6.6	6.7	6.4
Friesian	6.3	7.6	8.6	10.4	9.7

Source: Survey data, 1990
Note: 'na' since too few of the highest income farmers had Zebu cattle.

[7] The lactation length for Zebu in this study is slightly shorter than that reported by Ngategize (1989). For crossbred cattle, average lactation length in this study compares well with those reported by Mchau (1991), Mpiri (1987) and Shekimweri (1982).

[8] These results compare well with the findings reported by Biwi (1990), Mchau (1991), Shekimweri (1982) and Zalla (1982) who also found significant differences in milk yield between cattle breeds.

their shortage and few farmers could afford the prices of those available.

3.4. Dairy enterprise economics

Economic returns to dairying were assessed by use of a cost–benefit calculation of keeping dairy cattle to give summary measures of an internal rate of return (IRR) and a net present value (NPV), the latter expressed per livestock unit (LU) – a better measure for assessment of livestock enterprises than per animal because of variations in animal age and size (Upton, 1993).

To estimate costs and returns to keeping dairy cattle, four herds, each representing the average size and composition in each scale groups, were projected over 15 yr. The growth model was deterministic and assumed that the production parameters remained unchanged over the period – see Appendix A for details [9]. Table 3 summarizes the cattle herd sizes in each scale group in the initial year and after 15 yr. Assuming no feed limits, cattle herds would have grown at average annual rates of 5.2, 7.2, 8.1 and 8.4% for the smallest, lower middle, upper middle and largest scale groups, respectively.

Estimated benefits included the value of milk, manure, culled animals, and of herd inventory gains. Milk was valued at T.shs 62.8 a litre, the weighted average of prices paid in the various marketing channels. This was multiplied by the average yield per lactation for each group (1470, 1697, 2077, and 2595 litres per cow from smallest to largest scale group).

Table 3
Change in average herd size per household by scale group

Item	Scale group			
	Smallest	Lower middle	Upper middle	Largest
Head of cattle				
Initial herd size	3.2	3.6	3.8	6.8
Year 15 herd size	6.7	10	11.8	22.7

Source: Herd projections

Manure was normally used to maintain fertility in coffee–banana and pasture plots in the highland zone. The reported market price of T.shs 2 per (four gallon) tin ('debe') of cattle manure was used in estimating the value of manure, giving annual value of manure production per animal of T.shs 1095 [10].

Culled animals and herd inventory gains were valued using market prices. Inventory gain was calculated by subtracting opening from closing valuations of the cattle herds using market prices, and discounting the result.

The costs of dairy production considered in the analysis were those of feed, labour, veterinary treatment, stalls and other equipment [11]. Estimates of these are summarized in Table 4. Crop residues costs consisted of expenses incurred in purchasing and transporting crop residues from the lowland to the highland zone. Concentrate costs were estimated by the amount used per household valued at the average price of T.shs 2 426 per 50 kg bag in 1990. The costs of planted forages include labour for cultivation, planting, manure application, irrigation and harvest; plus the opportunity cost of the land occupied

[9] To make the modelling tractable, no limits were placed on the number of animals in the herds, other than culling of older animals (set at 14% for cows and 35% for bulls), allowing them to grow unrestricted by considerations of feed availability. In reality, however, farmers with herds that grow are likely to take off stock for sale or home consumption, in addition to culls. Unfortunately, it is impossible to say with any certainty when such removals would take place. Leaving the animals in the modelled herds produces a large inventory gain. This is not a problem in estimating the benefits to keeping dairy cattle, so long as the value of any stock that would in reality have been taken off was considered equivalent to the sum of their discounted net benefits – a reasonable assumption. An alternative would have been to have modelled the herd sizes as constant and to have taken off in each year any additional stock. But given that farmers in the area were increasing the number of cows kept, this would have been no more realistic than expansion without limit.

[10] An estimate of 1.5 'debes' of fresh cow dung collected daily from one cow was obtained using information from the sample households. This is equal to about 5.4 tons of manure per cow per year. An alternative method of estimating the value of manure would be to use its fertilizer value in terms of nutrient status, but calculations of the fertilizer value of manure were lacking in the study area.

[11] Costs were calculated per livestock unit, and these figures were then multiplied by the number of stock predicted by the growth models to get total costs for an herd in a given year.

Table 4
Costs of dairy production by scale group

Cost item	Scale group			
	Smallest	Lower middle	Upper middle	Largest
T.shs per LU per year				
Crop residues (1)	2065	2971	3796	6147
Concentrates	2164	3513	4235	10823
Planted forages	2841	2665	5526	3559
Other feeds	1017	1647	2421	5473
Hired labour	1092	1893	2581	5934
Family labour	19941	22254	24253	19481
Stall, equipment	2160	2101	2751	2031
Veterinary bills	580	938	2015	4291
Total	31860	37982	47578	57739
Feed	8087	10796	15978	26002
Labour	21033	24147	26834	25415
Other	2740	3039	4766	6322

Source: Survey data, 1990
Note 1: Cost of labour for crop residue collection and head carrying appears under labour costs
LU = livestock unit

by the forage crops, taken as the annualised net value of coffee and banana production [12] given up.

Other feed costs include those of purchasing and transporting hay, mineral, molasses and molasses–urea mixture. Whilst hay and minerals were valued at the average market prices in 1990, molasses were valued at a subsidized price of T.shs 57 per litre. Veterinary costs include various veterinary medicines, deworming and treatment of other cattle diseases, dipping against ticks, and vaccinations. All were highly subsidized by the government.

Labour costs consisted of hired labour, valued at the market price of T.shs 21.7 per hour in 1990, plus the opportunity cost of household labour used for dairy activities. This latter was taken as the going rate in farm work, since there were few better-paid jobs available.

The main capital costs in dairying were those of building a stall and acquiring tools like a hand sprayer, wheelbarrow, feed chopper, pails, etc. The costs entered in Table 4 are annualised values of these assets.

It is clear from Table 4 that the larger scale farmers invest more heavily in their dairy cattle, but most of the difference between the spending is accounted for by feed, and above all by concentrates and molasses.

Estimating a discount rate to reflect opportunity cost of capital and the rate of social time preference rate is fraught with difficulty. Whilst the willingness to make long-term investments in the study area suggests low discounting of the future, the value of capital and the need to consume in the short-run cannot be set lightly aside. On balance, the average rate of borrowing of 7% per annum, reported by the sample households which borrowed cash in 1990 was adopted. This is a somewhat lower discount rate than those typically used in project appraisal, where rates of 10–12% are common (Gittinger, 1982).

Table 5 summarizes the results of the analysis. Two results are striking. First, discounted benefits outweighed discounted costs of dairy production for all scale groups, giving positive net present values per livestock unit (NPV/LU), and these increased with scale. Second, the rates of return (IRRs) to dairying were high, at 19–20%, well above the assumed discount rate, but, surprisingly, both IRRs and benefit-cost ratios (B/C) to dairying were virtually identical across the groups.

Although smallholder dairying gave good returns, benefit-cost ratios of only 1.1 suggest that net returns were sensitive to key parameters such as milk yields,

Table 5
Summary of the base run results of the budgeting analysis

Item	Scale group			
	Smallest	Lower middle	Upper middle	Largest
Discounted benefits (T.shs/LU)	624741	854077	1011127	1316878
Discounted costs (T.shs/LU)	596961	771168	923195	1206591
NPV per LU (T.shs)	56777	82909	87932	110287
Internal rate of return (%)	20.0	19.2	21.1	19.9
Benefit-cost ratio	1.1	1.1	1.1	1.1

Source: Budgeting analysis

[12] Since coffee and bananas are perennials, the calculation involved computing net returns to the two crops over 10 yr, discounting them, summing them, and then using an annuity factor to get an annualised net present value for coffee and banana cultivation.

milk prices, and input costs. For example, whilst at milk prices averaging T.shs 62.8 a litre NPV/LU was large and positive, only a 12% price fall would reduce the NPV/LU to zero. This price, T.shs 55 a litre, was still above the price offered to farmers by TDL in 1990 of T.shs 51.33 a litre. Thus over-production of milk or significantly reduced demand for milk could be a major risk to dairy production. The largest scale farmers would be most vulnerable to falling prices.

On the cost side, smallholder dairy production in Hai District was subsidized through government programmes and donor agencies which provided direct subsidies to molasses or molasses/urea and veterinary medicines, vaccines and services. In addition, diesel fuel was also subsidised, cutting motorised transport costs. If these inputs were not subsidised, returns to dairying would have been greatly affected. Removing the diesel subsidy reduces the NPV/LU by 56% in the smallest and by 147% in the largest scale group. Taking away the molasses subsidy would cause NPV/LU to fall by 6 and 19% for the smallest and largest scale groups respectively, whilst removing the veterinary subsidies would reduce NPV/LU by 8 and 38% for the same two groups. If all subsidies went, then the NPV/LU would fall to zero for the smallest scale group, and would become minus T.shs 143 242 for the largest scale group.

4. Discussion and implications for dairy development and policy

The results of this analysis confirm the financial attractiveness of dairying: 20% is an excellent return on investment.

Since the mid 1970s, dairying in Hai has intensified in terms of improved cattle breeds and feeding practices. Many smallholder farmers, especially the larger scale, prefer raising Friesians because of their high potential for milk yield.

It is, however, somewhat surprising that comparisons between the scale groups suggest that there is no increase in the rate of return to capital from adopting the upgraded animals or using more intensive systems or both. Internal rates of return and benefit–cost ratios were almost identical across the scale groups, despite the marked differences in the intensity of spending on feed seen in different scale groups. The better technical results achieved by the larger scale farmers using more intensive management and more specialised breeds have been gained by spending on inputs to a point where the marginal return – a ratio of marginal benefit to marginal cost of 1.1 to 1 – has been the same as that obtained in lower-input systems with less impressive technical results.

On the other hand, if the smaller scale dairy farmers were prepared to invest to obtain similar rates of return and benefit–cost ratios as their larger-scale neighbours, albeit on a lesser scale and intensity, why did they not invest in better cattle and more feed? Probably the answer lies partly in not having the capital to make investments (and perhaps also not having confidence in their ability to manage a more intensive system). But perhaps of more importance is the added risk of the more intensive systems where returns are more sensitive to the price of milk sold and the cost of purchased inputs.

Moreover, the returns to larger scale dairy farmers have only been possible through subsidies. The economics of intensive raising of Friesians were more sensitive to removal of dairy input subsidies and to increases in the transport costs resulting from charging border prices of fuel, than those pertaining to lower intensity rearing of crossbreeds. It seems that the pattern intensive raising of Friesians in Hai is only viable with government subsidies.

Policy makers and donor-funded dairy development programmes, it appears, may have over-encouraged intensive dairying and subsidised the larger scale (and better-off) farmers to adopt technology which depends on subsidies to be profitable. Subsidising intensive dairying is difficult to justify economically, and still less socially. Since the Tanzanian government is short of funds, it might reconsider if it should spend money subsidising such inputs, or whether funds would be better spent on other purposes, such as improving the feeder roads of Hai so that access to markets during the rains is improved.

Of course, if the larger scale farmers had to bear the full costs of their inputs, it is unlikely that they would abandon their Friesians but rather would modify their dairying systems – perhaps reducing the use of molasses and using more cut fodder. They would almost certainly try to cut the costs of hauling crop residues up the mountain, by using less expensive transport or by baling residues. The overall conclusion is that research efforts should be directed as much towards reducing unit costs of production and marketing as towards boosting yields. Given the impact that changes, quite small in some cases, in milk prices and input costs can have on the returns to dairying, development programmes need to present farmers with a 'menu' of technical options which allows them to adjust to the inevitable changes that take place in relative prices. Such a menu would also recognise the needs of dairy farmers of different scale, who probably face different availabilities of capital, management skill, and ability to bear risk.

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Appendix A

A.1. The herd model

The inputs used in the herd projection were initial herd structures, calving, culling and mortality rates. Since cattle herds of individual households in each scale group were small, all cattle owned by households in the same scale group were considered as one herd. This solved the problem of having fractional animals in the herd projection which happens when the technical coefficients are applied to the number of animals in a small herd. The herd in each scale group was divided into ten age/sex classes (cohorts), with the number in each cohort given in Table 6. The calving, mortality and culling are incorporated in the model as annual production parameters. These parameters were assumed to remain constant throughout the projection period of 15 yr.

Other assumptions used in the model:

(i) No animal leaves the sample herd in each scale group other than by way of unplanned death until it

Table 6
Initial herd structures and parameters used for the herd projection

Item	Scale group			
	Smallest	Lower middle	Upper middle	Largest
Initial herd structure:				
Cows aged 3 yr or more	33	39	76	89
Heifers aged 2–3 yr	10	13	8	18
Heifers aged 1–2 yr	10	8	10	19
Female calves aged 6 months to 1 yr	6	10	10	16
Female calves aged under 6 months	6	10	10	17
Bulls aged 3 yr or more	2	3	4	11
Steers aged 2–3 yr	2	3	4	3
Steers aged 1–2 yr	4	3	3	5
Male calves aged 6 months to 1 yr	5	2	7	16
Male calves aged under 6 months	4	2	7	16
Production parameters (all %):				
Weighted mean calving rate	67.90	69.80	72.00	74.50
Weighted mean adult mortality	5.40	5.00	4.30	4.00
Weighted mean calf mortality	10.50	9.50	9.10	8.40
Culling rate for cows	14.00	14.00	14.00	14.00
Culling rate for bulls	35.00	35.00	35.00	35.00

reaches the age of 3 yr or over, after which it could die a natural death or be culled because of reproductive failure or old age.

(ii) The initial number of animals (in year 0) in each animal class is based on actual number of animals reported by the sample farmers in each scale group.

(iii) The mortality rates for each animal class and fertility rate of cows are constant over the entire period of 15 yr.

(iv) The animals that die in each period die at the end of that period. Thus the reduction in their number is observed in the next age class.

(v) The number of male and female calves born each year are equal. It is further assumed that half of the calves are born at the first half and the other half at the second half of the year. Hence only those calves born in the first half of the year are promoted to heifers or steers (1–2 yr) at the end of the year.

(vi) The number of male or female calves aged 0–0.5 yr in year t, is given by:

$$X1_t = X6_{t-1} \times C/4,$$

where $X1_t$ is the number of male or female calves of age 0–0.5 in year t, $X6_{t-1}$ is the number of breeding cows in the previous year, and C is the calving rate for the herd.

(vii) The number of male or female calves aged 0.5–1.0 yr in year t is given by:

$$X2_t = X1_{t-1} - X1_{t-1} \times M_1 + X6_{t-1} \times C/4 - (X_t \times C/4) M_2,$$

where $X2_t$ is number of calves aged 0.5–1 yr in year t, M_1 is mortality rate of calves aged 0–0.5 yr, and M_2 is mortality rate of calves aged 0.5–1 yr.

(viii) The number of heifers or steers in each age class is calculated as follows:

$$X_j = X_{j-1} - X_{j-1} \times M_{j-1},$$

where X_j is the number of animals in the jth age and sex class, X_{j-1} is the number of animals in the immediately junior age in each sex class in the previous year, and M_{j-1} is mortality rate of the previous age class.

(ix) The number of cows or bulls (aged 3 yr and above) in year t is given by:

$$X6_t = X5_{t-1} - X5_{t-1} \times M_5 + X6_{t-1} - X6_{t-1} M_6 - X6_{t-1} \times C_u,$$

where $X5$ is the number of animals in the previous animal class, $X6$ is the number cows or bulls (aged 3 yr and above), M_5 is mortality rate of animals in the previous class, M_6 is mortality rate of animals in the last class, and C_u is culling rate of cows or bulls.

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