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ECONOMIC AND TECHNICAL ASPECTS OF SMALLHOLDER MILK PRODUCTION IN NORTHERN TANZANIA

By

Thomas M. Zalla

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1982

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THOMAS M. ZALLA

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ABSTRACT

ECONOMIC AND TECHNICAL ASPECTS OF SMALLHOLDER MILK PRODUCTION IN NORTHERN TANZANIA

By

Thomas M. Zalla

This study provides data on smallholder milk production on Mount Kilimanjaro. It analyzes alternative smallholder milk production systems in current use there and outlines a strategy for expanding smallholder milk production on the mountain.

Data for the study were gathered in 1973 from a single visit farm management survey of over 680 randomly selected households in the coffee-banana zone of Mount Kilimanjaro. These are discussed and analyzed in the context of post-Hicksian neo-classical economic theory as well as the political and social context of Tanzania. Technical data are supplemented with information on production traits and management practices for cattle available from elsewhere in Africa.

The study estimates that zebu cattle and grade cattle each accounted for about one-half of cattle milk production on the mountain in 1973 even though only 12 percent of all cattle were grade dairy animals. Lactation milk production averages around 380 liters for zebu cattle and 1,470 liters for grade cattle, net of milk suckled by calves. Reducing calf mortality and the calving interval by making veterinary and breeding services more easily available to farmers

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appear to be the only two factors that are likely to lead to substantial increases in milk production by zebu cows. For grade cows the marginal value product of resources invested in providing water, salt, grain products and forage are all considerably in excess of their marginal factor cost and the potential for increasing milk production quite significant. Overall, variables over which a well-organized extension service can have some influence explain about 70 percent of the variation in milk production for grade cows.

The economic analysis of returns to alternative milk production systems shows that upgrading zebu cattle yields returns to resources that are considerably above their opportunity cost and not far below the returns available from a pure grade dairy enterprise that requires much more sophisticated management and over twice the capital investment. The major constraint on expansion of upgraded and grade cattle milk production is a dearth of good quality grade bulls and poorly functioning extension and artificial insemination programs. Forage supplies are also a problem. Improvement of extension and veterinary services and research into forage crops that can be integrated into existing farming systems merit immediate attention.

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Education involves the assimilation of ideas and observations from teachers, colleagues, family, students, scholars and others in such a way that their contribution to our knowledge and skills is not always obvious. I wish to publicly acknowledge the contribution of a few such people to the intellectual content of this dissertation without in any way diminishing the contribution of others less remembered but equally helpful. In particular I wish to express my gratitude to Mark Wurtz, Clive Thomas, Manuel Gottlieb and other colleagues at the University of Dar es Salaam for their stimulating insights and patient explanations of dimensions of political economy which, though no longer so evident in the body of this paper, have had a profound impact on my understanding of economic and social dynamics. I also wish to express my appreciation to Lester Manderscheid in helping me to grapple with some of the methodological issues raised by this study and in methodically reading and commenting on the many drafts of various components that have risen and fallen over the past several years. Tjaart Schillhorn-van-Veen has played a similar and equally valuable role over a somewhat shorter period. Glenn Johnson was another persistent and loyal critic who persevered in his efforts to keep me from wandering too far from the fold.

Though the intellectual contributions to a work such as this are usually the most obvious they are not always the most essential.

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KEY TO EXCHANGE RATE AND CURRENCY EXPRESSIONS

1/= = One Tanzanian Shilling = 100 Tanzanian Cents = $.14 U.S.

7/14 = Seven Shillings And Fourteen Cents = $1.00 U.S.

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CHAPTER I

HISTORICAL FRAMEWORK

A. Introduction and Purpose

This study investigates political and economic aspects of the smallholder dairy industry on Mount Kilimanjaro in Northern Tanzania as it existed in 1973-74. The mountain contains about 60 percent of the grade cattle[1] on small holdings in Tanzania and produces about 30 percent of the country's coffee—its principal export in 1973. The research was stimulated by government concern over the rapidly rising dairy imports and declining coffee prices which were occurring during the 1960s. Expanded smallholder milk production in Kilimanjaro was seen as the antidote for both these problems while helping to alleviate an increasingly visible young child nutrition problem in the areas.

Specifically, the study has three objectives: 1) to provide farm management data on smallholder milk producers in Kilimanjaro for planning purposes; 2) to analyze alternative smallholder milk production and 3) to outline a strategy for expanding smallholder milk production in Kilimanjaro should policy-makers decide that it is desirable in light of the analytical results obtained.

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[1] Grade cattle in East Africa refer to dairy animals with varying amounts of exotic genes. For the purposes of this study a grade dairy animal is defined as one with sufficient exotic genes to have lost the hump typical of the Tanzania Short Horn Zebu, the dominant type in Tanzania. The hump generally disappears when zebu cattle are crossbred to European breeds of cattle.

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Input-output data for the study were gathered from a single visit farm management survey of over 680 households in the coffee-banana zone of the mountain. The study also reflects on some strengths and weaknesses of post-Hicksian modern market economics and gives some attention to historical and contemporary political economy issues, especially as these relate to defining a viable strategy for promoting agricultural development in Kilimanjaro.[1]

This chapter outlines the geographical, historical and political context of the smallholder dairy industry in Kilimanjaro. Chapter II offers some perspectives on post-Hicksian neo-classical theory and delimits the context of the analysis of enterprise returns. Chapter III outlines important social, economic and political dimensions of the survey area and begins the discussion of the dairy industry in Kilimanjaro. It also outlines the various production systems in use as well as current government assistance provided to the industry. Chapter IV details the structure of both the zebu and grade cattle herds as well as offtake, mortality and other dynamic aspects of each, based on data gathered in the farm management survey. Chapter V estimates aggregate milk production, presents a brief summary of milk marketing on the mountain, and discusses some public health aspects of encouraging interfarm sales of unpasteurized milk. In Chapter VI management practices for each of the herds are outlined

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[1]Almost the entire mountain and surrounding lowlands lie in what, until 1973, was Kilimanjaro District. In 1973 Kilimanjaro District was split into two new districts, Moshi and Rombo Districts. It is this area we refer to when speaking of Kilimanjaro. It is to be distinguished from Kilimanjaro Region which includes, in addition to Moshi and Rombo Districts, a third district, Pare District. Pare District covers the Pare Mountains to the southeast of Mount Kilimanjaro.

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and lactation milk yields are estimated. Chapter VII looks at labor and other inputs used in milk production.

In Chapter VIII the determinants of milk production for both zebu and grade cows are analyzed using ordinary least squares multiple regression. Then, in Chapter IX eight separate enterprise size/type combinations are simulated and capital budgets measuring their economic profitability are analyzed. The potential of each of these systems for increasing milk production is also discussed. Finally the last chapter, Chapter X, summarizes the findings of the study, outlines interventions for upgrading the smallholder dairy industry in Kilimanjaro and speculates on the impact of an upgraded dairy industry on coffee production. It raises some unresolved policy issues and concludes by suggesting areas needing further research.

B. Geographical Description

1. Tanzania

The United Republic of Tanzania is a loose union formed in 1964 between Tanganyika, a former British East Africa Trust Territory which received independence in 1961, and the Island of Zanzibar, a former British Protectorate which received independence in 1963. The political evolution of Tanzania is very much dominated by its charismatic president, Julius Nyerere. A one party state, Tanzania nonetheless experiences some sharp and remarkably candid debate, centered in TANU (Tanganyika African National Union), the only political party on the mainland.

Tanzania has an area of 363,000 square miles, about the size of Texas and Oklahoma combined. The country is bounded on both north and south by mount

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south by mountains and highlands which have a rather temperate climate and some of the most fertile soils and highest population densities in Africa. Its vast interior is largely dry to semi-arid bush with very low population density. Overall, the country's land resources are sufficiently varied in soil type, topography and climate so as to provide a base for a diversified and productive agriculture.

Tanzania's 1973 population was estimated to be 14.4 million with an aggregate growth rate of about 2.7 percent per year. About 410,000 of this total are located in Zanzibar [Egero and Henin, 1973]. The population is composed of more than 130 ethnic groups of African origin, the largest of which, the Sukuma, comprise about 13 percent of total mainland population. Only slightly more than 1 percent of the population is non-African [Lucas and Philippson, 1973].

Like most African countries, Tanzania is predominantly agricultural with 93 percent of the mainland population living in rural areas and 90 percent of the economically active segment describing their main occupation as agriculture [Tanzania, 1971b]. Major agricultural enterprises by order of the farm value of output are sugar (450), maize (440), cattle (385), bananas (385), coffee (355), cotton (290), cassava (285), millet and sorghum (175), sisal (140), cashew (130), paddy (110) and beans (100).[1] Major agricultural exports in 1973,

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[1]Figures in parentheses are the farm value of output in millions of shillings. Quantities are 1972 harvested production for maize, bananas, cassava, millet and sorghum, paddy and beans; 1973 marketed production for sugar, coffee, cotton, sisal and cashew; and 1973 total offtake for cattle. The value for cattle does not include the farm value of milk, hides or manure. Producer prices are those prevailing in the 1974-75 crop year except for beans, and sugar. For the latter two crops the 1972 price was used. Prices and quantities were taken from International Bank for Reconstruction and Development [1974]. Additional prices imputed by the author were 320 shillings per ton for

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using FOB values, were coffee (495), cotton (333), cloves (233), sisal (222) and cashews (141). Diamond (170) exports are important but sisal cord (72) is the only manufactured export of any significance. In the aggregate, raw and semi-processed agricultural products accounted for 80 percent of total export earnings in 1973.[1]

1973 GDP for mainland Tanzania was estimated to be 11,257 million shillings or about $112 per capita at exchange rates then prevailing. Thirty-nine percent of this originated in agriculture and 21 percent in the subsistence sector which includes both agricultural and non-agricultural subsistence activities. Over the 1968-73 period the real growth rate in agriculture averaged about 2.4 percent as compared with 4.4 percent for GDP and 2.7 percent for population. Noteworthy in the GDP growth rate, however, is the 8.6 percent growth rate in public administration and other services accounting for over 9 percent of GDP by 1973. After allowing for growth in these and other services of dubious productive value, it appears that overall goods available for consumption and investment barely kept up with the growth in population over this period.[2]

2. Kilimanjaro

The actual area covered by the farm survey includes only the coffee-banana belt of Mount Kilimanjaro. This area lies between 3000

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bananas and 350 shillings per head for livestock. These figures indicate orders of magnitude only and do not include Zanzibar.

[1]Figures for cashews do not include 32.7 million shillings worth of processed cashew products. All figures include intra-community transfers [East African Customs and Excise Department, 1973].

[2]1973 national accounts and growth rates taken from International Bank for Reconstruction and Development [1974].

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and 6000 feet but includes about 95 percent of all households in Rombo District and 77 percent of those in Moshi District. The 1973 population of the survey area is estimated to have been 475,000 persons in 86,500 households.

The high volcanic peaks of Mount Kilimanjaro (19,390 feet) dominate the climate, topography and soils of the two districts. Rainfall has a bimodal distribution and is concentrated on the southern slopes. It increases with altitude up to about 10,000 feet and diminishes thereafter. Mean annual rainfall on the southern side of the mountain ranges from 34 inches in Moshi Town, which lies at about the 3000 feet level, to over 90 inches at Kibosho Mission (5000 feet), six miles up the mountain from Moshi Town [Brevin, 1965]. Still higher amounts fall in the uninhabited rain forests which circle the mountain between 6000 and 10,000 feet. Rainfall diminishes moving along the eastern and western slopes in a northern direction and the north slope is dry and sparsely populated. Mean annual temperatures follow a reverse pattern with a mean value of about 74° in Moshi Town and much lower temperatures on the upper slopes [Tanzania, 1972].

Ethnically practically all of the population included in the survey area are Chagga (99 percent), historically an amalgamation of some 400 clans which have come to inhabit the mountain over the past 300-400 years [Marealle, 1952]. The Chagga are noted for their excellent animal husbandry and agricultural practices. Their cattle are almost entirely stall fed[1] and the accumulated manure is valued for the banana groves surrounding the homestead—bananas being a staple of

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[1]Stall feeding is a zero grazing system. All the forage and water is brought to the animals, usually by women, often carried as far as three miles.

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the Chagga. Banana by-products, in turn provide an important source of energy, roughage and water for their cattle.

The Chagga irrigate their farms by means of an intricate and sophisticated network of gravity fed irrigation furrows which rise up the sides of steep river valleys and crisscross the entire coffee-banana belt. At the present time this system has reached the limit of available dry season water supplies and little has been done in recent years to harness greater volumes of water. Nevertheless it remains an impressive tribute to the organizational and technical ingenuity of the Chagga.

C. The Colonial Heritage

Turning toward historical forces which have left their mark on the political economy of Kilimanjaro and its dairy industry, four are of particular interest to the present study: German commercial policy, the commercialization of African agriculture, the influence of Christian missionaries, and the growth in population and land pressure. The first three have contributed in a fundamental way to the extreme social and economic differentiation which exists within Kilimanjaro, and between Kilimanjaro and most other areas of the country. As such they provide important background to Tanzania's socialist objectives—in part a reaction to the differentiation and unequal opportunity which these forces created. Together with population growth on the mountain they have led until recently to a secular decline in the dairy industry in Kilimanjaro—per capita milk production in the area today probably amounting to no more than 25 percent of what it was 50 years ago. Clearly, any effort to reverse this trend requires an understanding of these forces and how they developed.

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1. German Commercial Policy

The main thrust of German colonial and commercial policy in East Africa was the development of plantation agriculture. Early in the German period a large concentration of settler agriculture arose in Kilimanjaro. A few coffee estates were established on the upper slopes of the mountain in areas inhabited by Africans, but never so many as to close off African expansion in the same way as it did on Mount Meru to the west. The majority of settlers in Kilimanjaro located on the drier, lower slopes where sisal, grains and legumes did well [Iliffe, 1971; Calvert, 1970].

German commercial policy had two lasting effects on the political economy of Kilimanjaro: it introduced and firmly established an export orientation and through this, was a factor in setting in motion a process of capital accumulation in an area already very favorably endowed with agricultural resources. The Tanga-Moshi rail link was completed in 1912 opening the area to world markets and establishing the metropolitan-periphery communication links which have dominated Tanzania's economy up to this day. By the beginning of the First World War the plantation sector had gained a powerful position in the Tanganyikan economy as it supplied the needs of Europe with the resources of Tanganyika.[1]

The emerging African commercial agricultural sector quickly adopted this export orientation, guided by effective demand which originated in Europe. Hut and poll taxes, initially imposed to force Africans to provide wage labor for the estates, exposed African

[1]For an excellent account of the dynamics of this process see Iliffe [1971].

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farmers to cultivation of exotic export crops. By the late 1920's Chagga farmers no longer were willing to work on the estates of Europeans and began to produce coffee on their own farms. In 1925 Chagga farmers formed the first Association of African Coffee Planters which grew into the powerful present-day Kilimanjaro Native Cooperative Union [KNCU, 1963]. Kilimanjaro thus got an early start relative to the rest of Tanzania in the development of commercial agriculture and the accumulation of capital made possible by it.

2. The Commercialization of African Agriculture

By the late 1920's African cash crop production in Tanzania had become firmly established and quickly grew to rival the plantation sector in economic power and significance. Coffee production in Kilimanjaro continued to expand, even during the depression, as did cotton production on small holdings in Sukumaland [IBRD, 1961].

The major expansion in African commercial agriculture in Tanganyika occurred in the period 1945-60 when the gross value of agricultural exports increased 6-1/2 times or more than 13 percent per year compounded [Fuggles-Couchman, 1964]. Coffee production on small holdings in Kilimanjaro did not increase so rapidly, doubling roughly every 10 years after 1935, but the advance was, nonetheless, impressive. Maize production in the Northern Province also increased rapidly as household consumption skyrocketed and marketed production increased 3-1/2 fold between 1945-47 and 1965-67.[1] Table 1.1 outlines the growth in marketed production of these and other crops for Tanganyika as a whole during this period.

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[1] For the 1945-47 production see Tanganyika Territory Department of Agriculture Annual Report, 1952. The 1965-67 figures are taken from Tanzania [1974].

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Pulses
•Pyrethrum
Rubber (exports)
•Seed beans
•Sisal
•Sugar
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TABLE 1.1

SALES OF CROPS IN TANGANYIKA, 1945, 1952 AND 1960
(LONG TONS)

Crop	1945	1952	1960
Cashew nuts	2,669	10,809	55,252
Cassava (manioc)	4,080[a]	29,277	29,659
Cereals			
Finger millet (eleusine)	...	...	12,800
Maize	20,450	42,316	77,946
Rice (paddy)	8,739[c]	15,639	34,859[b,d]
† Wheat	3,975[e]	5,264	11,660
†Coffee (clean)			
Mild			
Estate	2,290	7,359	7,170[d]
African	3,462		14,208[d]
Hard	8,213	9,122	9,746
†Cotton (raw)[f]	7,512	14,109	34,241[g]
Essential oils (exports)	10	3	3
Kapok	140	443	986
Oilseeds and oil			
Castor seed	428	7,239	10,925
Copra	10,000	14,893	9,544
Cottonseed	7,600[h]	15,000[h]	52,817
Groundnuts	4,756[i]	10,882	22,852
Oil palm			
Oil	65	35	95
Kernels	42	334	761
Sesame seed	3,810	1,899	9,482
Sunflower seed	2,288[j]	12,292	7,314
Onions	2,654	2,160	8,058
Papain (exports)	101	43	72
Potatoes (European)	2,000	1,880	3,000[h]
Pulses	4,480	20,751	24,443
†Pyrethrum	799	240	1,010
Rubber (exports)	2,320	2	...
†Seed beans	490	1,651	5,620
†Sisal	112,218	162,185	204,868
†Sugar	7,300	9,666	28,624
†Tea	580	1,117	3,722
†Tobacco			
Flue-cured	595	1,074	1,801
Fire-cured	248	597	498
Vegetables	2,000[h]	...	3,000[h]

SOURCE: N.R. Fuggles-Couchman, 1964. Agricultural Change in Tanganyika: 1945-1960: Stanford: Food Research Institute, p. 40.

°Data from Tanganyika, Dept. Agr., Annual Reports, 1945-60.
†Sales of these crops may be considered as total production.

[a]1946. [b]Crop in Western Region was five times that of 1945. [c]Bad year.

[d]Above average season.

[e]Excludes 6,837 tons produced by the Government War Wheat Scheme.

[f]Converted to long tons, assuming bales weigh approximately 400 pounds.

[g]The 1959 crop was 36,579 tons. [h]Estimated. [i]Drought in the Lake Region.

[j]1948, the first year of production.

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This rapid expansion of commercial agriculture among African farmers led to increasing economic differentiation between and within different areas of the country. While development in those areas continuing to export labor to the plantation sector was stagnating, areas ecologically more favorable for agricultural production—Kilimanjaro, West Lake and Mwanza—became more actively engaged in cash crop production. The world market, which received most of their crops via the transportation network established for the plantations, facilitated accumulation of wealth and capital in a way not possible in a traditional, locally interdependent, essentially closed system, where price effects eventually shift the gains of increasing relative output to local consumers. The first areas to concentrate on cash crops thereby established an early lead over other less favored areas and added an ever increasing capital accumulation advantage to their existing ecological advantage.

Cash cropping led to increasing social and economic differentiation within the major producing areas themselves as well. The incentive for accumulation which it offered stimulated an expansion of land under cultivation which led, in turn, to favoritism, increasingly severe conflicts over land, and abandonment of traditional guarantees of access. The large number of court cases involving land disputes in Kilimanjaro, one of the most highly differentiated areas of the country, provides evidence of this.[1]

It was the larger, more commercial farmers who led the rapidly growing cooperative movement during this period (1945-60). Frequently

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[1] For an analysis of court cases including land disputes see Maro [1974].

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the cooperatives became tools of these elite farmers and provided opportunities for further accumulation of capital, often at the expense of the less educated, less knowledgeable membership. The cooperative movement in Kilimanjaro to this day is dominated by this class of farmers which, as we shall see later, has been able to initiate cooperative services which benefit themselves at the expense of other members.

3. Influence of Christian Missionaries

Early mission activity in Tanzania tended to be concentrated in the more temperate, agriculturally more favorable areas of the country and Kilimanjaro was not overlooked. Mission activity there began in 1884. By 1910 missions had carved up the mountain into separate distinct spheres of religious influence.

The Chagga quickly grasped the importance of education as a means of improvement within the colonial structure. As a result, mission enrollment showed remarkable progress in the period preceding the First World War. By 1914 Shann [1956] counts 20,000 children enrolled in mission schools in Kilimanjaro. Although this figure may be somewhat high it does indicate that this area of Tanganyika established its lead over the rest of the country in access to education at a very early stage.

Mission education throughout Tanzania was, at one and the same time, divisive and a stimulus for improvement. Generally strict, it promoted European ideals of behavior—individualism, enterprise and material improvement. In so doing it weakened many traditions which tended to make material improvement a collective as opposed to an individual affair. As a result it encouraged a process of internal differentiation which continues to the present. Attacking many traditiona

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traditional customs as uncivilized—sometimes not realizing the important role they played in maintaining a delicate techno-ecological balance—mission teachings often had the effect of dividing African societies. The seriousness of this division became apparent in the Maji-Maji uprising which very clearly was directed against missions and their converts.[1]

The very forces which divided traditional societies, created an opportunity for personal improvement which previously did not exist. The Christian educated convert came to be regarded as an example of modern man. Some were finding in modern education access to wage employment and the beginning of capital accumulation. Others found in it a basis for social and political authority. Still others perceived in it the means of overcoming what they had come to believe was the technical weakness of their own societies <u>vis</u> <u>a</u> <u>vis</u> the Europeans. Yet whatever the motivation for individuals and families seeking education for their children, mission education with its foreign value system led to growing economic and social division.

Ranger [1969] very succinctly sums up the feelings which were running through Tanzanian society at that time:

> It can be seen then that as far as religious ideas are concerned there was a great deal going on amongst Tanzanians in the 1920's and 1930's and that not all developments were in the same direction. Some people were finding in orthodox Christianity or Islam a way of entering the new colonial world and of making opportunities for themselves. Other people were reacting against the inequalities of the colonial world, often drawing upon the Bible and the Koran to do so. There was tension between the

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[1]The Maji-Maji uprising was an armed uprising against German rule which took place in 1905-07. An estimated 120,000 Tanzanians died before active resistance was crushed. Tanzania's total population at this time was only 4 million. For more detailed accounts of the uprising, see Gwassa [1969] and Iliffe [1969].

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improvers and the egalitarians. In this way these religious arguments started many of the political arguments which have become important in independent Tanzania.

It is important here to realize that the critics of the improvers were not all of them blindly reacting against change. Some of them, like the African National Church, wanted change but under some sort of control so that it did not bring inequality and division with it. They also wanted to protect the customs and ideas of African society from unnecessary attack. They were saying in their various ways that a man could be a Christian or a Muslim or adopt new economic practices and still remain in essentials an African.[1]

4. Population Growth and Land Pressure

Table 1.2 describes the growth in the population of Chagga both in Kilimanjaro and on the mainland as a whole. The figures date back to 1921, the first year for which an estimate is available. From 1948 onward, the figures are actual census results.

The rate of growth of population in Kilimanjaro District for the period 1921-31 was 1.9 percent, about the same as for mainland Tanzania. From 1948 to 1967 population growth in the district increased to almost 3.2 percent per year as compared to 2.5 percent for the mainland. However, the growth rate of the Chagga population in the district was not as great as that for the district as a whole, amounting only to 2.9 percent per year from 1948 to 1967. The same rate of growth no doubt prevailed in the survey area since few non-Chagga live there.

In spite of the fairly high rates of growth in population which existed prior to 1940, land pressure in Kilimanjaro was not a pressing social problem, although it was in evidence. During the first quarter of the 20th century ample land for new settlement was available within

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[1] Ranger [1969, p. 184].

HUMAN POPU[illegible]
KILIM[illegible]

Year	Kiliman[illegible]
	Chagga
1921	128,000[a]
1928	143,013[b]
1931	154,860
1948	228,412
1957	N.A.
1967	393,707

SOURCE: Ta[illegible] [1971a, 1971c], [illegible] [1973].

[a]Estimated[illegible] District.

[b]Includes[illegible]

[c]Excludi[illegible]

[d]Include[illegible] from 1931 on [illegible]

[e]Exclud[illegible]

TABLE 1.2

HUMAN POPULATION IN MAINLAND TANZANIA AND PRESENT-DAY KILIMANJARO DISTRICT, 1921-1967, INCLUDING THE NUMBER OF CHAGGA

Year	Kilimanjaro District		Mainland Tanzania	
	Chagga	Total	Chagga	Total
1921	128,000[a,b]	136,000[a,b,c]	N.A.	4,124,328
1928	143,013[b]	147,447[b,c]	N.A.	4,740,706[e]
1931	154,860	162,057[d]	N.A.	5,063,660
1948	228,412	259,646	239,215	7,480,429
1957	N.A.	351,255	318,167	8,788,466
1967	393,707	476,223	440,239	11,958,654

SOURCE: Tanzania National Archives File 5/23/69, Tanzania [1971a, 1971c], Lucas and Philippson [1973] and Egero and Henin [1973].

[a]Estimated by author. Official 1921 figures included Pare District.

[b]Includes Moshi Town.

[c]Excluding non-natives.

[d]Includes 3,802 non-natives. All totals for the district from 1931 on include non-natives.

[e]Excluding about 30,000 non-Africans.

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the traditional Kihamba belt at 3500-5500 feet.[1] Then, as coffee production expanded and population growth accelerated after the First World War, pasture land which used to surround the homestead was put in permanent crops. By 1945-50, mounting pressure was in evidence as permanent crops spread into the less favorable upper and lower belts. By 1967 population density had become a serious problem, approaching 400 per square kilometer in the kihamba belt proper. For the first time large numbers of male heirs faced the prospect of being landless.

The gradual shift in land use from pasture and annual crops toward coffee production, and the accompanying shift in annual crop production to the drier lowlands, enabled the rapidly growing population of Kilimanjaro to be absorbed by means of successive marginal changes in the Chagga agricultural system. The steady expansion of coffee provided ever increasing cash income to the area's growing population. At the same time, expanding production of maize in the lowlands provided households with at least some of the calories necessary to replace the milk, bean, millet, banana, and meat production lost to coffee and not replaced by market purchases. On balance

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[1]Chagga agricultural land is differentiated into two types: kihamba and shamba. Kihamba land is clan land to which the occupant has what amounts to permanent freehold rights. Traditionally located in the well watered middle-belt of the mountain, the kihamba is where an individual establishes his residence and plants permanent crops, almost always coffee and bananas. Shamba land is less securely held. It lies on the lower slopes of the mountain and is utilized mainly for maize and beans. Traditionally shamba land was held on a year-to-year basis at the discretion of the chief. Today shamba tenure is growing increasingly secure and fathers desiring to acquire an inheritance for their sons often are obliged to purchase shamba land. Although officially the sale of land in Tanzania is illegal, practically it is quite common in Kilimanjaro with good coffee land selling for $600-$1000 per acre. For a more detailed discussion of Chagga land tenure customs see Johnston [1940] and Maro [1974].

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the Chagga appeared to be adapting quite well to their swelling numbers although clearly, declining availability of well watered land and swelling population pointed toward a less promising future.

5. Kilimanjaro at Independence

By the end of the colonial period Kilimanjaro was an apparently prosperous area, constrained only by the large land area which had been alienated to Europeans—increasingly eyed as an answer to the area's growing population pressure. Consumption of education and health services were among the highest in the country, facilitated in no small way by the cash income generated by coffee, but also reflecting the political power of the Chagga and the pleasant climate which attracted the missionaries. Total consumption and cash incomes were the highest of any rural area of comparable size in Tanzania and modern cement houses and radios were visible everywhere. The Chagga were proud of their accomplishments and were held out as an example of what capitalist development and production of cash crops for export can bring.

Yet underneath this prosperity is a society under pressure, the extent and nature of which has only recently become apparent. For every cement block house, there is one with a banana leaf roof;[1] for every two radios, one malnourished child.[2] Traditions of cooperative

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[1]The field study showed 15 percent of main dwellings have cement block walls and 12 percent have grass roofs.

[2]The study also showed that 35 percent of the households have a radio or one for every 14 people. Among children attending under five clinics in Kilimanjaro, Lindner [1972] found 20 percent malnourished (less than 80 percent of Harvard Standard). Children in this age group account for 20 percent of the district's population. An earlier study, conducted in 1968, reported that 28 percent of 1100

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distribution of food within the extended family or clan, which served to protect nutritionally vulnerable groups, had atrophied. As coffee production has increased, farm production of meat, milk, beans and millet—all staple protein sources in traditional diets—has declined. And the traditional irrigation system that was important for production of high protein food crops in earlier generations had long ago ceased to be adequate for the needs of annual cropping. Clearly something was wrong and increasing cash incomes and education did not appear to be providing a very effective solution.

D. Post Independence Political and Economic Development

1. Prior to the Arusha Declaration

In the first years after independence the direction of agricultural development in Tanzania and Kilimanjaro followed the pattern laid down during the colonial period. Peasant and estate agriculture expanded side by side. The market value of agricultural sector GDP grew an average of 6.9 percent per year between 1961 and 1966, in spite of a 7 percent decline in the prices Tanzania was receiving for its export crops [Tanzania, 1964 and 1972]. Increases in production continued to arise primarily from expansion of the area under cultivation; but in Kilimanjaro, evidence of intensification began to emerge.

The commercialization of African agriculture was proceeding apace over this period. The proportion of agriculture sector GDP

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preschool children randomly selected in Kilimanjaro District had moderate to mild protein calorie malnutrition and 5 percent had severe Kwashiorkor or marasmus [Tanzania Nutrition Committee, 1970].

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derived from the subsistence sector declined from 59 percent to 53 percent between 1963 and 1970 [Tanzania, 1964 and 1972]. Although few time series data exist it appears that social and economic differentiation within the peasantry was increasing as well. Gottlieb [1972] questions the overall magnitude of this differentiation based on an analysis of 1969 Household Budget Survey data. But Mbilinyi [1975], citing cross-sectional studies by several authors, shows that in certain areas, especially the most commercially developed, housing, land holding and labor use patterns leave no question as to the direction of economic evolution.

Public sector and service employment became an even more important source of social and economic differentiation within Tanzanian society especially between urban and rural areas at this time. Although salary levels were held remarkably constant over the period, the continuing replacement of expatriates with Tanzanians meant rapid promotion to higher paying positions. Since the former were paid largely by external sources this shift generated explosive growth in the public sector wage bill. Between 1961 and 1966, for example, the public sector wage bill increased 75 percent versus a 9 percent increase in public sector employment. This compares with a 19 percent increase in the retail price index of goods consumed by wage earners over the same period [Tanzania, 1964]. As a result, the average purchasing power of the urban employed increased at least 50 percent while rural per capita purchasing power increased by no more than 5 percent. This rapid differentiation between the employed tenth of the labor force and a rural self-employed eight-tenths was causing increasing government concern [Green, 1974].

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Education continued to provide the principal medium of access to public sector and civil service employment and a visible class of educated elite was emerging. This class had easy access to the better schools, especially English medium schools, for their own children. In spite of government efforts to provide more balance to educational opportunities, the Chagga still maintained a considerable edge over other tribal groups in Tanzania with respect to access to quality education. At the time of the 1967 population census Kilimanjaro District still had proportionately twice as many children enrolled in school as the mainland average and a slightly larger proportion enrolled in secondary school [Tanzania, 1971b].

In 1964, Tanzania launched its First Five Year Plan. The plan projected a growth rate of 14.8 percent for the industrial sector and 7.3 percent for agricultural output. However, while the surge in commercial agriculture and cash crop exports which occurred between 1964-66 pushed the share of agriculture in GDP from 57 percent to 59 percent, investment and production in the industrial sector fell short of expectations. Principally this resulted from the inability of ministries and parastatal organizations to implement projects as quickly as intended over the first plan period. But it also was due to a planned heavy reliance on private investment and foreign aid which did not materialize for political reasons. It was the latter which proved particularly sensitive and in no small way, led to the Arusha Declaration.[1]

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[1]Rather than the 78 percent of the five year development budget expected to be covered by external loans and grants, only 41 percent of the actual development expenditures had been so financed by 1967. See Tanzania [1967] and Henick, et al. [1968].

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2. The Arusha Declaration and Its Aftermath

In 1967, concerned with the growing inequality which was engulfing Tanzania and a growing economic dependence which threatened its freedom of political action, Tanzania committed itself to a radical break with the pattern of development it had inherited from the Colonial administration. In the Arusha Declaration the government declared its intent to gain effective control over the economy and to implement policies of African socialism and self-reliance in Tanzania. Hitting hard at income disparities and persons who live on the work of others (landlords, persons who hire labor), the declaration called for nationalization of the major means of production and effective democratic control over public institutions by workers and peasants. It emphasized that hard work and not money would bring about development in Tanzania and pointed out the danger to Tanzania's independence of relying on foreign gifts and loans for its development. The declaration noted that Tanzania was predominately agricultural and that agriculture must be the basis of its development. It laid down a stringent leadership code, applying to all TANU members, which forbade owning shares in companies, collecting rent and receiving two salaries—widespread practices at the time [TANU, 1967].

Since 1967, many of Tanzania's development policies have been directed toward implementation of the principles laid down in the Arusha Declaration. Nationalization of banks, insurance companies, import and export trade, and agricultural processing industries occurred immediately. Government acquired a controlling interest in other firms employing large numbers of Tanzanians. In responding to the call to "put great emphasis on actions which will raise the

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standard of living of the peasants and the rural community,"[1] the Party adopted, in October of 1967, the policy of Ujamaa Vijijini or, literally translated, "Brotherhood in the Villages." Under this policy the government initiated a program of integrated rural development intended to lead in the direction of a peasant socialist society.

With respect to rural areas it was not until the beginning of the Second Five Year Plan (1969) that Tanzania began seriously implementing the policies laid down in the Arusha Declaration. Constructed around the five principles of social equality, Ujamaa (brotherhood), self-reliance, economic and social transformation, and African economic integration, the plan sought to improve the basic material conditions of the mass of the population. Rural water supplies, food production and adult education were not singled out for special emphasis, rather they were part of a broad based rural development strategy. It was primarily the drought of 1973-74 and a growing feeling that peasants could not be effectively mobilized to plan their own development unless they were at least somewhat literate that established the high priorities those areas currently receive.

The reaction to the Arusha Declaration in Kilimanjaro has been one of mistrust. Intensely individualistic and distrustful even of each other, farmers there fear any suggestion of Ujamaa production and would, no doubt, actively resist any effort to make them participate. Partly in recognition of this, government has let it be known that people in Kilimanjaro already live sufficiently close together that few if any economies in providing services could be obtained by

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[1] TANU, 1967, p. 20.

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their moving into villages. Government still encourages farmers to join together in agricultural and small scale industrial pursuits for their common benefit. However, since early 1974, cooperative production has been played down throughout the country.[1]

E. The Impact of Historical Forces on the Kilimanjaro Farming System and Diets[2]

The cattle enterprise was the first to come under pressure from expanding coffee production. Initially, coffee took the grasslands surrounding the kihamba belt and necessitated a 100 percent stall feeding system. This increased the work load of women and made the animals much more dependent on man for their food. It also eliminated the traditional morning grazing and the frequent contact with the bulls which this provided. Judging from the very long calving interval on

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[1]By the end of 1974 an estimated 3,000,000 Tanzanians lived in Ujamaa villages. In the spring of that year, growing impatient with the progress of the shift to Ujamaa villages, government "ordered" all peasants to group themselves into villages before the end of 1976. Over the course of 1974 the concept of planned villages rather than Ujamaa villages came to the fore and gradually became the focus of what was amounting to a massive bootstrap resettlement effort. Peasants living in planned villages are not required to participate in cooperative production activities.

[2]Most of the historical information on diets is drawn from small bits of information provided by early explorers and colonial administrators. See, for example, the accounts of Kraph [1968], New [1968], Johnston [1886] and Dundas [1968]. Stahl [1964] gives a more general account of Chagga history.

In addition to these published accounts, I have relied on oral accounts of Chagga elders. These accounts tend to make a much stronger case for the negative impact of coffee on food production than that made in the text. However, there appears to be a distinct tendency on the part of elder Chagga to glorify the past more than it deserves to be. As a result, I have tended to discount much of what they have reported.

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the mountain (28-29 months) this appears to have induced a lengthening of the average calving interval by six months or more. Furthermore, because coffee yields are severely depressed by dense banana cover, it became necessary to reduce the number of banana clumps per acre. This, in turn, reduced availability of banana feedstuffs for livestock, and increased the work load of women still more as they went farther and farther afield for more and more grass. No doubt it also led to a decline in the standard of feeding. Coupled with the lengthening of the calving interval and farmer observations it appears that average annual milk production per cow may have declined by as much as 50 percent over this period. Allowing for the growth in human population, farm production of milk per capita today is probably less than one-quarter of what it was 50 years ago.

Over this same period bean and millet production also declined due to expanding coffee production, though it is difficult to say by how much. Formerly, both were intercropped with bananas, pulses being used to regenerate the soil after a millet crop. Dundas [1924] gives a detailed account of the importance of millet production to Chagga agriculture in the 1920's. Older accounts note the importance of both millet and beans. By 1973, only about 43 (±3) percent[1] of households cultivated .1 hectare of millet or more. A much higher percentage, 87 (±2) percent, still cultivated beans (.1 hectare or more) but everyone readily notes the marked decline in both production and use of beans over their lifetimes. Shifting bean production from a dry season irrigated system in the kihamba belt to a rainy season lowland

[1]Numbers in parentheses following mean population estimates are their standard errors.

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system has exposed yields to the vagaries of weather. As a result crop failures are frequent when rains are heavy or bi-modal, about once every two or three years. More recently, there is a reluctance to intercrop beans with hybrid maize. Whereas 30 years ago virtually all maize was intercropped with beans [Swynerton, 1945], unofficial results of the recent agricultural census show that now 75 percent of it is grown in pure stands.[1]

Paralleling the decline in milk production in Kilimanjaro has been a decline in per capita meat production. It is impossible to tell whether consumption has declined, however (according to Chagga elders it has), since commercial meat sales using animals purchased from outside the area have grown fairly steadily. What is clear is that over the past 50 years the cattle-man ratio in the district has fallen from about 0.8 or more to less than 0.3 with no evidence of an offsetting increase in the rate of offtake. Nor is there any evidence that production of meat from goats and sheep has increased.[2]

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[1]The reader should be careful not to place too much faith in the results of the agricultural census. For some crops census results differed by such a wide margin from previous estimates that the government was considering not releasing the data at all. It showed, for example, no millet production at all in Kilimanjaro Region; bean production less than half of that implied by the very reliable minimum estimates obtained in our study (proportion of households with .1 hectare or more of beans); and maize production less than half of what is implied by reasonably good consumption, marketing and average yield figures.

[2]Dundas [1924] gives an account of the German attack on Sina, the chief of Kibosho, in 1891 that suggests a cattle-man ratio of about 1.0 and a small ruminant-man ratio of about 2.0. Hill and Moffett [1955] cite cattle estimates, and the British Naval Intelligence Division [circa 1920] cite population figures that suggest a ratio in 1910 of more than one, but over a larger geographical area. Finally, in 1924 Dundas [1924] the first British colonial administrator and longtime resident of Kilimanjaro, noted that Chagga cattle holdings numbered between 140,000-150,000. The Chagga population

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While bean, millet, meat and milk production have been declining, maize production has increased dramatically. Indeed it has been the availability of maize which has permitted reduction in the density of bananas so necessary to improve coffee yields. Reasonably precise estimates of the amount of increase are not available but marketed production for what is now Kilimanjaro Region grew from about 800 tons per year in 1939-41 to 12,000 tons per year in 1965-67. Most of this appears to have been produced by African smallholders and is in addition to sharply increased household consumption.[1]

Given the rather high level of malnutrition among preschool children in Kilimanjaro documented in other studies [Tanzania Nutrition Committee, 1970; Lindner, 1974], the question arises as to whether the declining production of high protein foodstuffs associated with the expansion of coffee is a contributing factor.[2] No historical data on nutritional status exist, of course, but we can speculate on the basis of changing consumption patterns and distribution traditions within the family.[3]

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at this time was about 130,000. As a rough approximation, then, average figures of .8 to 1.0 head of cattle and 1.5-2.0 head of sheep and goats per capita seem reasonable up to about 1920.

[1]Swynerton [1945] reports marketed production of 1390, 561, and 516 tons for 1939-41, respectively. Figures for 1965-67 are from Tanzania [1974].

[2]Both Lindner [1974] and the Tanzania Nutrition Committee [1970] indicate that insufficient protein rather than insufficient calories is the major cause of malnutrition in Kilimanjaro. This is not uncommon in societies where bananas are a staple foodstuff. However Zalla [1979] provides quantitative data on diets in the area that indicate calories are much more limiting than protein for all but children under five.

[3]For a description of traditional diets and distribution traditions see Freyhold et al. [1973].

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For adults the shift in production described above has probably not had a significant nutritional effect. Cash purchases of meat imported into the district probably offset most if not all of its declining production. Traditionally adults consume less milk and more meat than children, and consume millet only as local beer—one product more available than ever before. The main foods they consume less today are bananas, beans and milk. Increased maize consumption would go a long way toward offsetting any protein lost. The traditional foods probably have a somewhat better amino-acid balance given the combinations in which they are prepared but if meat consumption has increased at all it would make up with crude intake what was lost in balance.

For older children the ready availability of beans and milk in family foods has always been important in Uchagga. Unlike meat dishes, those prepared with milk and beans are distributed within the family in proportion to total intake. Meat, on the other hand, is known as a man's food which often is maldistributed. Had the shift toward maize not been accompanied by a decline in beans and milk, older children would most definitely be better off. As it is, however, they may have fallen back some, though not as much as the younger ones.

Children under five are the critical problem. Many parents are reluctant to feed weaning children meat or beans. Without milk added to the traditional porridge it is difficult to see how they can obtain sufficient protein intake for adequate development. To be sure, the variety of millet historically grown in Kilimanjaro has one of the lower concentrations of protein among millets (7.5 percent) and is considera

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considerably lower in protein content than maize (9.4 percent).[1] But when mixed with milk in the traditional fashion, the resulting milk and millet porridge has about 75 percent more protein than the water and maize porridge in common use today.

To a person not familiar with traditional societies the question of possible adverse changes in diet associated with increases in cash income might never arise—especially where cash income has increased by considerably more than the market value of the loss in production of food crops. But production of food crops for household consumption remains a paramount concern at the farm level in Tanzania as it does in most of Africa. Few households without at least one member engaged in full-time off-farm employment rely more than marginally on the market for staple foodstuffs. Concessions to the exchange economy have tended to be in the form of land and labor resources for the production of cash crops, not so much with specialization and exchange leading to increased productivity and aggregate output as an object, but rather, the growing need for cash for non-food purchases. The result too often has been a decline in production of nutritionally superior foodstuffs which makes itself felt more severely at those times when cash income has been exhausted and farmers cannot purchase foodstuffs in the market [Colis, Dema and Omololu, 1962; Lev, 1981]. Even more serious perhaps, is the tendency to make marginal shifts in consumption

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[1]Red finger millet (Elusine coracana) of the type grown in Kilimanjaro has a crude protein content of 7.5 percent versus 10-11 percent for bulrush millet (Pennisetam typhoides). By comparison white maize, the traditional variety, has a protein content of 9.4 percent. Recently introduced hybrid varieties of maize range one-half to one percentage point lower than this. See Food and Agriculture Organization and Department of Health, Education and Welfare [1968].

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patterns which appear insignificant or reasonable at the time but which in the long run take their toll in terms of health and nutrition. Whether or not the shifts that have occurred in Kilimanjaro have had an adverse impact on the nutritional status of young children is a matter about which we can only speculate. The weight of available evidence, however, suggests that this consequence not be dismissed lightly.

F. Summary and Implications

The description of Kilimanjaro emerging from the previous discussion is one of increasing individualism and differentiation in the context of rapid population growth and land pressure. Coffee is important both as a source of cash income for producers and foreign exchange for the country as a whole. Yet the spread and intensification of coffee production is not without problems. It has increased the pressure on land resources and may have led to a decline in the nutritional status of young children, though this conclusion must remain speculative. It has contributed in a very direct way to differentiation both within Kilimanjaro and between Kilimanjaro and much of the rest of Tanzania. It has made Tanzania very dependent on international markets for disposing of the products of the labor of Kilimanjaro peasants and for acquiring dairy products for their consumption. What this means from the perspective of modern market economic theory is the subject of the next chapter.

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CHAPTER II

ECONOMIC PERSPECTIVES

As a nation, Tanzania is attempting to reduce the marked differences in consumption among its citizens while at the same time maintaining its freedom of political and economic action. Its principal objective is to radically restructure its economy along socialist lines so as to provide adequate diets, clothing, housing, health care and education for all of its population within a reasonable period of time. In this chapter, some of the strengths and limitations of a price-oriented, Pareto optimal neo-classical project approach to economic development are reviewed. Other development issues that relate to the study are raised but no attempt is made to analyze them. These issues are raised only to bring them to the attention of policy-makers who must grapple with development in a broader context than that provided by an analysis of the returns to resources used to produce coffee versus milk, meat and manure.

A. Pareto Optimal Market Economics

The essence of modern market economics is its reliance on individual preference as revealed in the marketplace for determining what to produce, and on the ownership and productivity of inputs for determining who gets the income to purchase what is produced. Free market prices communicate both relative preferences and relative scarcit

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scarcities and encourage an allocation of resources which maximizes the value of output for the existing pattern of resource ownership by rewarding the owners of each resource in proportion to the value of product their resource creates. Through the pricing mechanism, individuals seeking to maximize their welfare and income cause the economic system to move toward equilibrium. In a perfectly informed equilibrium, no person in the system can be made better off through the use of non-market force without someone else being made worse off. Such an equilibrium is described as Pareto optimal or Pareto efficient.

Without interpersonally valid measures of welfare, it is not possible to determine in the context of the theory of modern market economics that society as a whole would be better or worse off if the ownership of resources, rights or privileges were shifted from one group to another via non-market actions.[1] This problem has not prevented many neo-classical economists and policy-makers from making what Baumol [1975] essentially calls "common sense" judgements concerning interpersonal utility and following these up with recommended policies. It has, however, made the theory vulnerable to misuse by those who would use Pareto efficiency alone as grounds for maintaining or altering the existing pattern of ownership of resources, rights and privileges.

Even if Pareto optimal market economics cannot evaluate non-Pareto optimal policies and programs, it can nonetheless predict their consequences. The behavioral assumptions of modern market

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economics apply reasonably well to the cash cropping enterprises of peasant farmers and an analysis of returns to resources allocated to coffee and dairying should give a reasonably good idea of what farmers will do under various non-Pareto optimal changes in input and product prices or services. Market economics can also give an idea of the amount of income that will be transferred from one group to another under programs and policies which redistribute the ownership of income-producing resources, rights and privileges. It also helps in estimating the amount of foreign exchange gained or lost as a result of such changes. These are important kinds of knowledge in any political context. Moreover, Pareto optimal market economics can help policy-makers identify those areas where markets do well in allocating resources and distributing products (real income) among consumers as owners of rights and privileges. Such knowledge can allow governments to focus their scarce managerial and planning resources on those areas where markets do not do so well.

These strengths of Pareto optimal, neo-classical theory should not blind us to some important problems related to it. On the ideological level, neo-classical behavioral assumptions conform so closely to capitalist ethical propositions that many trained economists fail to see the differences between the two. Indeed, Friedman [1966] finds himself compelled to point out to his students that the proposition that an individual <u>deserves</u> what is produced by the resources he owns is a capitalist ethic, not a marginal productivity ethic. In a similar way, the theory lends a moral character to charging what the market will bear since only if inputs are allocated to their most efficient or highest use is aggregate welfare, in the P

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in the Pareto sense, maximized. The question of "efficient with respect to what pattern of resource ownership" is not asked by some as often as it should be. Average annual earnings of physicians in the U. S. provides an excellent example of both these phenomenon. Protected by a wide range of policies which restrict the supply of and competition between physicians they have been consistently able to earn returns to their labor and capital investment well in excess of those available to other groups within the economy. These returns are often justified in terms of their being "worth" it as though the value of services provided is independent of the supply of such services.[1] In a related vein, maximizing coffee production may be a particularly efficient way of acquiring foreign exchange and increasing incomes but a particularly inefficient way of improving nutritional status among coffee producers if cash income does not translate into increased consumption of food.

Many of these kinds of contradictions relate to implicit or explicit changes in the ownership of resources, rights and privileges and the need for interpersonally valid welfare measures to evaluate them. The question that poses itself from a development perspective is whether aggregate welfare in a more meaningful sense than that provided by Pareto optimality might be higher if resource ownership patterns were changed, or lacking the ability to do that, if resources were "misallocated" in the existing context. Lacking universally accepted, interpersonally valid measures of utility, we

[1] From a "common sense" point of view there can be little doubt that total social welfare would be increased if some of the rights and privileges protecting physicians were removed.

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have too often shied away from such considerations. The "theory of second-best" as articulated by Lipsy and Lancaster [1956] and interpreted by Baumol [1965] does not really address this issue since that discussion relates to optimization after reallocations of resource ownership instead of evaluating alternative ownership patterns. When it takes initial ownership as given, Pareto optimal market economics abstracts from those political and property relations which determine, by and large, what any economic system (either capitalist or socialist) will produce and for whom.

The ownership of resources, rights and privileges gives rise to a whole set of resource scarcities and demand patterns which generate a set of equilibrium prices. Different patterns of ownership will give rise to different patterns of demand and different relative prices. One only has to reflect on current demand for electric tooth brushes in African capitals versus what that demand would be if existing national income were divided equally per capita to appreciate this. The value of computer programmers and Ph.D.'s in history would probably be similarly affected.

Since the ownership of resources, rights and privileges is partially politically determined, it follows that prices derived from any pattern of ownership are, in effect, partially politically determined as well. It also follows that evaluating public investments by adjusting such prices to correct for market imperfections, taxes, subsidies, etc. in order to obtain real opportunity-cost shadow prices does not, in fact, break the link between the distribution of the ownership of income-producing resources and relative prices. Opportunity-cost shadow prices—or, for that matter, market prices—

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in a Pareto optimal equilibrium would reflect real social costs and benefits only if the underlying distribution of income-producing resources and the pattern of demands arising therefrom are socially optimal, whatever this may be.

Analyzing any proposed course of action requires the use of prices which reflect socially optimal objectives. Such prices may not reflect the interests of existing resource owners in the same way as free market or opportunity-cost shadow prices since alternative distributions of the ownership of resources, rights and privileges will alter relative prices. The problem is not merely one of deriving prices which embody the desired ex-post redistribution. Demand patterns established under an unacceptable pattern of ownership of resources, rights and privileges may need to be constrained before a country can rely heavily on markets to make rapid progress toward new social goals. An unanswered question in this regard is whether policy-makers have sufficient knowledge of interpersonal welfare to enable them to go beyond Pareto optimality.

If the meaning of prevailing prices, and opportunity-cost shadow prices based on them are partially dependent on the political relations which underly them, alternative methods may need to be adopted for allocating scarce resources, especially where those political relations cannot be altered directly. These methods may indeed involve the use of shadow prices but not shadow prices automatically derived from prevailing prices and present resource ownership patterns. They would have to take account of distributional objectives which cannot be met within the context of the existing distribution of resources, rights and privileges. These prices would be no more nor less p

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nor less political in nature than opportunity-cost prices would be. They would, however, be more effective in allocating resources toward desired societal objectives provided they are based on a knowledge of welfare having sufficient interpersonal validity.

B. Implications for the Analysis of Milk Production in Kilimanjaro

Development defines a dynamic process. Where radically altering the existing distribution of income and the ownership of income-producing resources is an important objective of public policy there may be a need for a more explicit political determination of what to produce, how it should be produced and for whom it should be produced than is likely to occur in a free market. Modern market economics can be very useful in analyzing information needed to make such determinations. Free markets can certainly be useful in implementing them. But the ultimate decision about what to produce and for whom—essentially a choice among alternative ownership patterns—is substantially a political decision.

The crucial question for the present study is the value to Tanzania of using its land, labor and capital resources to produce dairy cattle and their products versus coffee. The answer cannot be provided without considering the distribution of the ownership of resources, rights and privileges both within and outside of Kilimanjaro. Information is required about nutritional dimensions of milk production and consumption as well as information on what happens to foreign exchange earned from coffee. One thing is clear: the answer calls for a broader framework of analysis than that provided by Pareto optimal market economics alone.

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Increasingly, dairying and coffee can be expected to compete for limited land, labor and capital resources in Kilimanjaro. The analysis in later chapters uses modern market economics to measure the income gains that appear to be available from various dairy cattle enterprises on the mountain. A similar analysis could compare returns from coffee production to returns from dairy cattle. These are important considerations for deciding the proper role of dairying in Kilimanjaro and what policies should be adopted to facilitate that role.

Such analyses yield information on costs and returns that governments can use to identify policies which can make maximum use of free markets to pursue desirable social, political and economic objectives. This kind of analysis can also suggest areas where free markets are not likely to produce the intended result, suggesting the need for changes, more direct intervention or possible revision of intended objectives. In using modern market economics in this way decision-makers need to keep in mind the partially political nature of opportunity costs; the difference between capitalist ethical propositions and the essentials of marginal productivity theory; and the need to incorporate many other factors in the policy decision.

We move now to a closer look at Kilimanjaro agriculture.

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CHAPTER III

KILIMANJARO AND ITS DAIRY INDUSTRY

Much of the information contained in this and subsequent chapters is derived from the results of a two-stage weighted random sample of approximately 450 households in Moshi and Rombo Districts and a second, more purposive sample of about 260 grade cattle owners, some of which were also included in the random sample. Details of sample selection, data collection and analysis are included in Appendix A. This chapter discusses some of the more general findings and relates them to other studies done in the area.

A. Demographic Characteristics

The average household in the random sample had 5.8 members present on the day preceding the interview. Slightly less than two-thirds of all households contained at least one child under five, though the ages of the household heads averaged 47 years. Most household heads were male (95 percent), lived at home (93 percent), and had only one wife. Thus the normal situation is a monogamous male head of household who lives at home with his wife and family.

Levels of education vary widely within Kilimanjaro, with substantial differences between generations. Heads of households averaged 2.

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averaged 2.9 years (s=2.8)[1] of education and their spouses 2.0 (s=2.3). However, the highest level of education attained by anyone in the household—including children who had moved away—averaged 6.8 years (s=3.4). Traditionally education has been held in very high esteem in Kilimanjaro and has represented an important investment for rural households. This investment has had substantial returns in the form of remittances from household members who find better jobs in urban areas as a result of their education.

Farming provides the principal source of employment in the area. Only 20 percent of the heads of household hold permanent employment off the farm. Most of these were lower skilled jobs such as evangelist, clerk, cook and driver. Only 1 percent of household heads are teachers while nearly 4 percent consider themselves businessmen and traders. Few women have outside employment.

Wage labor within the agricultural system does not, at first glance, appear to be an important source of income for the average household. On the average, households reported hiring out 19 man days of labor and hiring in 18 man days during the 12 months prior to the interview. The similarity of these two independent estimates is deceiving, however. A breakdown in the numbers hiring in and those hiring out as well as the observations of the enumerators themselves suggest that both hiring in and hiring out of labor were seriously underreported. The Tanzanian government opposes the hiring of labor

[1]The letter "s" refers to the sample standard deviation. The standard error of the estimated mean is designated by (±) and is included where an appreciation of precision is more important than a measure of dispersion. Both are expressed in the same units as the mean value.

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on the grounds that it expropriates the wage earner's surplus and deprives a person of participation in the management of his/her labor. Because of this, many farmers hesitate to report information relating to the use of hired labor. At the same time, labor hired out would tend to be underreported because of the area's greater than normal anxiety over income-related questions. The field survey therefore, probably yields only minimum estimates of the use of hired labor on farms in Kilimanjaro.[1]

There is some evidence of the existence of a class of wage laborers in Kilimanjaro. At the time of the survey, over 70 percent (± 5) of hired labor was provided by a neighbor. About 90 percent (± 3) of all hired labor originated from within the survey area, though perhaps not a neighbor, and had its own family coffee plot. Yet only 16 percent of households hiring out labor also hired in labor. Thus the practice of hiring labor is not simply a more rational allocation of available labor within the context of the different seasonal demands of coffee picking at different altitudes on the mountain. Rather it probably reflects different access to land and the need to supplement limited incomes from small family plots.

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[1]Other evidence suggests these numbers are not reliable. Virtually all coffee estates in Kilimanjaro rely on hired labor from nearby small holdings for picking coffee. In terms of the magnitude of output these large farms account for about 20 percent of coffee production on the mountain. Accurate population estimates for casual labor hired out from small holdings should, therefore, be considerably higher than estimates for labor hired into small holdings rather than equal as the data suggest.

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B. Reflections of Wealth

Kilimanjaro is one of the richest agricultural areas in all of Tanzania. Its altitude and rainfall patterns create a very favorable environment for agricultural production, especially for Arabica coffee. The mountain's wealth is reflected in everything from housing conditions to the distribution of water, health and education services. Over 18 percent (± 2) of the principal dwelling units in the area are constructed of cement, stone or bricks as opposed to 3 percent for the rural mainland as a whole. Moreover, 87 percent (± 2) have tin, tile or concrete roofs as opposed to 14 percent for the rural mainland; and 36 percent (± 2) of all households get their drinking water from a tap or sealed well versus 7 percent for the rest of the country.[1]

In education the statistics are equally lopsided with 15 percent of the population enrolled in primary school and 1.1 percent in secondary school. This compares with 7.7 percent and .3 percent respectively for the rural mainland as a whole [Tanzania, 1971b]. Health services are less skewed with one hospital bed to 623 inhabitants in Kilimanjaro District versus 1:745 nationally. But the area's dense population creates easier physical access with 40 percent of the population living within 5 kilometers of a hospital versus 13 percent nationally [Freyhold et al., 1973].

C. The Agricultural Economy

Kilimanjaro agriculture is quite advanced by African standards. The entire mountain is laced with a gravity flow irrigation system

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[1]Housing statistics for Mainland Tanzania are taken from Tanzania [1971d].

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fed by ground water retained by the rain forest as well as by melting snow from the mountain's peak. Rainfall and snowfall patterns vary sharply from one side of the mountain to the other, dominated largely by the influence of the peak on prevailing winds as these interact with temperature changes at different altitudes. This results in marked differences in water available for agriculture both during the rainy season and the dry season, depending on altitude and aspect. Coffee does best in the 3000-5000 feet range, though most farmers outside this belt also grow coffee. Maize, on the other hand, does better in the drier, hotter lowlands. Bananas, the traditional staple in the Chagga diet, seem to do better under the same altitude, temperature and resulting rainfall conditions as coffee.

Almost 95 percent of households in the survey area grow at least some coffee and nearly 90 percent grow at least .25 hectares of maize and .1 hectares of beans. Farms in Kilimanjaro are generally small, estimates ranging around 1.2 hectares of mountain (kihamba) land and .8 hectares of lower lying (shamba) land [Beck, 1961; Maro, 1974; Sykes, 1959; Wallace, 1968]. Of this, about .5 hectares are planted in coffee and bananas with coffee yields averaging between 320 and 380 kilos of parchment per hectare [Coulson, 1972; Mphuru, 1965]. Cash income from coffee accounted for roughly 70-75 percent of total cash income from agriculture for small holders in 1967 [Ministry of Economic Affairs and Development Planning, 1968]. The proportion would have been at least this great in 1973 when coffee prices were considerably higher.

Apart from coffee, the agricultural economy of Kilimanjaro is based on bananas, maize, beans and livestock. Some bananas, between

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5 and 10 percent, are grown in pure stands. Generally, however, bananas are intercropped, first with maize and millet and then, once established, with coffee. At any point in time, about 90 percent of bananas are intercropped with coffee. Virtually all coffee is intercropped with bananas. Together coffee and bananas are the main cropping activities on the mountain kihamba homestead.

Maize and beans are important to Kilimanjaro agriculture but take up very little kihamba land. Rather, both tend to be planted in the drier lowlands on plots of land (shamba) detached from the homestead. In general, maize and bean shamba are one to two hours walk from the homestead. In some cases, however, the distances are greater. Some maize and beans are grown on the upper slopes near the forest reserve (6000 feet) but both do poorly there. More commonly, land near the forest reserve not in coffee or bananas is left as pasture and forage for livestock in nearby homesteads. Table 3.1 shows the minimum proportion of farms having specific crops and livestock enterprises as indicated by the random sample.[1]

Table 3.1 gives some idea of the importance of livestock to Kilimanjaro agriculture. Cattle, goats and sheep contribute most to meat production but swine and poultry are also important. Cattle and goats are important sources of milk while all livestock are valued for their manure. Slightly more than 10 percent (±1.8) of households

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[1]Because of the very sensitive nature of acreage and income data in Kilimanjaro most questions alluding to important crops and economic status were general or indirect. For coffee, for example, farmers were not asked whether they grew coffee but whether they used certain cultural practices. Maize and bean farmers were asked whether they grew .25 or .1 hectares or more respectively. In general, such minimum estimates should not be far from the actual proportions since cultural practices and field sizes known to be common to most farms were used.

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TABLE 3.1

PERCENTAGE OF HOUSEHOLDS IN KILIMANJARO WITH SELECTED AGRICULTURAL ENTERPRISES OR GROWING SPECIFIC CROPS

Enterprise or Crop	Producing Households as Percent of Total	Standard Errors
Bananas	99[a]	N.E.[b]
Coffee	94[c]	1.4
Maize	89	1.9
Beans	87	2.0
Cattle	67	2.8
Goats	57	2.9
Millet	43	2.9
Cabbage	32	2.7
Tomatoes	25	2.5
Squash	22	2.4
Spinach	11	1.8

SOURCE: Random sample estimates.

[a]Question not actually asked because of its obvious answer.

[b]Not estimated.

[c]Actually the proportion of farms which prune their coffee.

have one or more grade dairy animal. None of the households in the random sample had exotic goats, though one in the grade cattle sample (n=261) did.

The 67 percent of households which have cattle have an average of 2.3 animals each, most of which are stall fed. Carrying forage to feed livestock is one of the principal tasks of women. The average household with cattle spends 20 hours ($\pm$1) per week gathering grass, banana leaves and banana stems for feeding livestock. Manure from livestock is highly valued and is the principal source of ferti

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fertilizer for the mixed coffee-banana groves that form the mainstay of Kilimanjaro agriculture.

Cultural practices among farmers in Kilimanjaro are quite advanced for smallholder agriculture in Africa. Very few farmers with coffee do not prune at least once a year and more than 85 percent spray fungicides to control coffee berry disease (CBD) and leafrust. This proportion is down from previous years because of the emergence of a strain of CBD that is resistant to conventional copper oxychloride compounds. More than 95 percent of coffee producing households use insecticides to control stem borer and leafminer insect parasites on their coffee.

Only about 6 percent of farmers use chemical fertilizers on their coffee. Soils on the mountain are very fertile and are maintained by applications of manure and by mulching with banana leaves. Coffee benefits from heavy applications of manure on the bananas which are intercropped with coffee. Nevertheless, coffee yields on small holdings continue to run at about one-third to one-half the level of the large estates. Better pruning techniques, more frequent and timely spraying, more frequent irrigation, fertilizer applications and a further reduction in the density of banana stems could raise yields on small holdings. However available evidence indicates that reducing the density of banana stems by itself would not stimulate sufficient yield increases in coffee to offset the lost value of the bananas, much less the banana leaves and stems which are important to the animal populations of the area [Wallace, 1968].

A relatively small percentage (16 percent) of farmers have planted hybrid maize at least once but this was just becoming

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generally available during 1973, the year of the survey. Not a small proportion (22 percent) of farmers trying hybrid maize fail to continue using it. This is related primarily to marginal rainfall patterns in the lowlands and appears to reflect a rational economic decision on the part of the farmers. Erratic rainfall in the lowlands may also be responsible for the large proportion of farmers growing hybrid maize who do not use fertilizer (77 percent ±7). More than one-third of those trying fertilizer on maize discontinued its use. Table 3.2 summarizes data on cultural practices in the area.

D. Alternative Milk Production Systems

In spite of the tremendous inroads made by coffee during the past 40 years, cattle are still a very important component of the farming system in Kilimanjaro. Cattle manure is the mainstay of the Chagga banana groves which, with bananas valued at market prices, yield more income per acre than coffee [Sykes, 1959; Wallace, 1968]. Milk continues to be highly prized and its relative scarcity is one of the most frequent of complaints. In addition, it's nutritional value, especially for young children, is widely appreciated. At the same time meat production continues to be important, attested to by the number of households that have only one male animal. In this sense at least, it is not appropriate to speak of cattle and dairying as though the two are synonymous, especially for zebu cattle. Increasingly, zebu cows are used as breeding stock for an artificial insemination program in the area.

TABLE 3.2

PROPORTION OF KILIMANJARO FARMERS USING SELECTED

TABLE 3.2

PROPORTION OF KILIMANJARO FARMERS USING SELECTED AGRICULTURAL PRACTICES, 1973

Practice	Percent of Households With Enterprise That Use Indicated Practice	Households Having Enterprise Concerned As Percent of Total Households
Milking Goats	32	55
Planting hybrid maize seed	18	89[a]
Apply chemical fertilizer on maize	05	89[a]
Apply chemical fertilizer on coffee	06	94[b]
Prune Coffee	100[a]	94[b]
Spray copper fungicide on coffee	88	94[b]
Apply insecticides on coffee	95	94[b]
Use acaricide on cattle	10	67

SOURCE: Random sample estimates.

[a]See footnote 1 on page 43.

[b]Proportion of households having enterprise is estimated from number of farmers reporting they pruned their coffee. Pruning is virtually universal in the survey area.

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1. All-Zebu Cattle Enterprises

The all-zebu cattle enterprise has been a mixed dairy-beef-manure enterprise. As expanding population and coffee production have exerted pressure on pasture and feed supplies, the importance of milk production from zebu cattle has declined. However zebu cattle still account for over half of all milk production on the mountain and were supplying more households with milk at the time of the survey than were grade cattle.

Management of all-zebu cattle enterprises does not differ greatly from that which probably existed 50 years ago. Cash inputs are minimal, breeding is mostly done with bulls rather than artificial insemination, many animals are still housed in traditional banana leaf structures and few are fed anything but forage, water and salt. Though problems with the availability of pasture and feedstuffs have increased the amount of labor required per animal unit, prolonged calving intervals and have led to a decline in milk production, the structure of the industry has remained basically the same.

2. Grade Dairy Enterprises

Grade cattle first were introduced onto small holdings in Kilimanjaro toward the end of the 1950's. Until 1962 it was government policy to discourage use of grade dairy cattle by other than expatriate farmers. In 1962 government policy was modified and shifted to the encouragement of two-cow, stall-fed units among African farmers. Since that time grade cattle numbers have grown from about 600 to 16,000 in 1973, when they accounted for about 10 percent of all cattle on the mountain and 40 percent of milk production.

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Management of the all-grade enterprises has always been relatively sophisticated since the high acquisition cost of grade cattle and their sensitivity to environmental factors have discouraged poorer, less educated farmers from experimenting with them. Calving intervals are shorter, milk production much higher, marketed sales of milk and the use of variable cash inputs much more important. Like zebu cattle, most grade cattle are stall-fed. Farmers rely more heavily on artificial insemination for breeding purposes and have much higher investments in housing as well as cattle. Not unexpectedly, grade cattle farmers acquire more veterinary services for their animals and take more prophylactic measures against tick born diseases.

3. Mixed Zebu-Grade Dairy Enterprises

A number of farmers have started to upgrade their zebu herd and combine both zebu and grade cattle in one enterprise. In most of these systems zebu cattle receive better care than those in all-zebu herds. More are fed at least some grain products, water, salt and planted grasses. Housing usually is better and more attention is given to veterinary services. Surprisingly, calving intervals and calf rearing practices are not much different for zebu cattle in these herds as compared to all-zebu herds.

Though zebu cattle in mixed herds appear to receive somewhat better care than those in all-zebu herds, grade cattle in these herds do not receive care as good as that received by those in all-grade herds. They are fed less grain supplement and are fed salt and water less frequently. They also have longer calving intervals with lower milk

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milk yields.[1] They are not as well housed as grade cattle in unmixed enterprises and do not receive as good a diet of forage. Less attention is paid to disease prophylaxis and more downbreeding to zebu bulls occurs. Clearly these are enterprises in transition and many farmers do not yet fully appreciate the need for a great deal more attention to feeding and breeding of grade animals in order to realize their full economic and genetic potential.

As more and more crossbreeding occurs it is becoming increasingly difficult to distinguish lower grade from higher grade dairy animals. Farmers aware that an animal is a second cross to a dairy bull will usually distinguish it from a "pure" grade animal. The same animal, if purchased from a distant farmer who either misrepresents or does not provide the ancestry of the animal, would often be referred to as a "pure" grade animal. Phenotypically, the degree of exotic blood is difficult to distinguish once the animals exceed a three-quarter cross. As a practical matter, all animals which do not have the hump typical of indigenous zebu breeds, are referred to as grade cattle. Since the hump usually disappears in the f_1 progeny [Williamson and Payne, 1965], this means that a grade dairy animal is one which has at least 50 percent exotic blood.

4. Goat Enterprise

The dairy industry in Kilimanjaro is based on goats as well as cattle. Apart from a few bits of information gathered on goats in

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[1] The lower milk yield is not really surprising since a greater proportion of grade cattle in mixed herds are half-crosses with less genetic milk-production potential than higher crosses or pure grade animals.

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order to ascertain their relative importance to the area's dairy industry, this study deals with cattle milk production. In terms of future potential, however, goats could play a very important role in meeting the area's overall demand for milk.

In Rombo District goats currently account for 15 percent of milk production and are much better adapted to the drier climate typical of Rombo. Rombo's goat population is three times as large as its cattle population with 90 percent of all households and 90 percent of those without cattle having at least one goat. Moreover, almost half of all households in Rombo milk their goats when they are fresh, versus only about 7 percent for Moshi District.

Goat holdings per household are small in Rombo District, around four animals per household. Moreover, milk yields for indigenous goats are low, averaging about .2 liters ($\pm$.02) per day per dam. But goats sustain a much more steady milk flow throughout their lactation period than do cattle. With four animals it would be possible to have at least one animal in milk throughout the year. Increased forage production coupled with improvement in the genetic potential of the goat herd should generate substantial increases in goat milk production in Rombo District.

Goat milk production is much less important in Moshi District where climate and rainfall allow cattle to flourish. Less than half of all farmers have goats and among those who do, average goat holdings are smaller as can be seen from Table 3.3.

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TABLE 3.3

SIZE OF GOAT HOLDINGS IN KILIMANJARO BY DISTRICT, 1973[a]

Number of Goats	Percent of Households with Goats			Total Goats
	Rombo	Moshi	Kilimanjaro	
0	8	57	44	0
1	4	7	6	5,500
2	15	14	14	24,300
3	19	8	11	29,400
4	22	5	10	34,300
5	14	3	6	25,400
6	7	4	5	24,700
7 or more	11	2	4	33,400
Totals	100	100	100	177,000
Average per Household	3.9 (.27)[b]	1.4 (.14)	2.0 (.14)	
Average for Households with Goats	4.2 (.26)	3.1 (.21)	3.6 (.17)	

SOURCE: Random sample estimates.

[a]For that part of each district included in the survey area only.

[b]Numbers in parentheses are standard errors of the estimated means.

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E. Herd Size

Whereas goats are more numerous than cattle in Rombo District, the opposite situation prevails in Moshi District. Table 3.4 gives the size of cattle holdings for households in the two districts and Table 3.5 compares the size of goat and cattle herds in each.

Though the average number of cattle per household and the proportion of households possessing cattle is not that much different between the two districts, Moshi District contains 77 percent of all cattle and more than 90 percent of the grade cattle on small holdings in Kilimanjaro. This is partly related to the larger human population and land area of Moshi District and partly due to its greater emphasis on cattle relative to goats as compared to Rombo District.

Overall, there are an estimated 133,000 cattle and 177,000 goats in the survey area. About 16,400 of the cattle are grade cattle, though the skewed distribution of grade cattle holdings in the area does not encourage a great deal of confidence in this estimate. However, considering that the survey area contains about 80 percent of the human population of Moshi and Rombo Districts combined, this estimate compares quite favorably with the herd size estimate of 147,500 for all of Kilimanjaro District in 1970 made by Coulson [1972]—though that estimate was not based on an actual sample.

The surprising finding of the survey was the large number of grade cattle in the area. Coulson (1972) estimated there were only 4900 in his study. Part of the difference between the two estimates arises from the large amount of crossbreeding that is occurring between zebu cows and grade bulls on the mountain. Many of the grade

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TABLE 3.4

SIZE OF CATTLE HOLDINGS IN KILIMANJARO BY DISTRICT AS INCLUDED IN THE SURVEY AREA, 1973

Number of Cattle	Percent of Households with Cattle			Total Cattle
	Rombo	Moshi	Kilimanjaro	
0	38	31	33	0
1	27	17	19	16,500
2	21	30	27	47,500
3	7	11	10	27,100
4	4	8	7	22,800
5	2	2	2	9,000
6	0	1	1	5,400
7 or more	1	0	1	4,800
Totals	100	100	100	133,100
Average per Household	1.3 (.17)[a]	1.6 (.11)	1.5 (.09)	
Average for Households with Cattle	2.1 (.20)	2.4 (.11)	2.3 (.09)	

SOURCE: Random sample estimates.

[a]Numbers in parentheses are the standard errors of the estimated means.

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TABLE 3.5

ESTIMATED CATTLE AND GOAT POPULATIONS
IN KILIMANJARO SURVEY AREA, 1973

Animal Type	Total Population		
	Rombo District	Moshi District	Totals
Goats	92,700 (6,504)[a]	84,300 (8,798)	177,000 (12,269)
Zebu cattle	28,900 (3,816)	87,700 (6,240)	116,600 (7,350)
Grade cattle	1,700 (888)	14,800 (3,370)	16,410 (3,450)
Total cattle	30,600 (3,960)	102,500 (6,614)	133,100 (3,456)

SOURCE: Random sample estimates.

[a]Numbers in parentheses are the standard errors of the estimated means.

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cattle in the random sample are first crosses which had not yet come to the attention of neighbors. Simply speaking, farmers have been rapidly upgrading their zebu cattle in spite of the largely ineffective artificial insemination program and the lack of Ministry of Agriculture bulls on the mountain.

F. Cattle Ownership Patterns

About 15 percent of all-zebu cattle and 3 percent of grade cattle on small holdings in Kilimanjaro are not owned by the household which cares for them. The practice of borrowing cattle has long historical roots in Kilimanjaro. In pre-colonial times all cattle belonged to the chief but were cared for by individual households [Kraph, 1968]. Today the practice appears to be fading as declining milk yields, lengthening calving intervals and interest in coffee have lowered returns to cattle and raised the opportunity cost of the borrowers' labor. On most parts of the mountain, farmers who care for borrowed cattle are permitted to keep all manure and milk and every third calf for themselves. Increasingly, borrowers are keeping every second calf to compensate for declining milk yields and calving rates. Some farmers, however, keep nothing more than a single borrowed male animal in order to get manure for their banana groves, some kind of consideration when it is used for breeding purposes, and perhaps some heat for their homes during the cold season. As would be expected, few farmers are able to borrow grade cows since milk production is the principal reason for owning them.

Most cattle are kept on the homestead itself. A small percentage are farmed out to herders in the plains or in the forest reserve

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under various arrangements, though this proportion is no doubt under-reported. Generally owners forego the milk of animals grazed in the plains. They pay 2/= per animal per year plus forego any milk from animals grazed in the forest reserve. Not surprisingly, no farmers reported having loaned cattle to other farmers even though 15 percent had borrowed cattle—another manifestation of the difficulty of getting income related information from farmers in the area.

Apart from those animals which were borrowed, most farmers acquired their zebu cattle through birth (60 percent) or inheritance (11 percent). A significant proportion, 16 percent, was purchased, usually from other farmers on the mountain. Farmers generally paid cash for purchased zebu animals as only 6 percent were purchased on credit, normally credit extended by the seller.

The situation for grade cattle is somewhat different. A similar proportion acquired their animals through birth but fewer than 1 percent inherited their animals from their parents. A larger proportion were purchased (38 percent) and of these, fully 28 percent were purchased on credit, three-quarters of which was extended by KNCU. These differences between zebu and grade cattle are quite logical given the recent history and high purchase price for grade cattle. The source of zebu and grade cattle on small holdings in Kilimanjaro is summarized in Table 3.6.

There is also a surprising amount of movement taking place in the cattle herd. Almost 40 percent of all animals were not born on the homestead where they are now held. For grade animals purchasing is essentially replacing borrowing as the principal means of acquiring cattle not born on the homestead. No doubt as time progresses

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TABLE 3.6

SOURCE OF CATTLE HOLDINGS IN KILIMANJARO IN 1973 BY TYPE OF ANIMAL

Source of Animal	Percent of Cattle type Acquired	
	Zebu (N = 387)	Grade (N = 297)
Born on homestead	59	60
Inherited from parents	11	0
Borrowed	12[a]	2[b]
Purchased	17	38
Received as Dowry	1	0
Total	100	100

SOURCE: Random sample estimates.

[a]Excluding 3 percent which were born on the homestead but which belong to owner of cow.

[b]Excluding 1 percent which was born on the homestead.

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inheriting from parents will become a more important way of acquiring grade dairy animals. In this early stage of development, however, older farmers shy away from the economic risks and labor exigencies of caring for grade cattle.

G. Extension, Veterinary and Artificial Insemination Services

1. Extension and Veterinary Services

The Veterinary Division and the Agricultural Division of the Ministry of Agriculture (KILIMO) are functionally separate at the regional level. Each is headed by a regional director who coordinates with the other but who, nonetheless, is independent. The Agricultural Division concerns itself with crop production and extension and the Veterinary Division with animal health. Since 1963 responsibility for animal husbandry has rested with the Agricultural Division of KILIMO.

At the time of the survey agricultural and veterinary extension services in Kilimanjaro were organized around a system of KILIMO Extension Centers (KEC). The centers are staffed by one or more artificial inseminators, and by animal health, animal husbandry, cooperative extension and crop husbandry extension agents. Some of the centers, especially those in more remote areas, use grade bulls instead of inseminators. In 1973 there were 15 KEC's serving Moshi and Rombo Districts. Most of these were in the survey area. Not all were completely staffed, however.

In theory the close proximity of extension agents should lead to coordination of veterinary, animal husbandry and artificial

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insemination activities, though each agent is expected to be able to advise farmers on matters outside his particular area of expertise. In practice coordination and systematic follow-up seem to be continuing problems. Though agents are supposed to make regular rounds, the thin staffing in relation to demand and the lack of transportation results in their spending a good deal of time responding to individual calls for assistance. As a result, agents are frequently off on other business when farmers call for their services. Farmers not finding an agent at his post leave a note informing him of the problem and requesting the agent to visit. Not infrequently the agents fail to follow-up such requests.

2. Artificial Insemination Service

Artificial insemination for stall fed grade cattle began in 1964 with a pilot scheme operated through a cattle association organized for that purpose at Marangu. The veterinary service arranged for importation of semen from Kabete in Kenya and collected payments from the association. The association, in turn, was responsible for collecting A.I. fees from its members. An extension agent was assigned to work with the cattle association both to inseminate the animals as well as to advise farmers on animal husbandry [Bornstein, 1971].

Between 1964 and 1967 other cattle societies were formed and use of artificial insemination expanded. However in 1968 the societies lost much of their raison d'être when OXFAM financed a program to make semen available to all farmers for 10/= for up to three inseminations per female. Finally, in 1970, the Northern Region Dairy Development Project began providing semen free to farmers and began aggressively

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pursuing the artificial insemination of zebu cows. After a brief spurt of activity and substantial increases in the number of inseminations in 1971 the gains slowed in 1972 in spite of a substantial increase in the number of inseminators. In 1973 there was an actual decline as can be seen from Table 3.7. Given the fact that there were about 70,000 breeding age zebu females[1] and 7,000 breeding age grade females[2] in the district in 1973 the lack of greater progress was disturbing.

The stagnating number of inseminations was only a symptom of other problems with the artificial insemination service. In an excellent summary of the history of A.I. in Kilimanjaro Region Bornstein [1971] notes the low motility of semen and the conflicting duties of the inseminators. Others have mentioned as problems the lack of experience of cattle owners in identifying estrus, problems in travelling on the mountain during the rain, and poor feeding as a factor upsetting heat periods and the way in which they are manifested. My own observation is that supervision and management of the A.I. personnel were almost totally lacking. Until minimum performance standards for inseminators and extension staff are set and enforced, there is little likelihood of substantial improvement in the number of inseminations per agent.

At the end of 1973 the A.I. service was reorganized along the lines of set daily rounds to static points so as to increase the number of services per inseminator which were possible in a day.

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[1]Three years of age or older.

[2]Two years of age or older.

TABLE 3.7

NUMBER OF ARTIFICIAL INSEMINATIONS IN
KILIMANJARO DISTRICT, 1964-1972

Year	Number of Artificial Inseminations
1964[a]	90
1967[b]	500
1968	360
1969	768
1970	1,368
1971	1,979
1972	2,342
1973[c]	1,800

SOURCE: Ministry of Agriculture files, Moshi.

[a]Includes only the Marangu cattle society.

[b]Rough estimate.

[c]Projected on the basis of six months of data.

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Farmers could then bring their animals to roadside crushes[1] located at these points for insemination. However the difficulty of handling large grade cows which have been confined was proving to be a problem for farmers. In practice many farmers were meeting inseminators at the crushes and taking them to their farms to service animals in heat.

At the time of the survey it was still too early to pass judgement on the new system. Indeed it was not yet operating in all extension centers. Given previous problems with transport, however, it does not seem wise to shift to a system even more dependent on vehicle movement than the previous one. Though in theory the system of set daily rounds to static points could be implemented on foot or bicycle as well, this is not what was occurring in 1973.

H. Credit

The Kilimanjaro Native Cooperative Union (KNCU) provides the only practical source of formal credit to farmers on the mountains. Historically KNCU emphasized credit for inputs for coffee. In 1969 it began extending credit for purchases of grade cattle and associated inputs by members. Initially the society used its own funds but as demand for grade cattle has increased, the Tanzania Rural Development Bank has stepped in with additional financing.

By the end of March, 1974, 937 head of cattle were purchased under the KNCU loan program. Of these 872 were purchased in Kenya for distribution to members. The remainder were purchased from local

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[1]A crush is a chute-like narrow-walled corral in which a cow's movement is progressively restricted to zero so as to permit insemination.

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farmers and estates. KNCU does not charge farmers for transportation, veterinary fees or other handling costs. Farmers pay only the purchase price of the cattle which varies from one shipment of cattle to the next, though average prices for in-calf heifers have risen steadily from 1300/= in 1970 to 1485/= in 1973.

Loans are repaid in three equal annual installments plus 7-1/2 percent interest on the balance outstanding over the previous year. The first installment on the loan is due at the end of the first year. KNCU debits the accounts of the primary societies for the loan repayments as scheduled. The primary societies, in turn, collect from farmers. In the event of default the primary society takes the loss.

To assure repayment of the loans and prevent needless mortality of expensive and, more importantly, scarce grade dairy animals each society preselects the loan recipients. KILIMO agents visit each loan applicant and evaluate their ability to care for grade dairy animals. After the agent passes his recommendation, the chairman of the executive committee of the primary society consults with various officials and members of the society and decides which members will get the cattle allocated to the society by the union. Obviously this leads to favoritism and one hears numerous complaints from farmers about it.

Though preselection may reduce mortality it does not seem to be very effective in insuring loan repayment. In a random sample of 11 of the 44 primary societies Zalla [1974] found that over 90 percent of the 226 loans scrutinized were in arrears. Of 140,000/= in payments due, only 42,800/= had been paid. And whereas only 18 percent of all households in the survey area have cement houses, 60 percent of those g

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getting cattle loans do. Clearly the preselection of candidates for loans follows class lines. Moreover, above average wealth and progressiveness do not seem to assure loan repayment. Indeed, at the time of the study the evidence pointed to a transfer of wealth from poorer, non-grade cattle-owning households, to wealthier grade cattle owners via unrepaid loans for a very profitable asset.

I. Summary

Kilimanjaro is a relatively well-educated, densely populated area that has rich agricultural resources and good rainfall. Coffee production has contributed to a growth in cash incomes and outward manifestations of wealth. Bananas, maize, beans and livestock also do well. Cultural practices are quite advanced for African farmers and in recent years grade dairy cattle have been growing in importance. There are an estimated 177,000 goats and 133,000 cattle in the survey area, most held in herds of one to four animals. Some farmers still borrow cattle to establish a cattle enterprise but this practice appears to be declining under the pressure of longer calving intervals and declining milk production for zebu cows.

Veterinary, extension and artificial insemination services all seem oriented more toward grade cattle farmers who also tend to be among the wealthier farmers. These services are constrained by a lack of transportation and a lack of supplies and quality semen. Like other services credit tends to flow to wealthier farmers who seem to be under no particular pressure to repay outstanding loans for grade cattle. The analysis of herd structures, herd dynamics and relative mortality rates for zebu and grade cattle in the next chapter suggests that this lack of pressure to repay is not caused by the poor performance of grade cattle.

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CHAPTER IV

HERD STRUCTURE AND HERD DYNAMICS

A. Herd Structure

1. Zebu Cattle

a. Age-Sex Structure of the Zebu Cattle Herd. Table 4.1 details the age-sex structure of the zebu cattle herd in Kilimanjaro as indicated by the sample survey. The sex structure is not too dissimilar from extensively grazed herds reported by Miles [c1968], Meadows and White [1977] and Wilson and Clarke [1976], though the number of mature bulls is on the low side. Roughly 37 percent of the herd are heifers and cows respectively, 20 percent are immature bulls[1] and 6 percent are breeding bulls.

The low number of breeding bulls is a source of concern for a herd that is essentially confined in groups of one to three animals. It confirms that access to bulls for breeding purposes is a problem. This may explain the very long 28-29 month average calving interval for zebu cows in Kilimanjaro.

The rather constant numbers of animals in the 1-3 age categories is slightly misleading since a number of purchased heifers for which the age was unknown would fall into this age category. Moreover

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[1]In cases where a farmer was not sure how to classify a male calf all those who had not been used for breeding purposes were classed as immature bulls.

TABLE 4.1

TABLE 4.1

AGE AND SEX COMPOSITION OF THE ZEBU CATTLE HERD IN KILIMANJARO, 1973 (WEIGHTED SAMPLE TOTALS)[a]

Sexual Maturity	Age in Years													Row Totals[b]
	>1	1	2	3	4	5	6	7	8	9	10	11 and over	un-known	
Heifers[c]	29	23	25	28	15	4	3	0	1	0	0	0	16	144
Cows	0	0	0	6	7	9	14	9	7	7	9	11	63	143
Steers	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Immature bulls	27	20	19	5	3	0	0	0	0	0	0	0	1	76
Mature bulls	0	0	2	4	4	4	1	0	0	0	0	0	8	24
Column Totals[b]	56	44	46	44	29	18	18	9	8	7	9	11	88	388

SOURCE: Random sample weighted totals.

[a]The unweighted number of animals is 583.

[b]May not add to exact totals due to rounding errors in aggregating weighted cases.

[c]Heifers are all females which have not yet given birth to or aborted a calf.

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purchases within this age category from herders in the plains tend to offset outflows. The large number of unknown ages for cows reflects the fact that many were purchased when younger. No doubt cow numbers would rise and fall more sharply with age if these animals could be allocated to their proper age category.

The average age of the 23 percent of cattle for whom age was not known is well above the 3.7 year average for the rest since most are cows. Imputing the average age of each category of sexual maturity to the unknown observations associated with it would raise the average age of the herd to just over four years. Since the zebu herd is relatively stable, this implies a gross offtake rate of about 25 percent per year.

Another, perhaps more important source of the relatively low numbers of animals in the 0-3 age category is the growing tendency to cross zebu cows to grade bulls, shifting their offspring to the grade cattle herd rather than increasing the size of the zebu herd. In 1973, for example, more than 21 percent ($\pm$6) of all confirmed pregnancies among zebu cows originated from grade bulls or artificial insemination, while about 9 percent of births from zebu cows over the previous twelve months were half-crosses.

The rather high number of immature bulls in the herd attests to the importance of the meat production aspect of the zebu cattle enterprise. None of the 70 calves born during the 12 months prior to the interview to zebu cows in the herd at the time of the interview had been slaughtered. On the other hand the mortality rate among bull calves separated from their mother clearly is much higher than for females as we shall see later.

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b. Transactions and Deaths. Table 4.2 summarizes all cattle transactions, movements, deaths and births occurring in the 12 months prior to the interview. The figures in the table reflect the tendency to borrow and purchase young breeding stock and to sell or slaughter older cows and male stock. All purchases of female stock and 80 percent of male stock were for purposes of raising the animals. The purpose given for borrowing all stock was, as would be expected, to raise them. Heifers and young bulls were sold about half for slaughtering and half for raising, whereas over 90 percent of the cows and all the bulls in the sample were sold for slaughter. Fattened males are prized locally and are generally slaughtered and sold by the farmer himself, keeping, of course, a portion for household consumption. Older females, on the other hand, are sold to local butchers for more impersonal disposition in the local meat market.

Overall, death as reported accounts for as much disappearance[1] as slaughter when sales are adjusted for sales to other farmers (25 percent) as opposed to sales to butchers for slaughter (75 percent). This may not have the same welfare implications as in some other parts of Africa, however, since in Kilimanjaro farmers report that many dead animals are discarded rather than eaten.[2]

The higher level of outflows relative to inflows suggests a rate of decline of slightly less than 4 percent per year in the zebu herd. In fact, the actual decline, if the figures are correct, would

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[1]Defined as the net outflow of animals from the herd.

[2]The survey data indicate that 84 percent of all dead animals not slaughtered in extremis were discarded. Only 16 percent were consumed. These proportions do not vary substantially with the age of the animal. However, enumerators insisted that farmers discarded few dead animals.

TABLE 4.2

NUMBER OF ZEBU CATTLE TRANSACTIONS MADE DURING THE TWELVE MONTHS PRECEDING THE INTERVIEW, BROKEN DOWN BY SEXUAL MATURITY (WEIGHTED SAMPLE TOTALS)

Transaction	Sexual Maturity					Transaction Totals[a]
	Heifer	Cows	Steers	Immature Bulls	Mature Bulls	
Inflows:						
Births[b]	40	0	0	40	0	80
Purchases	18	3	3	5	3	32
Borrowed	10	1	0	2	0	13
Other inflow	2	0	0	0	0	2
Total Inflows	70	4	3	47	3	127
Outflows:						
Deaths[c]	18	19	0	20	1	58
Slaughtered	3	7	0	8	10	28
Sales	9	16	0	5	6	36
Returned to owner	6	4	0	4	2	16
Other outflows	2	2	0	0	1	5
Total Outflows	38	48	0	37	20	143
Weighted sample herd size	144	143	1	76	24	388

SOURCE: Random sample totals unless otherwise noted.

[a]May not equal row total due to rounding errors in aggregating weighted sample totals.

[b]Includes three female and eight male births imputed to the 38 cows which died, were slaughtered or sold for slaughter over the previous 12-month period and an estimated four females and three males which are half-crosses with grade bulls and are not, therefore, zebu cattle.

[c]Includes a single one-year old immature bull slaughtered *in extremis*.

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be close to 6 percent since part of the herd is crossed to grade bulls. Seven of the 80 births to zebu cows recorded in Table 4.2 are estimated to have been zebu/grade crosses and not, therefore, technically part of the zebu herd.[1] A breakdown of the transaction data by age confirms this failure to replenish the zebu herd at historical rates in that outflows in later years are excessive in relation to the current population of the 1-3 age groups and implied age specific mortality rates. Farmers in Kilimanjaro are rapidly replacing their zebu cattle with half-crosses and upgrading their cattle herds. This is confirmed by the genetic histories of grade calves.

Even granting the growing tendency to breed zebu cows to grade bulls the almost 6 percent decline in the zebu herd implied in the transaction and birth data is not plausible. The random sample suggests that about 2100 calves representing around 2 percent of the zebu herd shifted into the grade herd because of crossing. The remaining 4 percent may reflect genuine contraction of the herd, especially given the returns suggested by the analysis in Chapter IX, but also, no doubt, includes some sampling error, telescoping non-birth transactions into the 12 month recall period, or unaccounted births to cows not now in the herd. Overall, however, the transaction, birth and age-sex structure data for the zebu herd are remarkably consistent with each other and confirm the gross offtake rate[2] of 25 percent implied by the average age of the herd.

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[1] Six of these are still in the herds where they were born.

[2] Defined as all outflows less non-birth inflows expressed as a percent of the average herd size for the year.

2. Grade Cattle

a. Age-Sex Structure of the Grade Cattle Herd. The age-sex structure of the grade cattle herd reflected in Table 4.3 and the summary of transactions, movements, deaths and births in Table 4.4 all confirm the rapid growth in the grade dairy herd at the expense of the zebu herd. The proportion of heifers and cows is higher, the age structure of the entire herd much younger, and the 0-4 age categories show a decline in numbers consistent with recent rapid growth. Average age is 2.6 years as compared with 3.7 for the zebu herd but the large number of cows for which age is unknown indicates the true average age is well above this. Even more than in the zebu herd, there is a dearth of mature males though, theoretically, the availability of an A.I. service relieves somewhat the need for them. There are fewer immature bulls than in the zebu herd. However comments by farmers suggest that more will be kept for breeding purposes as they become available unless the artificial insemination service improves.

b. Transactions and Deaths. In contrast to the transaction data for zebu cattle, those for grade cattle reflect a very large excess of inflows over outflows. Reported mortality is lower, reflecting lower calf mortality, the younger age structure and the rapid growth in the herd. Purchases are higher and more concentrated on heifers and cows. Unlike in the zebu herd, purchases exceed sales by almost 50 percent, reflecting the large influx of grade animals from Kenya, West Kilimanjaro and other areas outside the survey area. Finally the large number of half-crosses born to zebu cows effectively increases the breeding stock for this herd and generates further

TABLE 4.3

AGE AND SEX COMPOSITION OF THE GRADE CATTLE HERD IN KILIMANJARO, 1973 (WEIGHTED SAMPLE TOTALS)[a]

TABLE 4.3

AGE AND SEX COMPOSITION OF THE GRADE CATTLE HERD IN KILIMANJARO, 1973 (WEIGHTED SAMPLE TOTALS)[a]

Sexual Maturity	Age in Years													Row Totals[b]
	>1	1	2	3	4	5	6	7	8	9	10	11 and over	un-known	
Heifers[c]	53	26	26	5	2	0	0	0	0	0	0	0	12	124
Cows	0	0	5	16	7	11	5	10	7	0	5	2	51	119
Immature bulls	28	14	2	5	0	0	0	0	0	1	0	0	2	51
Mature bulls	0	0	4	2	1	0	0	0	0	0	0	0	1	8
Column Totals[b]	81	40	37	27	9	12	6	10	7	1	5	2	65	302

SOURCE: Composite grade cattle sample totals.

[a]The unweighted number of animals was 548.

[b]May not add to exact totals due to rounding errors in aggregating weighted cases.

[c]Heifers are all females which have not yet given birth to or aborted a calf.

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TABLE 4.4

NUMBER OF GRADE CATTLE TRANSACTIONS MADE DURING THE TWELVE MONTHS PRECEDING THE INTERVIEW, BROKEN DOWN BY SEXUAL MATURITY (WEIGHTED SAMPLE TOTALS)

Transaction	Sexual Maturity					Transaction Totals[a]
	Heifer	Cows	Steers	Immature Bulls	Mature Bulls	
Inflows:						
Births[b]	61	0	0	37	0	98
Purchases	26	9	0	3	0	39
Borrowed	0	0	0	0	1	1
Other inflow	0	2	0	0	0	2
Total Inflows	87	11	0	40	1	140
Outflows:						
Deaths[c]	4	11	0	11	0	26
Slaughtered	0	7	0	5	4	16
Sales	12	4	0	6	3	25
Returned to owner	0	0	0	0	0	0
Other outflows	0	0	0	1	0	1
Total Outflows	16	22	0	23	7	68
Weighted sample herd size	124	119	0	51	8	302

SOURCE: Composite grade cattle sample totals unless otherwise noted.

[a]May not equal row total due to rounding errors in aggregating weighted records.

[b]Includes two female and four male births imputed to cows disposed of over the previous 12-month period and seven males and eight females born to zebu cows and grade bulls.

[c]Includes seven cows slaughtered *in extremis* and two calves which were aborted.

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rapid growth. Overall the data imply a growth rate of 31 percent during the 12 months preceding the survey.

This is not a true growth rate. It is biased upward by the exclusion from the sample of those households which had lost or disposed of all their grade cattle over the previous 12 months. In the random sample such households accounted for 10 percent of all non-birth transactions, including 18 percent of all deaths and 14 percent of all sales. Overall these households accounted for 6 percent of non-birth inflows and 12 percent of outflows. Adjusting the aggregate inflow/outflow data in Table 4.4 accordingly gives a growth rate for the grade cattle herd of 27 percent over the past 12 months, still a very impressive rate. This represents an addition to the grade herd of 3500 animals.[1] The recent nature of such tremendous growth partially explains why current official estimates of the grade dairy herd in Kilimanjaro are so far below the sample survey estimates.

A look at the slaughter and mortality figures in Table 4.4 shows a greater tendency for bull calves to die and be slaughtered relative to females. According to the veterinary service, this

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[1]The reader is reminded that the composite grade cattle sample is a non-random sample for the most part. The growth data shows how much of a bias this can cause. The random sample, for example suggests that about 9 percent of all births to zebu cows over the previous 12 months were zebu-grade crosses. This comes to about 2100 f_1 calves. About 35 percent of all live grade cattle calves under one year found in the random sample—which included only a small number of grade cattle—were f_1 crosses. Given our estimate of current grade cattle herd size of 16,400 this would imply that calves under one year make up 37 percent of the grade herd instead of 27 percent as implied by the composite sample. Coupled with the fact that only 19 percent of the calves in the grade cattle sample are f_1 crosses it is clear that the non-random grade cattle sample is biased away from farmers who are upgrading and toward wealthier farmers who are able to purchase grade cattle outright.

arises from farmers' desire to have more milk for sale. Though the data support this assertion, they also suggest some accumulation of bull calves for fattening and for eventual use as breeding stock—a very logical response on the part of farmers given the poor performance of the A.I. service at the time.

Deaths account for a much lower proportion of offtake for the grade cattle herd than for the zebu herd. Distress slaughter accounted for 30 percent of home slaughter versus 3 percent for the zebu herd, though this figure is misleading.[1] Moreover, 85 percent of sales were for husbandry purposes rather than for slaughter, in contrast to 25 percent for the zebu herd. This proportion is reflected in all the maturity categories except for bulls. The total numbers sold, however, are not enough to give much reliability to disaggregated numbers. As with zebu bulls, there is a marked preference to slaughtering bulls at home for local sale rather than selling them to butchers.

B. Mortality Rates

Obtaining reliable estimates of mortality for different age-sex groups from cross-sectional data is difficult when there is so much change taking place in the composition of two interrelated herds. Moreover, death rates are clearly different for calves remaining with their mothers and those permanently separated from them for one reason or another. A look at the data on the zebu herd demonstrates this.

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[1]These data are heavily influenced by a single household in which a herd of seven grade cows had to be slaughtered within 24 hours after receiving an incorrect dosage of medication from a veterinary agent.

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1. Zebu Cattle Mortality

Data on zebu calves born over the previous 12 months to cows in the herd at the time of the survey suggest a very low under one year calf mortality rate for those remaining with their mothers. Only 7 percent of all calves born to existing zebu cows (N = 67) had died by the time of the interview, and most of these occurred during the first three months of life. Since the average age of calves in this age group is 5.3 months and the average age at death of those having died thus far was 3.3 months, the actual 12 month mortality rate for calves under one year staying with their mothers suggested by those data is under 10 percent.[1] Three calves had either been loaned out or returned to their owner, and could not be identified as alive or dead at the time of the interview.

An under one year mortality rate around 10 percent is not unheard of among extensively grazed indigenous cattle herds in Africa

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[1] $$r_o = \frac{12}{\bar{a}_o} \times \frac{\bar{a}_{m_o}}{\bar{a}_o} \times \frac{m_o}{n_o + m_o} = \frac{12}{5.3} \times \frac{3.3}{5.3} \times \frac{4.4}{67} = 9.3\%$$

where r_o = mortality rate for under one year old age group
$\bar{a}_{m_o}$ = average age at death of animals which were in the o^{th} age group when they died
$\bar{a}_o$ = average age of all animals currently in the o^{th} age group
m_o = the number of animals in the o^{th} age group which have died
n_o = the number of animals currently in the o^{th} age group

If births were evenly spaced over the year the terms

$\frac{12}{\bar{a}_o} \times \frac{m_o}{n_o + m_o} = 13.1\%$ would give the under one year mortality rate since the average calf in this age group would have lived six months. The fact that the average age is lower than six months and the average age of those animals which have died is lower still necessitates addition of the adjustment factor $\frac{\bar{a}_{mo}}{\bar{a}_o}$.

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since most calves nurse for their first year of life.[1] It is not likely under a stall feeding system where diseases and infection are more difficult to control. This is supported by the large number of reported deaths for animals in the under one year age group.

A look at the herds in which the 15 reported deaths of calves under one year of age occurred shows that about 30 percent were born to cows still in the herd, 35 percent to cows which themselves died and 30 percent died in herds where there is no cow which could have given birth to them. One calf died either before or after its mother was sold.

Four of the five calves which died for which there was no mother were 7-9 months old when they died so it is possible they were either acquired or their mothers were removed from the herd prior to the 12-month period to which the recall data apply. However, there appears to be some telescoping of mortality from previous periods as well. Overall the data suggest that about 10 percent of the mortality reported for calves under one year actually occurred prior to the reference period and should not, therefore be included in computing calf mortality.

Breaking down the transactions data in Table 4.2 by age yields age specific mortality rates for zebu cattle. This is done in Table 4.5. These data confirm the very high mortality for animals separated from their mother during the first year—especially male

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[1]Pullan [1980] found 12 percent under one year mortality in a one year study of white fulani cattle on the Jos plateau but all sick animals were treated in order to secure owner cooperation in the study. Mishra et al. [1979] found a calf mortality rate of 11.9 percent in northern Ivory Coast but this was based on a study of herds in a "managed environment."

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TABLE 4.5

MORTALITY AND AGE SPECIFIC MORTALITY RATES
FOR ZEBU CATTLE IN KILIMANJARO, 1973

Description	Age Group (years)							Total[a]
	<1	1	2-3	4-5	6-8	9+	un-known	
Number of Deaths[b]								
Male	10	6	4	1	0	0	0	21
Female	5	3	8	2	6	3	10	37
Total[a]	15	9	12	3	6	3	10	58
Current Herd Size								
Male	27	20	30	11	1	0	9	101
Female	29	23	59	35	34	27	79	287
Total[a]	56	44	89	47	35	27	88	388
Implied Age Specific Mortality Rates[c]								
Male	.27	.23	.13	.08	...	...	...	.17
Female	.15	.12	.12	.05	.15	.10	.11	.11
Overall rate	.21	.17	.12	.06	.15	.10	.10	.13
Estimated Actual Mortality Rates as Used in Enterprise Simulations[d]								
Male with Mother	.24	.21	.10	.10	.10	.10		
Female with Mother	.13	.10	.10	.10	.10	.10		

SOURCE: Random sample estimates and researcher judgement.

[a]May not equal apparent totals due to rounding errors in aggregating weighted files.

[b]Includes a one-year old male slaughtered in extremis.

[c]Implied age specific mortality r_i is calculated as follows: $r_i = \frac{m_i}{n_i + m_i}$
where m_i = number of animals which have died in age group i
n_i = number of animals in age group i

[d]Calculated as follows: $\frac{.9 \times m_i}{n_i + .9m_i + \frac{b_i}{2}}$

where .9 adjusts for telescoping of deaths amounting to 10 percent of the number of reported deaths, n_i and m_i are defined as above and b_i is the number of crossed grade calves estimated to have been born to grade cows in year i. The term $b_i/2$ reflects the fact that the average herd size in the ith age category has declined over the year due to crossing of zebu cows to grade bulls. The rate for years 2 through 9+ is calculated by combining males and females and assuming $b_i = 0$.

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calves. Only two of the 56 calves in the sample were living without their mother. Eleven other calves separated from their mother died, though for half of these it is not clear whether the calf or the mother died first.

Under two year mortality for males is about twice as high for bull calves as for heifer calves. Partly, this arises from the fact that more male calves are returned to their owners and given as bride wealth. It is also possible that farmers prefer to report slaughtering of young bulls as deaths since slaughtering male calves is not traditional practice, and normal beneficiaries of home slaughtered meat might complain.[1] Other explanations for the high ratio of male calf mortality relative to female mortality include a lower value attached to male calves relative to female calves—something one would expect under a stall feeding system constrained primarily by available labor and feedstuffs[2]—leading perhaps to shorter nursing periods or more bucket feeding, even though the reported frequency of nursing is the same.

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[1]As in many parts of Africa precise guidelines exist for the distribution of home slaughtered animals. These traditional distribution relations are breaking down, to be sure, but there is no doubt still a good deal of shame in not following them.

[2]It is interesting to note that the author was skeptical of extension agents' assertions that slaughtering of young calves is common practice among farmers on the mountains especially in grade herds. This skepticism led to a fairly careful distinction between deaths, emergency slaughter and slaughter of young calves during the survey. Initially the absence of slaughtering and distress slaughter and the equal periods and frequency of nursing both bull and heifer zebu calves suggested this skepticism was warranted. The disparity in mortality rates suggests otherwise. Perhaps enumerators were not careful in probing differences in management practices between bull and heifer calves. Or maybe farmers conceal this practice for some unknown reason. At the time of data collection this inconsistency was not apparent and was not pursued. However, high differentials in

Looking at the other age groups, it appears that mortality from year two onward averages around 11 percent per year, on the basis of reported deaths, with no difference between the sexes. The implied crude death rate of .13 percent is not bad for sedentary cattle herds in Africa and reflects the generally good husbandry practices of the Chagga.[1]

Table 4.5 also includes the mortality rates used in the enterprise simulations. In light of the inconsistencies between inflows and outflows, due presumably to a telescoping of deaths and sales relative to births,[2] we have reduced mortality by 10 percent from that actually reported. For the two lowest age groups we have also adjusted the base herd size to reflect the decline in average size that is taking place as a result of crossing zebu cows to grade bulls. The recomputed under two year mortality rate of 22 percent for heifer calves reflects the kind of mortality one would expect from a basically well managed stall feeding system undertaken by peasant farmers.

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male versus female mortality suggest something systematic leads to a higher rate of elimination of young males from the herd. An anonymous report of a survey of grade cattle in Kilimanjaro carried out in 1963 [Tanzania, 1963] by animal husbandry assistant field officers noted that the majority of farmers who experienced calf mortality were rearing them artificially. This appears to mean the calves were bucket fed. It is not unlikely that farmers are more willing to bucket feed male calves than female calves, though our data do not show this to be the case.

[1]For an example of much higher mortality rates among sedentary cattle see Wilson and Clarke [1976].

[2]Reported births should be much more accurate since the majority of time the calf or cow concerned was still in the herd.

2. Grade Cattle Mortality

Table 4.6 presents similar data for the grade cattle herd. Across the board, mortality rates appear very low and reflect the fact that, for the most part, grade cattle are still raised only by relatively wealthy, educated progressive farmers. These farmers have better access to veterinary services and purchased inputs, though this is not always an advantage.

Actual mortality rates are not quite this low since the large net inflow of new animals into the herd reduces the number of months of the year over which mortality can occur and inflates the actual base relative to the average base. There also seems to be some underreporting of deaths on the transactions form from which the mortality data were taken. On the basis of calving histories of cows in the herd at the time of the survey there should have been another death for males and one for females reported for the first year.

In fact, the calving histories alone imply an average under one year mortality figure of 13 percent for all grade calves with the figure for males being 23 percent and for females, 5 percent. The high rate for males, given the low rate for females, suggests that some farmers are indeed disposing of male grade calves in order to salvage milk for sale. These may be reported as deaths rather than slaughter because the animals are discarded rather than consumed. In any case, the calving histories almost certainly give a more correct picture of actual mortality than the implied age specific mortality rates since few grade calves are given away or returned to their owners. The mortality rates used in the enterprise simulation, also

TABLE 4.6

MORTALITY AND AGE SPECIFIC MORTALITY RATES
FOR GRADE CATTLE IN KILIMANJARO, 1973

Description	Age Group (years)							Total[a] mortality
	<1	1	2-3	4-5	6-8	9+	unknown	
Number of deaths[b]								
Male	6	1	0	0	0	0	4	11
Female	4	1	2	0	7	1	1	17
Total[a]	12	2	2	0	7	1	5	28
Herd size								
Male	28	14	13	1	0	1	3	59
Female	53	26	52	20	22	7	63	243
Total[a]	81	40	65	21	23	8	65	302
Implied age specific mortality rates[c]								
Male	.18	.07	0	0	...	0	.57	.17
Female	.07	.04	.04	0	.24	.13	.02	.07
Overall rate	.13	.05	.03	0	.23	.11	.07	.09
Estimated actual mortality rates as used in enterprise simulations								
Male	.20	.10	.10	.10	.10	.10		
Female	.07	.07	.06	.06	.06	.06		

SOURCE: Composite grade cattle estimates and researcher judgement.

[a]May not equal apparent totals due to rounding errors in aggregating weighted files.

[b]Includes animals slaughtered *in extremis*.

[c]Implied age specific mortality, r_i, is calculated as follows: $r_i = \frac{m_i}{n_i + m_i}$
where m_i = the number of cattle which have died in age group i
n_i = the number of animals in age group i

[d]Calculated approximately as follows:

$$\frac{m_i \times 1.20}{\frac{n_{i_t} + n_{i_{t-1}}}{2} + m_i}$$

In contrast to the random sample, mortality for grade cattle has, if anything, been underreported rather than overreported. This is not surprising given the progressiveness and levels of education of most grade cattle owners which makes them aware that high mortality reflects poorly on their management skills. For this reason no adjustment has been made for this kind of underreporting as was done with zebu cattle, apart from that mentioned in the text. In addition the actual m_i for years one and over used in calculating these rates have been increased by 20 percent to compensate for mortality occurring in households which had a grade cattle enterprise at the beginning of the reference period but not at the time of drawing the grade cattle sample.

The term $n_{i_t} + n_{i_{t-1}}/2$ adjusts base period herd size to reflect the rapid growth occurring over the year with the consequence that average age for the category is less than its midpoint. $n_{i_{t-1}}$ is assumed to be 79 percent as large as n_{i_t} to reflect the estimated 27 percent growth rate.

Two of the deaths recorded for years 6 through 8 for females were assumed to not have occurred in calculating female mortality from year 2 onward. This is justified by the highly atypical way in which these deaths occurred.

Finally the above formula yielded unreasonable estimates of male mortality for years 2 onward. Figures obtained for zebu males are used instead. Other adjustments have been made to remove anomalies.

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listed in Table 4.6, reflect our best judgement of actual mortality rates after adjusting for all these factors.

C. Summary

The analysis of herd structure and cattle transactions in this chapter reveals a grade cattle herd that is rapidly expanding at the expense of a declining zebu cattle herd. High mortality rates and long calving intervals effectively prevent growth in the zebu herd in the absence of purchases from outside the area. Lower mortality rates, earlier and more frequent births for grade cows and the high proportion of the grade herd which consists of females all served to generate an increase of around 25 percent in grade cattle numbers in 1973.

In the next chapter we begin a more detailed look at those factors which influence returns to resources invested in alternative cattle enterprises, both now and over the longer term.

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CHAPTER V

AGGREGATE MILK PRODUCTION, MILK MARKETING AND RELATED PUBLIC HEALTH ISSUES

A. Aggregate Milk Production

The study yielded only very crude estimates of aggregate milk production. The failure to obtain more refined estimates was due partly to the crude measuring techniques possible in a single visit interview but more importantly, to probable underreporting by farmers. The survey generated two relatively independent estimates of annual milk production: the amount reported directly by farmers for the day prior to the interview; and the amounts indicated by the lactation histories of cows. Though these two measures are not entirely independent they can be cross-checked against raw milk consumption as reported on a food consumption questionnaire as a check for accuracy. These three estimates are summarized in Table 5.1.

The estimates in Table 5.1 suggest that farmers either underreported milk production or overreported milk consumption by a substantial amount. Looking first at reported milk production, 78 percent of cattle milk production and all of goat milk production was reported to have been consumed by household members. The means 6.9-8.0 million liters were consumed at home—depending on the estimate of total production used—as opposed to the 7.3 million indicated by the food consumption figures—scarcely a difference in statistical terms. In all likelihood reported production is more accurate than

TABLE 5.1

COMPARISON OF TWO ESTIMATES OF ANNUAL MILK PRODUCTION IN KILIMANJARO WITH REPORTED CONSUMPTION, 1973

(1,000 LITERS)

Type of Estimate	Estimated Annual Totals	Standard Error of Estimate
a. Reported milk production[a]		
Zebu cattle	5,856	893
Grade cattle	4,177	422
Goats	284	95
Sub-Total	10,317	1,960
b. Cow Lactation histories adjusted for calving interval		
Zebu cattle[b]	4,239	347
Grade cattle[b]	4.293	345
Goats	284	95
Sub-Total	8,816	787
c. Household fluid milk consumption		
Raw milk from own production	7,275	1,314
Other raw milk[c]	10,567	1,325
Total fluid milk consumption	17,842	1,734

SOURCE: Random sample estimates.

[a]Extrapolated from production reported for the day preceding the interview.

[b]Raised sample totals divided by average calving interval for animals in the random sample only.

[c]Includes fluid milk imports from outside the survey area.

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the production estimate based on lactation histories since, like food consumption, it relates to the previous day's activities for a sample of households visited over a period of six months. Thus, of the two production figures, the higher is probably more reliable. Moreover, there is also good reason to believe that the lactation milk production figures are biased downward, as is explained in a later section.

No matter what production figure is taken, however, it is difficult to explain the origin of other raw milk consumed by the household if the consumption figures are to be believed. To be sure not all of it came from within the survey area, sales figures for Northern Dairies Limited (NDL), a local processing plant for milk from estates and state farms, indicate sales of about 1.1 million liters in the survey area for 1973, though this amount is difficult to estimate.[1] Substantial amounts of raw milk flow into the survey area from Samé and lowland herders to the east, and from herds near Sanya Juu in the west. It is difficult to estimate this flow as well but it can hardly exceed three hundred liters per market per market day. This would amount perhaps to another .9 million liters per year at most. Partially offsetting this is a small amount of milk which flows from Uru and Machame into Moshi Town, though such trade is presently illegal.[2] On balance, then, probably no more than 2.0 million liters of other raw milk came from outside the survey area. Allowing for 400,000 liters of milk consumed by calves after milking, the

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[1]1.1 million liters constitute 33 percent of total NDL sales in and near Moshi Town for 1973.

[2]Direct sales of unpasteurized milk from farmers to consumers in Moshi township were made illegal in 1952 (Ministry of Agriculture, 1959).

gap between reported production and consumption amounts to 5.9 million liters of milk per year.

In all probability both the production and consumption figures are in error. Since the variances of the separate estimates are very similar in spite of the substantial differences in totals, it would be appropriate to increase the production estimate and reduce the consumption estimate by one-half of the 5.9 million liter gap. However this procedure leads to estimates of lactation milk production that are unrealistic in relation to reasonably well informed opinion in the District. Since farmers were aware of the nutritional objectives of the study and since only two-thirds of the households had cattle it seems reasonable to conclude that consumption of milk was overreported by more than milk production was underreported. Increasing production by one-third of the difference and reducing consumption by two-thirds, a guess would be that fluid milk consumption in the survey area arose approximately from the sources listed in Table 5.2.

Thus total milk production in the area in 1973 was probably around 12.3 million liters, including .4 million liters fed to calves after milking. Somewhere between 40 percent and 50 percent of this probably came from grade cattle. Overall milk production based on production reported for the day before the survey would have been underreported by about 16 percent and that based on cattle lactation histories by about 28 percent. Market sales would have been underreported by about 50 percent. These figures, of course, are only orders of magnitude and should be treated as such.[1]

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[1]The difference between production and consumption as reported in Table 5.1, after allowing for purchases from outside sources, is

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TABLE 5.2

ESTIMATED FLUID MILK PRODUCTION AND CONSUMPTION
IN KILIMANJARO IN 1973 BY SOURCE, ADJUSTED FOR UNDERREPORTING
(1,000 liters)

Source	Estimated Annual	
	Production	Consumption
Reported own production used at home	8,000	7,300
Northern Dairies Limited	...	1,100
Other outside producers	...	900
Marketed sales by Kilimanjaro producers		
Reported	1,800	1,800
Unreported	2,100[a]	2,800[b]
Milk fed to calves after milking	400	400
Totals	12,300	14,300

[a]Excluding 700,000 liters of that reported as used at home but which the consumption figures suggest was sold.

[b]Assuming all error was in production for sale and consumption from market purchases.

B. Milk Marketing

If our interpretation of the survey data relating to milk production is correct, then about 65 percent of total milk production in Kilimanjaro in 1973 was consumed on the farm by people and calves. Virtually all the rest was given or sold to neighbors either directly or through local markets. Approximately 14 percent of fluid milk consumption came from outside the survey area and 55 percent of this, or about 8 percent of overall consumption, came from Northern Dairies as pasteurized milk. Thus, more than 90 percent of all fluid milk consumed in the area was not commercially pasteurized or packaged.

In addition to fluid milk, the food consumption survey suggests that approximately 3.8 million liters ($\pm$.34) whole milk equivalent of manufactured milk products such as milk powder and evaporated milk were consumed in the survey area in 1973. Prices paid for these products on a fresh milk basis were similar or slightly higher than local fresh milk prices. In general, it appears to be the scarcity of local milk supplies at prevailing prices that gives rise to the purchase of manufactured products.

Good longitudinal data on farm level milk prices are not available for smallholders. Data which are available do not always clearly relate to the same part of the mountain. Most authors simply quote price ranges or average prices. In Table 5.3 available data on milk prices received by grade cattle owners over the 1963-1973 period are compared to coffee prices. The reader must be careful in interpreting these data since evidence suggests that owners of grade cattle

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significant at the 98 percent level if we assume the two estimates are independent. In fact, they are not and probably have a substantial positive covariance.

TABLE 5.3

PRICES OF MILK AND COFFEE IN KILIMANJARO, 1963-73

Year	District Covered	Season	Type of Milk	PRICE: MILK (Cents Per Liter) Range	Average	COFFEE[a] (£ Per Ton)
1963[b]	Moshi	Short	Unknown[c]	88-132	99	288
	"	Flush	"	70-106		
1965[d]	Moshi	Average	Unknown[c]	114	114	322
1969-70[e]	Moshi	Average	Fresh	132-141	121	354
	Rombo	Average	Fresh	88-123		
1973[f]	Sample	Average	Fresh	165(S=37)	157[g]	389[h]
	Area	Average	Sour	143(S=31)		

[a]Source: KNCU. Prices are quoted f.o.r. (freight on rail) per ton of parchment produced by KNCU. Prices are published on a mid-year to mid-year basis. Those listed here are the average for the two periods which include the year in question, except for 1969-70 for which the milk price data conform to the coffee price data, and 1973 for which the 1973-74 price of coffee was not available.

[b]Source: Tanzania, 1963.

[c]Very probably fresh milk.

[d]Source: Tairo, 1965.

[e]Source: Ministry of Agriculture Division Records.

[f]Unweighted combined sample estimates. The number of observations in the weighted samples were too small to give reliable estimates.

[g]Weighted by the proportion of actual sales.

[h]Price for 1972-73. The 1973-74 price was not available but was considerably higher.

are a more market oriented group of farmers than others. Also, most milk that is sold is sold as fresh milk whereas most milk consumed on the farm is consumed as sour milk and sour milk generally sells for less than fresh milk.

The data in Table 5.3 reveal a strong association between milk prices and f.o.r. coffee prices. We do not have data on the actual price for coffee that was received by farmers over this period but presumably the relative changes were similar. The absence of a 1973-1974 price for coffee to average with the lower 1972-1973 price means that the 1973 average price for coffee is understated. Nonetheless milk prices have clearly kept pace with coffee prices, if not increased somewhat more rapidly.

Demand for on-farm consumption and inter-farm sales of milk in Kilimanjaro is so strong at prevailing prices that few producers have to deliver milk. In most areas consumers come to producers' homes in search of supplies surplus to household needs. Complaints about the lack of available supplies are widespread. Only 10 percent of all farmers with cattle reported ever selling milk, though 36 percent of those with grade cattle did so. While both figures are no doubt underreported, only six of 71 farmers in both samples who reported they did sell milk ever had a problem disposing of what they had. Most of these had a problem only during the rainy season when milk supplies are at their peak and cash is most scarce.

Interestingly, of the six farmers reporting a problem in selling milk, only one felt that lowering the price would increase sales. No doubt in periods of such severe cash shortage price elasticities are extremely low—so low as to lead to surplus consumption or gifts to neighbors rather than lower prices.[1]

The predominant situation in Kilimanjaro, however, is one of inadequate supplies at prevailing prices rather than inadequate demand. Thus residual or unmet demand for local fresh milk supplies is no doubt considerably higher than the 5.8 million liters per year implied by fresh and manufactured milk sales by themselves. Judging from comments by both producers and consumers, unmet market demand for locally produced fluid milk in 1973 may have amounted to somewhere around 20 percent of current production or another three million liters, though only a very crude guess is possible. Adding to this the additional on-farm consumption which would be stimulated by increased on-farm production of milk, the increase in production required to saturate the local market at <u>existing</u> prices would no

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[1]Some find it difficult to believe prices can be so sticky in both upward and downward directions. This phenomenon is not unique to Kilimanjaro. The author observed similar rigidities in Mara and Tabora Regions. Upon reflection, they are really quite rational and understandable. In more traditional societies personal relationships often take precedence over market relationships. Though raising the price would no doubt reduce demand, many producers would rather place greater reliance on non-price mechanisms for allocating scarce supplies. They do not want to run the risk of being accused to taking advantage of their neighbors in time of need. In times of plenty, lowering the price by a substantial amount may indeed lead to increases in market demand, but then producers must face the reaction of neighbors if they raised prices again when supplies fall short of demand. Where market relationships overlay a strong set of personal and community relationships, it is probably safer to hold prices relatively stable and let non-price mechanisms play an important allocative role. Of course as these traditional personal and community relationships begin breaking down or as people begin expecting markets to perform allocative functions, prices may indeed become more flexible. But this takes time. Even in impersonal market economies price movements are limited by consumer reaction. We have only to look at recent confusion and bitterness over energy prices in the U.S. to appreciate this.

doubt be over twice current production levels. This means aggregate milk production would have to rise from the present 12.3 million liters per year to around 25 million liters per year just to bring supply and demand into balance at current prices—a formidable task indeed.

Only in Machame, Uru and Marangu was milk produced in such quantities in 1973 that some locally produced milk ended up in urban markets. These areas accounted for the majority of grade cattle on the mountain at that time. In this respect a crucial policy question which needs to be addressed is whether to continue to emphasize milk production in these areas with a view towards minimizing increases in on-farm consumption and collecting surpluses for possible treatment and sale elsewhere, or to distribute grade cattle and veterinary services more evenly over the mountain so as to encourage more widespread production and on-farm consumption.

C. Milk Consumption

Turning to the form in which milk is consumed, Table 5.4 shows that the major source of milk protein, about 57 percent of the total, comes from fermented milk. About 25 percent of milk protein comes from sweet local milk but over 80 percent of this is consumed in tea or coffee as is virtually all the commercially pasteurized and manufactured milk. Less than 5 percent of total milk protein is consumed as unfermented, uncooked local milk. These food habits have public health implications for a nutrition policy oriented toward an expanding role for milk among smallholders in Kilimanjaro.

TABLE 5.4

GRAMS OF PROTEIN OBTAINED FROM MILK BY AN AVERAGE HOUSEHOLD IN KILIMANJARO BY TYPE OF PRODUCT AND PREPARATION, 1973

Product	Type of Preparation	Grams Consumed	Proportion of Total Milk Protein Consumed
Local Milk:			
Sweet	incorporated in tea or coffee	5.6	.21
	other heat treated[a]	*	*
	not heat treated	1.1	.04
Fermented	heat treated[a]	11.3	.43
	not heat treated	3.7	.14
Pasteurized Milk:			
Sweet	incorporated in tea or coffee	0.1	.01
Fermented	heat treated[a]	*	*
Other Manufactured Milk:			
	incorporated in tea or coffee	4.6	.17
	other heat treated[a]	*	*
	not heat treated	*	*
Totals		26.4	1.00

SOURCE: Random sample estimates.

[a]Heat treated milk includes that actually pasteurized as well as that incorporated in dishes other than tea or coffee which themselves are cooked. Virtually no local milk is pasteurized as such.

*Less than .1 gram or 1 percent of total milk protein.

1. Public Health Aspects of Milk Consumption in Kilimanjaro

a. Disease and Contamination in Milk. Tuberculosis, brucellosis and salmonella are important diseases which can be transmitted in milk. The desire to control tuberculosis among urban populations was an important factor in the spread of pasteurization in Europe. It is also a factor behind laws forbidding the sale of unpasteurized milk in towns in Tanzania. However, a number of factors suggest that the public health risks of consuming unpasteurized milk in Kilimanjaro and Moshi Town are not as great as they might have been in Europe.

An analysis of the incidence of brucellosis in blood samples from more than 1700 randomly selected zebu and grade cattle in Kilimanjaro carried out in 1973 found that only .5 percent of the zebu animals and 1 percent of the grade animals had positive readings [Zalla, 1974]. Only one of seven infected animals for which histories were available was actually born on the farm where it was sampled, suggesting that brucellosis is not indigenous to the area.

Some protection against brucellosis, tuberculosis and other pathogens transmitted in milk is provided by the process of fermenting milk. Fermentation destroys mycobacterium tuberculosis pathogens and, somewhat less effectively, destroys brucella and several species of salmonella pathogens.[1] Moreover, when salmonella become excessive, milk does not sour properly, is recognized as bad and is discarded. In addition, the practice of boiling tea leaves and milk together when making tea provides an effective treatment for milk consumed in a

[1] For a discussion of the affect of fermentation on mycobacteria, brucella and salmonella species of pathogens, see Soulides [1949], Kosikowski [1980] and Marth [1968].

non-fermented form. Given the low percentage of milk untreated by either cooking or fermentation, and considering the enormous costs of collecting and redistributing milk so it can be properly treated, encouraging inter-farm sales of unpasteurized milk may be a good way of keeping incomes to producers high and costs to consumers relatively low, while not exposing either of them to inordinate health risks. There is a real need, in this instance, to balance the added economic and nutritional costs of pasteurization with the public health benefits. One thing is certain, peasants and the urban poor do not attach the same value to the latter as do relatively wealthy medical personnel and civil servants, as evidenced by brisk black market sales of unpasteurized milk in towns with milk processing plants throughout Tanzania.

b. Lactose Intolerance. When a person ingests milk the enzyme lactase normally breaks down the lactose into its constituent monosaccharides glucose and galactose. The monosaccharides are then absorbed by the body. If much of the lactose remains unhydrolyzed because of insufficient or non-existent amounts of lactase in the body, stomach gas, cramps, diarrhea or vomiting can result. This malabsorption of lactose is commonly referred to as lactose intolerance. Though most infants have no problem digesting lactose, many lose this ability as they grow into mature adults.

In an excellent review of research on lactose intolerance Simoons [1978] supports the hypothesis that patterns of consumption of lactose-rich dairy products over a long period of time may contribute to genetic changes in human populations and to present day differences in the prevalence of lactose malabsorption among adults

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from different ethnic groups. The prevalence of lactose intolerance in African peoples with no history of milking livestock is very high. On the other hand, pastoralists, such as the Fulani, Hima and Tussi, have very low incidences. Adults from "mixed" groups have intermediate levels of prevalence.

Apart from genetic based lactose malabsorption, there is evidence that nutritional stress and infection reduce an individual's ability to absorb lactose. Simoons [1978] points out that such secondary malabsorption is common among infants and children of the poor. He goes on to caution against wholesale reliance on milk-feeding programs, suggesting that the long-term hope for improving tropical African diets lies in the availability of cheap, locally available plant foods which can substitute for milk.

The ethnic origin of the Chagga of Kilimanjaro, having strong pastoralist roots as it does, would suggest that lactose intolerance is not a serious problem in Kilimanjaro. Though the only sure way of knowing is through biological testing, our survey did inquire into problem foods and the symptoms experienced when these foods were consumed. The results are summarized in Table 5.5.

Slightly over one-third of those persons experiencing digestive problems related to food reported diarrhea as a problem. A similar proportion reported stomach ache and the remainder vomiting and other problems. These are the kinds of problems associated with lactose intolerance and other digestive problems.

Upon close examination the data in Table 5.5 do suggest minor problems with digesting milk. In relation to the number of calories of a particular foodstuff which are consumed, milk is about five

TABLE 5.5

INCIDENCE OF DIGESTIVE PROBLEMS RELATED TO CONSUMPTION OF MILK AND OTHER COMMON FOODS IN KILIMANJARO

Problem Foodstuff	Persons in Sample Having Digestive Problems: Total Number	Persons in Sample Having Digestive Problems: Proportion of Sample Population[a]	Proportion of Calories Supplied by Foodstuff[b]	Ratio of Proportion With Problem Over Proportion of Calories Supplied
Maize	39	.018	.22	.082
Milk	38	.017	.04	.425
Beans	23	.010	.11	.091
Bananas	16	.007	.40	.018
Meat	9	.004	.09	.044
Vegetables	6	.003	.11	.027
Other Foods	25	.011	.13	.085
All Types	138[c]	.062[c]	1.00	

SOURCE: Random sample estimates.

[a]Total sample size was 2,215.

[b]In the entire sample population.

[c]Not equal to column total since a respondent could report more than one problem food.

times more likely to cause problems than maize, beans, or other foods and ten and twenty-five times as likely to cause a problem as are meat and bananas respectively. In part, this may be explained by the specific manner in which the question was asked concerning milk products as contrasted to the general way it was posed with respect to other foods.[1] Still, the overall incidence of digestive problems related to milk is low in relation to the number of households actually consuming milk on the day of the survey (1.7 percent of household members affected versus 55 percent of households consuming more than 10 grams of milk protein). The data do suggest that the problem will probably become more severe as milk consumption increases. But on the basis of the data presented here, lactose intolerance would not seem to present an important public health problem; nor does it threaten to limit the market for locally produced milk in any substantive way.

With the potential demand for milk now clearly established, we turn in the next three chapters to a detailed look at some of those management practices which influence its supply.

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[1] Farmers were asked whether any member of the family had digestive problems related to milk or any other foods.

CHAPTER VI

MANAGEMENT PRACTICES FOR ZEBU AND GRADE DAIRY ENTERPRISES

This chapter describes and analyzes the level of inputs and those management practices which directly affect the returns which farmers receive from their cattle/dairy enterprises. The typical all-zebu or all-grade cattle enterprise consists of a cow and a calf, more often a heifer calf. The typical mixed zebu-grade cattle enterprise consists of two cows and a calf but "herds" of two and four animals are almost as common. Well over half the animals on the mountain are held in groups of 2-3 animals. Larger herds are not uncommon and account for over 30 percent of all cattle, but only 15 percent of cattle-owning households. Holdings of one animal, on the other hand, tend to be in transition to a larger herd size or are held by households which offer little dynamic growth potential. Table 6.1 summarizes the size distribution of cattle herds by enterprise type.

A. Breeding Practices

1. Zebu Cattle

a. Age at First Breeding. The average zebu heifer is first bred at 40 months (± 2.2) with the mean, median and mode all falling between 37 and 41 months. The average zebu cow is first bred around 14 months (± 1.4) after parturition, though both the median and modal values are below 12 months. This reflects the fact that 12 percent

TABLE 6.1

CATTLE HERDS BY ENTERPRISE

TABLE 6.1

SIZE OF INDIVIDUAL CATTLE HERDS BY ENTERPRISE TYPE IN KILIMANJARO, 1973

	Percent of Enterprises		
Herd Size	All-Zebu Cattle	Zebu and Cattle Grade	All-Grade Cattle
1	32	0	18
2	41	24	49
3	14	36	17
4	8	30	12
5	2	8	4
6	2	2	1
7+	1	1	-
Avg. Herd Size	2.2	3.3	2.4

SOURCE: All-zebu cattle percentages are estimated from the random sample. Percentages for mixed and all-grade herds are estimated from the composite grade cattle sample.

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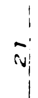
of the cows went for more than 24 months after their last calf before being bred again.

b. Type of Breeding. In spite of the expanding artificial insemination program only one of 74 zebu heifers and cows in the random sample was bred by artificial means. The principal reason for this, according to farmers, is the reluctance of the A.I. inseminators to respond to calls from farmers not having grade females. However a growing percent of zebu cows and heifers (16 percent in 1973) are bred to grade bulls. There is no evidence of a hesitancy on the part of farmers to cross their zebu heifers with the larger grade bulls in spite of often voiced concern about the size of the calf. Not surprisingly, zebu cows and heifers in mixed herds are more likely to be bred by a grade bull than those in all-zebu herds.

c. Seasonality of Births. Looking at seasonal influences on the time of birth, Figure 6.1 reflects a tendency for births to be concentrated during the early parts of the year. Kilimanjaro has a bimodal rainfall distribution with an extended dry season from around November to March on the southern slopes and one to two months earlier on the northeast side in Rombo District. This results in large numbers of animals coming into heat shortly after the onset of the rains and the improvement in feed availability. The bulge in August and September results from improved feeding during the October-November short rains when farmers have more time to arrange for breeding.

d. Age at First Calving. The average age at first calving for zebu cattle was 49 months ($\pm$1.9) with 61 percent of the 73 cows for which data are available reporting 36, 48 or 60 months exactly. In spite of the lumping of the responses the average value is reasonably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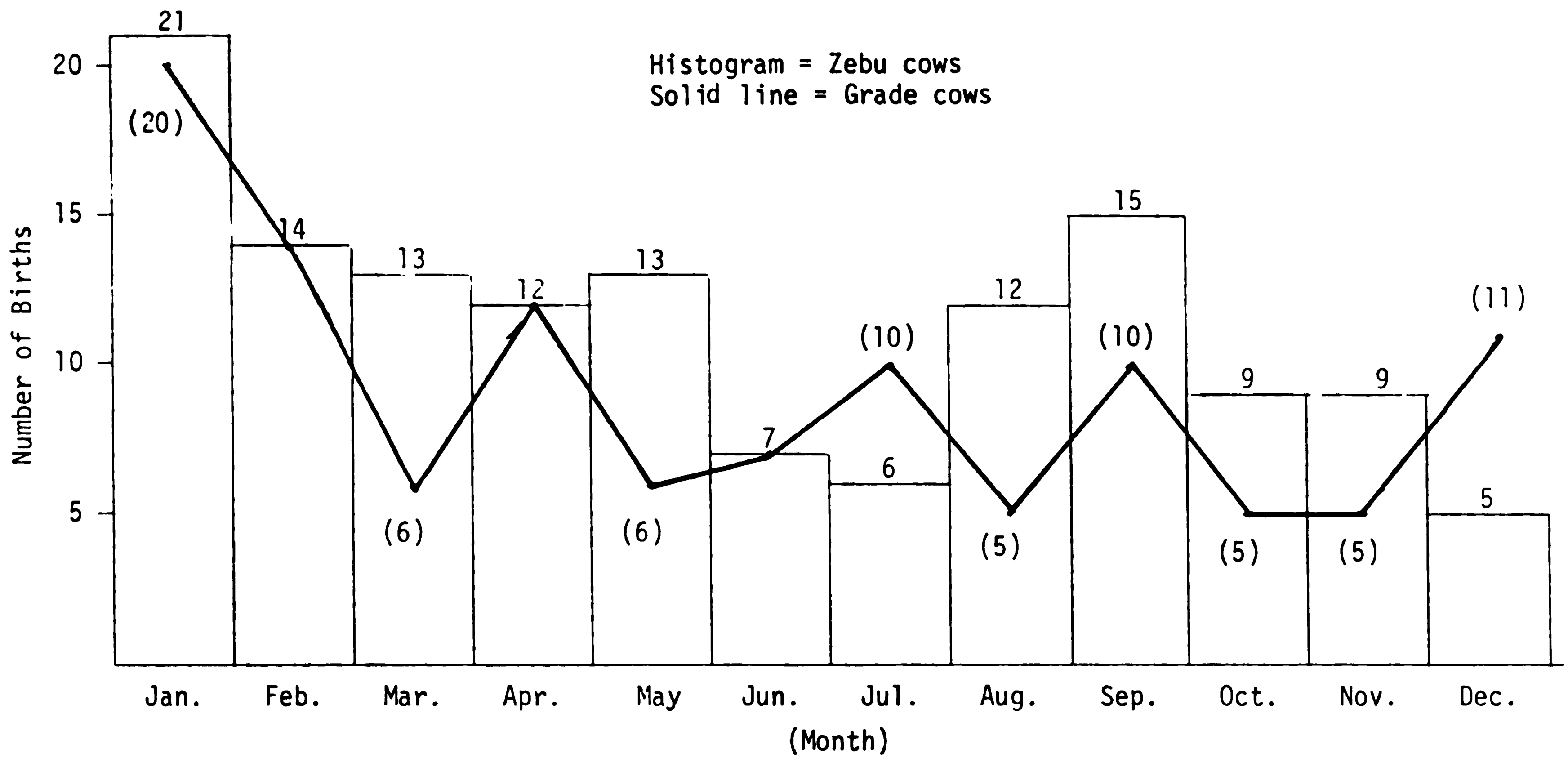

Source: Random sample and composite grade cattle sample estimates.

FIGURE 6.1

NUMBER OF BIRTHS TO ZEBU AND GRADE COWS IN KILIMANJARO
BY MONTH OF THE YEAR, 1972-1973

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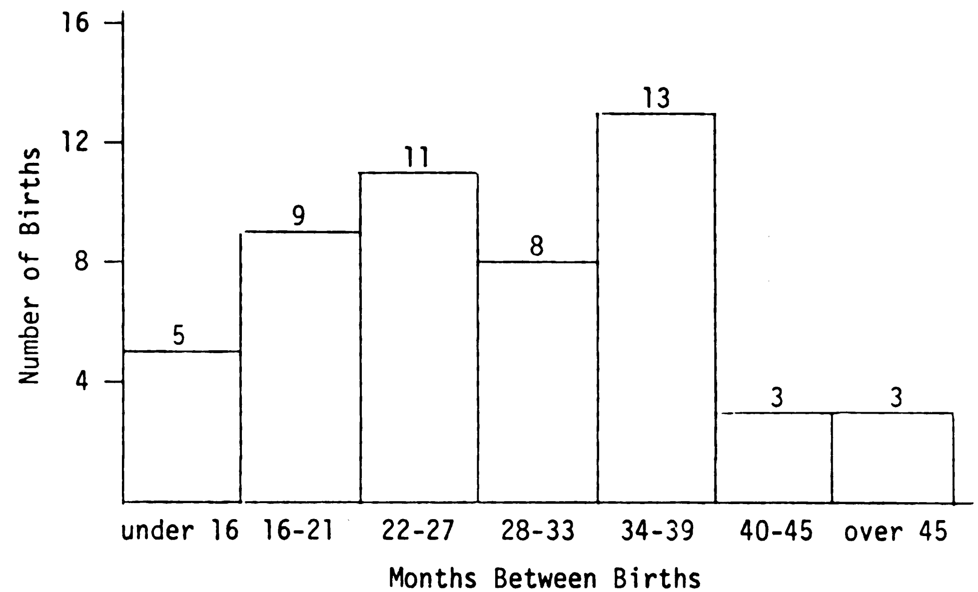
consistent with the age at first breeding, though perhaps a bit too close given that 25 percent of the zebu animals bred do not conceive on the first service. The figure of 49 months compares with 3-1/2 to 5 years reported by Pullan [1979] for Nigeria, 52 months for zebu cattle in Uganda reported by Sacker and Trail [1966] and 41 to 44 months found by Stobbs [1967] in a Uganda research station. Wilson and Clarke [1976] provide data from the Sudan showing that 29 percent of cows in sedentary herds and 65 percent of those in migratory herds were in calf before they were four years of age.

e. Calving Interval. Data on both the most recent as well as the previous parturition indicate that the average calving interval for zebu cows is between 27 (±2) and 29 months (±1.5) respectively. The difference between the two reflects the fact that the survey took place shortly after the peak calving season with the result that average time since last calving was shorter than would have been the case had the study been evenly spread over a year. The higher figure is based on the calving interval between the last and the previous calf and is, therefore, a more reliable measure of the average calving interval, though sample size is smaller. The mean and median are very close to this estimate and the distribution of observations rather well spread. Figure 6.2 gives an idea of the distribution of calving intervals between the most recent and previous parturitions.

Using a deductive approach Wilson and Clarke [1976] found calving intervals of 18 months for migratory herds and 30 months for sedentary herds studied in Sudan. Pullan [1979] found 27 months in Nigeria and cites other studies done there indicating a range of 16-24 months. Sacker and Trail [1966] and Stobbs [1967] found



SOURCE: Random sample estimates.

FIGURE 6.2

NUMBER OF BIRTHS OCCURRING AT SPECIFIC INTERVALS BETWEEN THE LAST AND THE PREVIOUS PARTURITION FOR ZEBU COWS IN KILIMANJARO, 1973 calving intervals of 11 to 13 months but their data refer to research station and stocking farm herds respectively. Williamson and Payne [1978] confirm the lower figures, citing a range of 11 to 14 months as being typical of the East African zebu. Thus the figure of 29 months found in this study, though on the upper range of estimates found under farm conditions elsewhere, is not unreasonable for a stall feeding system facing a scarcity of bulls.

The long calving interval for zebu cows arises partly from farmers' belief that zebu cows tend not to come into heat while they are nursing and if they do, breeding them will make a cow go dry as will withdrawing the calf from nursing. Whatever the truth of these beliefs, and they should certainly be researched, the mere fact that they are held suggests that a major benefit of upgrading the zebu herd would arise from breaking an actual or perceived genetic bottleneck to shorter calving intervals. As we shall see in the next section, farmers have no trouble breeding grade cattle while they are still in milk. Upgrading through an effective artificial insemination program should also overcome the second major factor accounting for the long calving interval, namely the dearth of mature bulls relative to the needs of a stall feeding system.

2. Grade Cattle

a. Age at First Breeding. For grade cattle the average age at first breeding is 27 months ($\pm$1.8), more than one full year earlier than zebu cattle. The mode and median are both 26 months and only 2 percent ($\pm$2.9) of the females were bred for the first time after they were 4 years old as compared with 22 percent ($\pm$7.9) zebu females. Moreover, 17 percent (±7.7) of the grade females were first bred when they were 18 months or younger, indicating that many farmers have no trouble adopting separate breeding practices for grade and zebu cattle.

b. Type of Breeding. Whereas only 1 percent of zebu females were bred by means of artificial insemination, 22 percent (±4.6) of grade females were serviced artificially for their first insemination since their last parturition. Slightly more than 6 percent (±2.7) were serviced by zebu bulls with the remainder being bred to grade bulls. The percent of second and subsequent inseminations with A.I. is higher, 42 percent (±7.1), reflecting the poor pregnancy rate (and consequent higher return rate) for artificial semen in Kilimanjaro.

In spite of the high proportion of grade cows bred by grade bulls, very few farmers on the mountain have their own grade bull. Most borrow a bull in return for caring for it until it breeds the borrower's cow. However, there is evidence that the quality of grade bulls used by farmers is downgrading the progeny of the cows served [Tanzania, 1963]. The Ministry of Agriculture would be better advised to make higher quality bulls available to farmers and to encourage rather than discourage their use, at least until the artificial insemination program is functioning properly.

c. Seasonality of Births. Not surprising, the distribution of births over the year for grade cows is similar to that for zebu cows (Figure 6.1). The magnitude of the variation between months is only slightly more subdued. One would expect less seasonal variation in the generally better managed grade cattle population. Many of the current owners of grade cattle possess sufficient resources to

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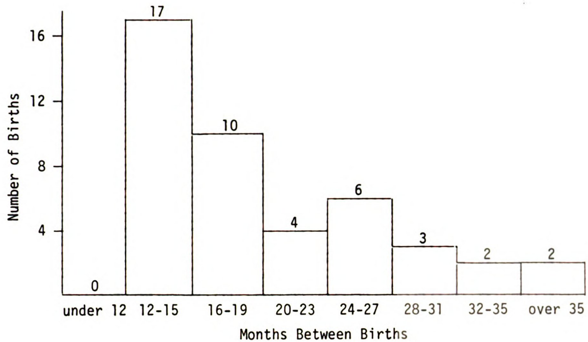
purchase feedstuffs or transport fodder over long distances to carry their animals through the dry season. This ought to reduce stress-related clustering of estrus periods.

d. Age at First Calving. In line with the earlier age at first service, grade heifers give birth for the first time at an average age of 34 months (±1.3), though the eight month difference between average age at first breeding and average age at first birth suggests that these mean estimates give orders of magnitude rather than precise measures. Data on grade heifers is especially unreliable in that a large proportion were purchased off the farm and farmers do a lot more guessing in reporting these kinds of events. As with zebu cows, reported values for age at first calving are clustered on 24, 36 and 48 months exactly. The modal value is 36 months, though the median is similar to the mean.

e. Calving Interval. The calving interval for grade cattle is 20.5 months (±1.9 and ±1.1) both according to the length of time since the cows' last birth and the length of time between her last and previous calf. The latter estimate is the more efficient of the two, though the histogram in Figure 6.3 indicates wide variation within the grade cow population.

The large number of calving intervals under 16 months suggests that many farmers see no problem in breeding grade cows while they are still in milk. Interestingly, these same farmers follow traditional breeding practices for their zebu cows. This suggests there may be something more than mere belief and tradition which prevents farmers from adopting similar management practices for their zebu cows.



SOURCE: Composite grade cattle sample estimates.

FIGURE 6.3

NUMBER OF MONTHS BETWEEN THE LAST AND PREVIOUS PARTURITION
FOR GRADE COWS IN KILIMANJARO, 1973

3. Summary of Reproduction Coefficients

Table 6.2 summarizes the average reproduction coefficients for zebu and grade cows as well as those prevailing for the top 25 percent with respect to milk production in the six months following parturition. These two sets of figures represent average and superior management and/or genetic potential respectively, for both types of cattle.[1]

The data in Table 6.2 show that differences in parturition-related variables do not accompany whatever it is that causes high milk production for zebu cows, though there is some association for grade cattle. The lack of more dramatic differences arises from the use of milk production for the six-month period following parturition rather than annual milk production. The latter would have been a better measure since it combines milk production with reproduction management factors. However the large proportion of observations for which the length of the last calving interval was unknown prevented use of this measure. Six month milk production does give a good indication of relative milk production due to factors other than drawn out calving intervals, however.

B. Calf Rearing Practices

Zalla [1974] has discussed calf rearing practices in Kilimanjaro based on a tabulation of unweighted sample responses. We present only a summary of that work here, with appropriate revisions where weighting of responses has changed the magnitude of some of the estimates.

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[1]Using the top 25 percent gave a weighted sample in excess of 20 for each type of cow.

TABLE 6.2

REPRODUCTION COEFFICIENTS FOR AVERAGE AND SUPERIOR ZEBU AND GRADE COWS IN KILIMANJARO, 1973

Coefficient	Type of Cattle			
	Zebu		Grade	
	Average	Top 25%	Average	Top 25%
Age at first calving (months)	49	47	34	25
Calving interval (months)	29	30	20	18
Average six month milk production (liters)[a]	180 (11)[b]	350 (18)	805 (53)	1485 (80)

SOURCE: Random sample and composite grade cattle sample estimates.

[a]Milk production as reported and not adjusted for underreporting or enumerator bias.

[b]Numbers in parentheses are the standard errors of the estimate.

Calf rearing practices for zebu calves are very similar throughout the survey area. All are nursed—most twice per day—the average period being 9.4 months (±.4) with no difference between average and high milk producers. No zebu calves in the sample were bucket fed and none (N = 114) were fed any kind of grain, including brewing residue, before they were two years of age. There is essentially no difference in the period over which bull and heifer zebu calves are nursed.

Calf rearing practices for grade calves are more heterogenous. Calves are weaned at a younger age on average ((5.2 months (±.4)), with 70 percent being weaned between 3 and 6 months, and calves of the top 25 percent of cows being weaned at 3.5 months on average. Again there is no significant difference in the period that male and female calves are given milk, though there is a greater tendency for male calves to die as has been noted previously.

Unlike zebu calves almost half of grade calves are fed milk from a bucket rather than nursing for an extended period of time. Only a few of these get any milk replacer.

The long period over which zebu calves are allowed to nurse relative to grade calves arises from an apparently genetic based milk let-down reflex closely tied to the nursing stimulus. Many farmers report problems with milk production after a calf dies or is sold and none of the households having only a cow were milking the animal at the time of the interview.

To ease the transition of grade calves through the weaning period a few farmers feed various sorts of grain supplements. These include such things as brewing residue, maize bran, wheat pollards as well as supplements manufactured specifically for weaning calves. The overall proportion receiving such supplements is low, approximately 15 percent, with perhaps a slight tendency for farmers in Moshi District to favor female calves and farmers in Rombo to favor bull calves, or at least not favor female calves. This may reflect the relative importance of bulls to the two areas, Moshi having access to A.I. and Rombo being almost entirely dependent on bulls.

Calves are usually raised by the farm household. The study revealed no clear tendency to slaughter male calves in an effort to conserve milk for home consumption or sale, though male deaths among all cattle are relatively high. This supports the hypothesis of a genetically based, nursing induced, milk let-down reflex for zebu cattle. It also points to the importance of meat and manure production for the zebu cattle enterprise relative to the grade cattle enterprise.

C. Feeding Practices

1. Zebu Cattle

None of the 388 zebu cattle in the survey were fed grain supplements. Over two-thirds (69 percent ± 2.3) were fed salt, almost all of which (98 percent) received locally available soda ash rather than regular salt. Of those getting salt, one-half received it once per day or more and the remaining half less than once per day but at least once per week.

Surprisingly, 43 percent (± 2.5) of all-zebu cattle are not given water. Many farmers rely only on the moisture in banana stems and banana leaves for their animals. Since banana leaves and stems were less than 10 percent of the forage ration for only 10 percent of the herd, all-zebu cattle were probably getting either banana stems or water. Though banana stems are indeed high in water content and most animals are confined inside, it seems quite likely that the animals would benefit from more explicit provision of water as a source of body moisture. The analysis of determinants of milk production in the next chapter confirms this.

Of those zebu cattle receiving water as such, over two-thirds (70 percent $\pm$3.1) received it once per day or more frequently. Most of the remainder got it at least once per week. Since about half got their water from nearby irrigation ditches, usually carried in by the women, availability does not seem to be the only reason for not feeding water. Irrigation furrows exist within rather brief walking distance of most homesteads on the mountain. Probably the reasons for not feeding water are related to a lack of perception of its importance on the part of farmers.

For forage most zebu cattle rely on what is brought to their stalls by household members, usually women. Over 81 percent ($\pm$2.0) of the zebu cattle on the mountain never leave their stalls to graze. Most of those who do, belong to farmers on the lower slopes nearer the plains. A small number have been entrusted to farmers who take them into the forest reserve to graze.

If one could speak of an average ration over such diverse feeding regimes as exist on the mountain he would find that about one-third of the average forage ration comes from banana leaves and stems, one-third from other grasses on or very near the farmers own fields, and one-third from the forest and plains. These are only very rough orders of magnitude since the actual weight of the various sized bundles of grass carried to cattle was not measured and varies greatly from one household to another. Nonetheless it does suggest that two-thirds of the forage now fed to zebu cattle comes from sources over which the farmer has direct control. Moreover, it shows the important role played by bananas in cattle diets. Table 6.3 summarizes feeding practices for zebu cattle.

Previous studies of cattle in Kilimanjaro made scant reference to the importance of banana leaves as a source of cattle feed, though some mention they are fed [Mbaga, 1968; Maro, 1974]. Additional investigation uncovered correspondence in Ministry of Agriculture files which indicated that the crude protein content of banana leaves can be quite high, in excess of 10 percent. Farmers clearly recognize this. The feed and water value of banana leaves and stems is an important reason why farmers resist thinning banana stems in their coffee fields so as to raise coffee yields.[1]

2. Grade Cattle

More grade cattle than zebu cattle are fed water, salt and grain supplements and all three are fed more frequently as well. As Table 6.3 indicates, only 10 percent ($\pm$1.7) of grade cattle do not receive salt this often. Of grade cattle getting salt, over half

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[1]Banana leaves are not the only traditional forage with such a high protein content. An unsigned memo found in Ministry of Agriculture files reported the findings of an analysis of 20 native grasses commonly gathered by women in the plains and forest reserve for their cattle. The memo reported species which contained as much as 17 percent crude protein. Clearly, research into native grasses and plants presents considerable potential for alleviating forage availability problems which constrain proper cattle feeding all over the mountain.

TABLE 6.3

PERCENTAGE OF ZEBU AND GRADE CATTLE IN KILIMANJARO RECEIVING WATER, SALT AND GRAIN AND THE PERCENTAGE OF FORAGE COMING FROM SELECTED SOURCES, 1973

Description	Type of Cattle	
	Zebu[a]	Grade[b]
Percent of cattle getting:		
Water		
Once per day or more	40	82
At least once per week	55	90
None	43	10
Salt		
Once per day or more	34	63
At least once per week	69	79
None	31	21
Grain Supplements[c]		
Manufactured feeds	0	11
Brans and other supplements	0	17
None	100	76
Percent of forage ration coming from:		
Own fields, of which:	74	74
Banana leaves and stems	33	27
Seteria	03	09
Elephant grass	1	05
Other planted grasses and legumes	1	1
Other grasses	36	32
Plains	12	16
Forest	14	10
Percent of cattle grazed:		
Once per day or more	14	10
At least once per week	19	11
Not at all	81	89
Number of observations	388	302

[a]Random sample estimates.

[b]Composite grade cattle sample estimates.

[c]Being fed at the time of the interview. The total proportion may exceed 1.0 since some farmers feed more than one type of supplement to their cattle.

received manufactured mineral salt with the rest being fed indigenous soda ash. Of those getting water, 74 percent (±2.7) get it from a nearby irrigation ditch. This supports the hypothesis that the relatively large percent of zebu cattle not getting water is due to management practices rather than convenience of access to water supplies. Though the percent of grade cattle getting grain supplements at the time of the survey is greater than for zebu cattle, the overall percentage is still rather low given the high proportion of cows and calves in the herd. This suggests considerable room for improvement, both in mortality related to weaning and in milk production.

In terms of sources of roughage, differences between the two herds are slight. Grade cattle have greater access to planted grasses and are fed a higher proportion of grass from the plains—much of which is transported by vehicles either owned or rented by the proprietor. This is another reflection of the stronger economic position of grade cattle owners. At the same time, however, banana leaves and stems are only slightly less important in the diets of grade cattle.

3. Feeding Practices for Cows

Table 6.4 compares feeding practices for average zebu and grade cows with those experienced by the top 25 percent with respect to milk production over the first six months of their lactation. A higher proportion of the higher producers are fed salt and water more frequently. For grade cattle, a higher proportion of superior producers are fed grain supplements. With respect to forage, differences between average and superior animals are slight, with the possible exception of a higher dependence on forage under a farmers direct management control for higher producing zebu cows.

TABLE 6.4

PROPORTION OF AVERAGE AND THE TWENTY-FIVE PERCENT HIGHEST YIELDING[a] ZEBU AND GRADE COWS IN KILIMANJARO RECEIVING WATER, SALT AND GRAIN AND THE PROPORTION OF FORAGE COMING FROM SELECTED SOURCES FOR EACH, 1973

Description	Type of Cattle			
	Zebu		Grade	
	Average	Top 25%	Average	Top 25%
Proportion of cows getting:				
Water				
Once per day or more	.42	.49	.88	.98
At least once per week	.61	.81	.92	1.00
None	.39	.16	.08	0
Salt				
Once per day or more	.36	.42	.54	.94
At least once per week	.72	.92	.85	1.00
None	.27	.08	.15	0
Grain supplements[b]				
Manufactured feeds	0	0	.20	.43
Brans and other supplements	0	0	.31	.52
None	1.00	1.00	.56	.48
Proportion of forage ration coming from:				
Banana leaves and stems	.22	.30	.27	.30
Own fields (except bananas)	.35	.44	.30	.27
Plains	.11	.14	.17	.17
Forest	.14	.07	.11	.09
Seteria	.03	.03	.10	.09
Elephant grass	.01	.02	.05	.06
Other planted grasses and legumes	.01	0	.01	.03
Proportion of cattle grazed:				
Once per day or more	.16	.14	.12	.03
At least once per week	.23	.20	.14	.09
Not at all	.77	.79	.86	.91
Number of observations	143	31	118	22

SOURCE: Random sample and composite grade cattle sample estimates.

[a]Based on milk production during the first six months of the lactation.

[b]Being fed at the time of the interview. The total proportion may exceed 1.0 since some farmers feed more than one type of supplement to their cattle.

D. Milk Yields and Lactation Histories

Though calving intervals are quite long for zebu cows, their lactations average only eight months (±.4). During most of this time they are milked twice per day and continue to nurse their calves. Their lactation milk yields are quite varied and average around 380 liters per lactation net of milk suckled by calves. Grade cattle have an average lactation length of 10 months (±.6) and produce about 1470 liters of milk per lactation, again net of milk suckled by calves.[1]

Figures 6.4 and 6.5 compare the distribution and level of lactation milk production for zebu and grade cows. Both sets of data have been adjusted by a constant factor to reflect underreporting and other sources of error as described in Appendix B. For both, the median and modal range are very low in relation to their respective mean values. At the same time both exhibit quite a range of potential for improvement within the system, though the very high values for zebu cows and very low values for grade cows no doubt reflect at least some misclassification of cattle types.

The cluster of observations between 300 and 1200 liters for grade cattle probably represents the normal range of production for the first lactation of f_1 crosses, many of which are the progeny of low grade bulls and do not receive water and salt on a regular basis. Above the f_1, management factors become more important determinants of performance. To date most of the higher crosses have entered the

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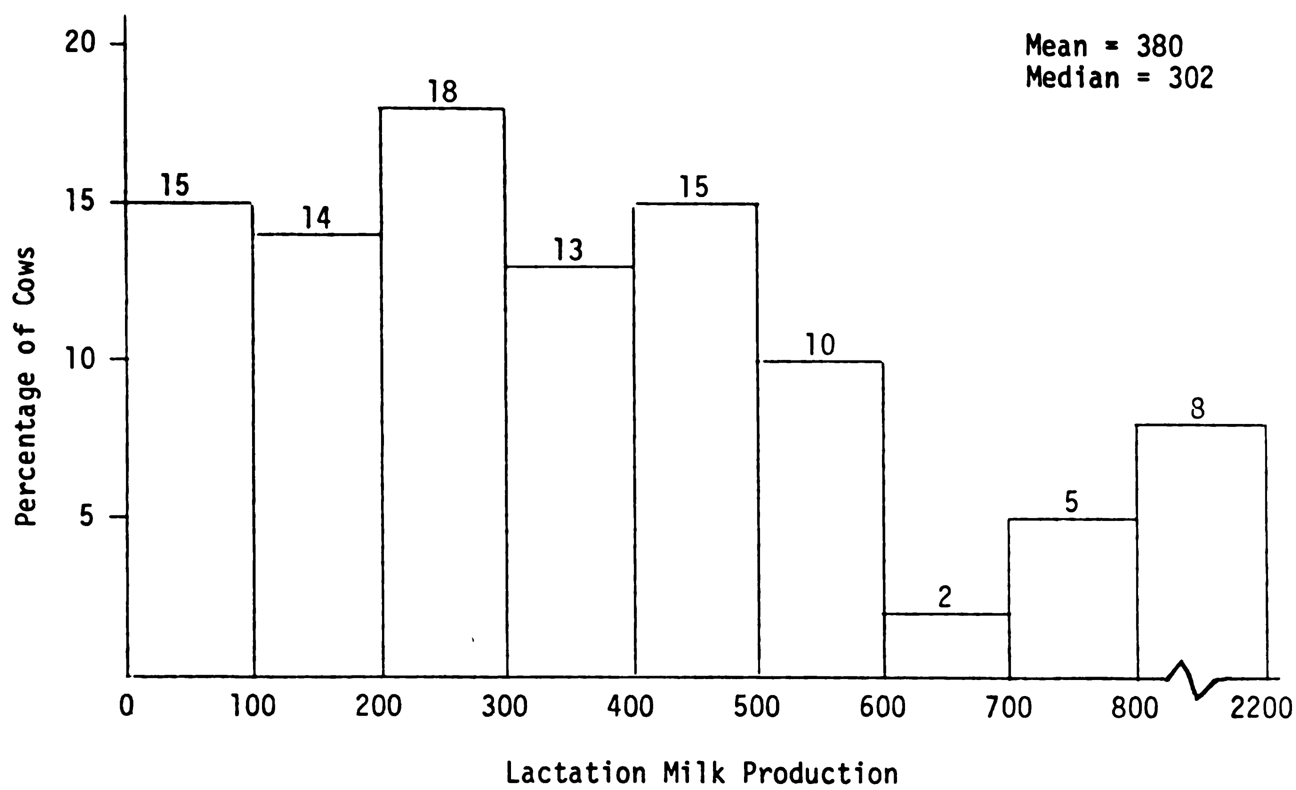
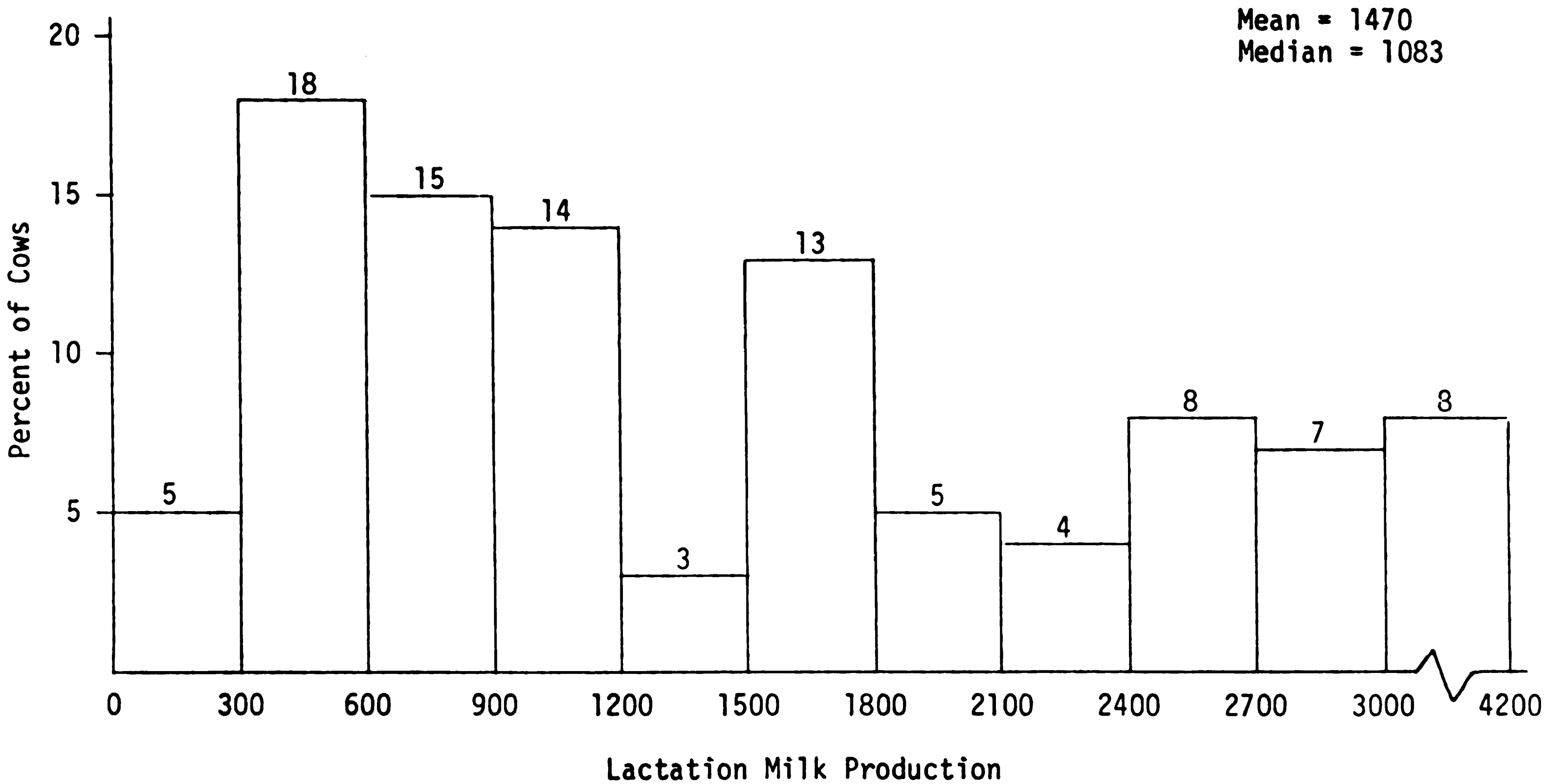
[1]Lactation milk yields as reported here have been revised from those actually reported by farmers. Appendix B discusses the reasons for and the nature of these revisions.



SOURCE: Adjusted random sample estimates.

FIGURE 6.4

LACTATION MILK PRODUCTION FOR ZEBU COWS
IN KILIMANJARO, 1973
(LITERS)



SOURCE: Adjusted composite grade cattle sample estimates.

FIGURE 6.5

LACTATION MILK PRODUCTION FOR GRADE
COWS IN KILIMANJARO, 1973
(LITERS)

farming system directly from the outside. As upgrading continues more higher grade animals will be in less well managed herds, and, ceteris paribus, average yields for grade cows may well decline.

Table 6.5 compares estimated lactation milk production for zebu and grade cows under average management with those among the top 25 percent with respect to milk production in the six months following parturition. Average lactation milk production for the higher producing group is 77 percent above the average for zebu cows and 71 percent above the average for grade cows. The similarity in the length of lactation between the two groups indicates that either inherent genetic potential or feeding related management practices account for the bulk of the difference in lactation milk production, though, clearly, higher yielding cows are milked for a longer period of time than average yielders.

E. Veterinary Practices

Because animals are generally confined throughout the day, health risks due to tick borne and other diseases present themselves mostly via the grass carried in from the plains or on the feed and hands of caretakers who may have had contact with sources of infection. Consequently infection rates are low and not much attention is paid to prophylactic measures.

Most farmers know whether their animals have been vaccinated, but not always for what. On the basis of reported responses, however, it would appear that 4 percent of all-zebu cattle are vaccinated against black quarter, anthrax and foot and mouth but almost none against brucellosis or hemorrhagic septicemia. Of grade cattle 30 percent are vaccinated against foot and mouth and 22 percent

TABLE 6.5

AVERAGE LACTATION MILK PRODUCTION AND LACTATION LENGTH FOR ALL-ZEBU AND GRADE COWS IN KILIMANJARO AS WELL AS FOR THE TOP PRODUCING[a] TWENTY-FIVE PERCENT OF EACH TYPE

Description	Type of Cow			
	Zebu		Grade	
	Overall Average	Average of Top 25%	Overall Average	Average of Top 25%
Lactation milk production (liters)				
All cows	380	675[b]	1470	2520[b]
F_1 crosses			750[c]	
F_2 crosses			1100[c]	
Lactation length (months)	8.1 (.4)[d]	9.1 (.6)	10.3 (.6)	10.9 (.8)

SOURCE: Adjusted random and composite grade cattle sample estimates.

[a]Based on milk production during the first six months of the lactation.

[b]Imputed assuming the same percentage difference between the top performing group and the average as was indicated by the unadjusted figures.

[c]Guestimated. These represent average zebu production plus one-third of the difference between average grade cows and average zebu cows for each successive cross to a grade bull. The 750 liter figure for the f_1 is supported by Figure 6.5. The 1,100 liter figure for the f_2 seems to be a reasonable figure given the overall average of 1,470 for grade cattle.

[d]Figures in parentheses are the standard errors of the estimated means.

against blackquarter and anthrax. Six percent are vaccinated against hemorrhagic septicemia and only 1 percent against brucellosis. Table 6.6 summarizes the figures for each type of animal but the numbers are more properly read as vaccinations of one kind or another rather than the specific type actually recorded by the enumerator.

Table 6.6 also outlines dipping practices for zebu and grade cattle. The majority of zebu animals (81 percent) are 100 percent stall fed. It is not surprising, therefore, that only 9 percent are either dipped or sprayed on a regular basis. For grade cattle the percentage is much higher reflecting both their greater susceptibility to tick borne diseases and the greater awareness and sophistication of many farmers who acquire grade cattle.

The relatively high percentage of both types which are not dipped is a matter of concern to the veterinary service but is not as serious as it might appear at first glance. Zalla [1974] reports that blood samples taken from 1400 cattle in the survey area showed the incidence of protozoan infections to be only 1 percent in zebu cattle and even less in grade cattle.

Most farmers who sprayed their animals with an acaricide did so using their coffee sprayers rather than the much more expensive, high pressure spraying units recommended by the veterinary service. Dipping was more widely used for cattle in Rombo District and at Sanya Juu in Moshi District where tick borne diseases are a more common occurrence and cattle are more frequently grazed. Cattle which were sprayed or dipped were generally treated once per week, the recommended practice. Most farmers either do it right or not at all.

TABLE 6.6

PERCENTAGE OF ZEBU AND GRADE CATTLE IN KILIMANJARO
VACCINATED AND TREATED WITH ACARICIDE, 1973

Treatment	Type of Cattle	
	Zebu	Grade
Vaccinated:		
Blackquarter/anthrax	5	22
Foot and mouth	5	30
Septicemia Hemorrhagic	1	6
Brucellosis	0	1
Dipped or sprayed with acaricide		
Four times per month or more	8	48
One to three times per month	1	6
Not at all	91	46
Number of observations	388	302

SOURCE: Random sample and composite grade cattle sample estimates.

As would be expected, vaccination and dipping are much more common for superior producing grade cows as compared to the average, though differences between the two groups of zebu cows are minimal. This reflects farmers' attempts to protect their investment in the higher valued, higher producing grade cows.

CHAPTER VII

VARIABLE AND CAPITAL INPUTS FOR ZEBU AND GRADE CATTLE ENTERPRISES

A. Labor Inputs

The study also collected data on labor inputs for each of the cattle enterprises. Farmers were asked to report normal labor hours expended by activity per week over both dry and rainy seasons. These were then converted to hours per week by the enumerators.[1]

Differences in herd size, in the age composition of the respective herds and in the proportion of households carrying out selected activities make labor inputs based on overall sample averages somewhat misleading for budgeting purposes. For this reason Tables 7.1, 7.2 and 7.3 give labor inputs per cattle unit for all-zebu, mixed zebu-grade and all-grade cattle herds of various sizes. The tables give both interval and regression estimates; the former for estimating minor labor activities and the latter for estimating more frequently reported activities.

Looking at all three tables we see that the average household with only zebu cattle spends 24.5 hours per week on an enterprise

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[1] In a separate survey of cattle owners in nearby Arusha District farmers were asked to estimate average weekly labor requirements for the two time periods separately. The average of these two responses was then taken as representative of average weekly labor inputs over the entire year. Not surprisingly for a stall fed cattle enterprise, differences between reported dry season and rainy season labor inputs were relatively small for most activities.

TABLE 7.1

TOTAL AND CATTLE UNIT LABOR INPUTS FOR ALL-ZEBU CATTLE ENTERPRISES OF VARIOUS SIZES IN KILIMANJARO, 1973

Labor Category	Number of Hours Per Week	Hours Per Week Per C.U. by Herd Size[a]				Regression Estimate[c] $(y = \alpha + \beta + \epsilon)$
		Average	1[b]	2[b]	3+[b]	
Cleaning Shed (N_C)	1.5 (.09)[d]	1.2 (.10)	1.5 (.15)	.8 (.10)	.5 (.10)	N_C = 1.50 - .29 C.U. (.155)(.082) *** ***
Supplying Forage (N_F)						
Gathering grass	19.7	15.9	19.5	11.1	6.4	
Herding	2.2	1.5	1.0	1.0	2.2	
Sub-Total[e]	21.8 (.97)	17.4 (1.10)	20.5 (1.18)	12.1 (1.11)	8.6 (1.40)	N_F = 21.1 - 4.01 C.U. (1.71) (.899) *** ***
Other Labor						
Obtaining water	.6	.5	.6	.5	.2	
Applying acaricide	.0	.1	.1	.0	.0	
Milking	.5	.3	.3	.3	.3	
Breeding, purchasing and other	0	0	0	0	0	
Sub-Total[e]	1.2 (.13)	.9 (.12)	.9 (.16)	.8 (.17)	.4 (.08)	
Total Labor (N_T)[e]	24.5 (1.01)	19.5 (1.18)	22.9 (1.2)	13.7 (1.19)	9.6 (1.40)	N_T = 23.8 - 4.49 C.U. (1.75) (.921) *** ***
Number of Observations	152	152	98	35	19	121

SOURCE: Random sample estimates.

[a]C.U. = Cattle Unit. The average household with only zebu cattle had 1.6 (±.08) cattle units. For the definition of a cattle unit see Appendix C.

[b]Actually ranges of .5 to 1.49, 1.5 to 2.49 and 2.5 and over.

[c]Excluding all households with fewer than .95 cattle units.

[d]Numbers in parentheses are standard errors of the estimated means or coefficients.

[e]May not add to column totals due to rounding errors in aggregating weighted files.

***Significant at the .001 level.

TABLE 7.2

TOTAL AND CATTLE UNIT LABOR INPUTS FOR MIXED ZEBU-GRADE CATTLE ENTERPRISES OF VARIOUS SIZES IN KILIMANJARO, 1973

Labor Category	Number of Hours Per Week	Hours Per Week Per C.U. by Herd Size[a]				Regression Estimate[c] ($y = \alpha + \beta + c$)
		Average	1[b]	2[b]	3+[b]	
Cleaning Shed	2.2 (.26)[d]	.8 (.09)[d]	.7 (.24)[d]	1.0 (.17)[d]	.7 (.12)[d]	N_C = 1.45 - .17 C.U. (.399)(.136) *** ***
Supplying Forage (N_F)						
Gathering grass	23.8	9.3	15.6	11.2	7.2	
Herding	1.2	.4	0	0	6	
Total[e]	25.0 (1.53)	9.7 (.60)	15.6 (3.3)	11.3 (.70)	7.8 (.73)	N_F = 16.1 - 2.42 C.U. (1.65) (.560) *** ***
Other Labor						
Obtaining water	1.1	.4	.6	.4	.4	
Applying acaricide	.2	.1	.1	.1	.1	
Milking	1.6	.6	.2	.6	.6	
Breeding, purchasing and other	.2	.1	0	0	.1	
Total[e]	3.2 (.40)	1.1 (.13)	.9 (.46)	1.1 (.24)	1.2 (.17)	
Total Labor (N_T)[e]	30.3 (1.75)	11.6 (.66)	17.1 (3.6)	13.3 (.89)	9.7 (.79)	N_T = 18.4 - 2.50 C.U. (2.06) (.700) *** ***
Number of Observations	55	55	4	21	30	55

SOURCE: Composite grade cattle sample estimates.

[a]C.U. = Cattle Unit. The average household with both zebu and grade cattle contained 1.3 (±.09) cattle units of zebu cattle and 1.5 (±.11) cattle units of grade cattle. For the definition of a cattle unit see Appendix C.

[b]Actually ranges of .5 to 1.49, 1.5 to 2.49 and 2.5 units and over.

[c]Excluding all households with fewer than .95 cattle units.

[d]Numbers in parentheses are the standard errors of the estimated means.

[e]May not add to column totals due to rounding errors in aggregating weighted files.

***Significant at the .001 level.

TABLE 7.3

TOTAL AND CATTLE UNIT LABOR INPUTS FOR ALL-GRADE CATTLE ENTERPRISES OF VARIOUS SIZES IN KILIMANJARO, 1973

Labor Category	Number of Hours Per Week	Hours Per Week Per C.U. by Herd Size[a]				Regression Estimate[c] ($y = \alpha + \beta + \epsilon$)
		Average	1[b]	2[b]	3+[b]	
Cleaning Shed	1.9 (.14)[d]	1.1 (.14)[d]	2.3 (.55)[d]	.8 (.08)[d]	.7 (.11)[d]	N_C = 1.32 - .20 C.U. (.206)(.087) *** **
Supplying Forage (N_F)						
Gathering grass	24.1	12.6	24.0	10.6	8.6	
Herding	.8	.4	0	.5	.5	
Sub-Total[e]	24.9 (1.22)	13.0 (1.00)	24.0 (3.06)	11.1 (.89)	9.1 (.91)	N_F = 23.2 - 4.49 C.U. (2.53)(1.04) *** ***
Other Labor						
Obtaining water	1.1	.6	1.6	.4	.4	
Applying acaricide	.4	.2	.2	.2	.1	
Milking	2.1	.8	.1	.9	1.2	
Breeding, purchasing and other	.3	.1	.1	.0	.2	
Sub-Total[e]	3.9 (.38)	1.8 (.17)	2.0 (.53)	1.5 (.23)	2.0 (.21)	
Total Labor (N_T)[e]	30.7 (1.41)	15.8 (1.11)	28.2 (3.28)	13.4 (1.05)	11.7 (.98)	N_T = 2.60 - 4.65 C.U. (2.64) (1.08) *** ***
Number of Observations	82	82	16	40	26	66

SOURCE: Composite grade cattle sample estimates.

[a]C.U. = Cattle Unit. The average household with only grade cattle had 2.2 (±.11) cattle units of grade cattle. For the definition of a cattle unit see Appendix C.

[b]Actually ranges of .5 to 1.49, 1.5 to 2.49 and 2.5 units and over.

[c]Excluding all households with fewer than .95 cattle units.

[d]Numbers in parentheses are the standard errors of the estimated means.

[e]May not add to column totals due to rounding errors in aggregating weighted files.

**Significant at the .01 level.

***Significant at the .001 level.

which averages 1.6 cattle units for an average of nearly 800 hours per year per cow. Households with only grade cattle spend almost 31 hours per week on an enterprise which averages 2.2 cattle units for an average of about 730 hours per year per cow. Households with mixed herds spend about 30 hours per week on 2.8 cattle units. Reducing labor time to a cattle unit basis yields 19.5 hours per unit for all-zebu herds, 15.8 hours per unit for all-grade herds, and 11.6 hours for mixed herds. The difference between average labor inputs per cattle unit between the three herds reflects primarily differences in their respective average herd size and the lower amount of labor per cattle unit required in the larger herds.

As reported in Tables 7.1 to 7.3, labor inputs for one unit herds are inflated by including herds containing less than one cattle unit while those for three unit herds are depressed by including larger, more frequently grazed herds. The regression estimates based only on herds containing .90 cattle units or more, remove these effects and give more realistic estimates for one to three unit herds than the interval estimates. Certainly the economies of size implied by the regression estimates are much more believable than those implied by the interval estimates. However, even the regression estimates indicate size economies for labor which are somewhat hard to believe.[1]

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[1]The data suggest that some factor was operating at the time of data collection that led to a similarity in the number of hours spent gathering grass between enterprises of different sizes. Several explanations are possible. It is possible that enumerators recorded only the labor of the wife of the head of household when, in fact, she was accompanied by her daughter in gathering grass for the larger herds. In the case of larger herds there is scarcely enough time in the week for the wife to make more frequent trips. She would almost

For all activities labor inputs for a one unit grade enterprise are higher than those for all-zebu and mixed enterprises of equivalent size. One explanation, apart from possible errors in the data, is that farmers are particularly careful with their first grade animal since it represents one of the largest investments most farmers will ever make.

The labor data need further scrutiny before settling on appropriate labor input coefficients for simulating the enterprise budgets. Hours spent milking do not reflect the fact that in many multiple unit herds only one cow is in milk. We can get some idea of this by looking at non-zero values for one cow herds since the animal is actually being milked. Also, labor inputs for forage need to be adjusted to reflect the fact that cows in the last three months of pregnancy and throughout their lactation need more roughage and presumably, require more than a one cattle unit share of available forage. A number of considerations such as these need to be made in arriving at realistic labor coefficients for any size of cattle enterprise, zebu or grade.

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certainly have to be accompanied by someone else. The nature of the recording instrument was not conducive to catching such situations consistently since it relied heavily on enumerator initiative. Other possibilities include suggesting their own answers or commingling labor inputs for goats and sheep with those of cattle. The analysis of variance in individual enumerator's recordings for total labor inputs contained in Appendix A confirms differences that are statistically significant at the .0000 level. The problem is in identifying whether differences between enumerators result from differences in the answers suggested to farmers or differences in the thoroughness with which they identified, separated and recorded labor inputs performed at the same time by more than one person or on more than one enterprise. Unfortunately the form in which the data were recorded on the questionnaires make it impossible to answer this question.

Table 7.4 outlines the labor coefficients used in simulating the enterprise budgets in Chapter IX. These have been calculated for zebu and mixed herds of 1.6 cattle units, for average grade herds of 1.6 and 2.2 units, and for a superior[1] herd of 1.6 units. The figure of 1.6 units corresponds with the average size of the zebu enterprise and presumably reflects labor and capital constraints on further expansion for the average household. By using a similar size for a mixed and an all-grade enterprise we can get an idea of the potential benefits to such households of upgrading their cattle enterprise. The 2.2 unit figure represents average size for the grade enterprise under present circumstances.

The labor data in Table 7.4 are broken into labor for maintenance and normal growth and labor for production. This is simply a recognition that pregnant cows and cows in milk—especially high producing cows—require greater intake of TDN in proportion to their state of pregnancy and milk production. In the enterprise budgets labor for production is charged to the enterprise only during the production period, defined as three months prior to parturition, and up to the end of lactation. At all other times labor inputs are allocated to cows and other cattle according to the values indicated for maintenance and normal growth. The relatively small difference between the grade and non-grade enterprises in labor expenditures for maintenance and growth reflects the fact that the former have substantial cash expenditures for forage and grain that the latter do not have.

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[1]Defined here and elsewhere as the top 25 percent of milk producing enterprises.

TABLE 7.4

HOURS OF LABOR PER WEEK REQUIRED PER CATTLE UNIT FOR ALL-ZEBU, ZEBU-GRADE AND ALL-GRADE CATTLE HERDS OF DIFFERENT SIZES, INCLUDING THE PROPORTION OF LABOR SUPPLIED BY WOMEN

	Percent of Labor Supplied by Women	Enterprise and Management Level					
		Zebu[a]	Zebu-Grade		All-Grade		
		Average	F_1[b]	F_2[c]	Average		Superior
Number of cattle units in enterprise		1.6	1.6	1.6	1.6	2.2	1.6
Weekly labor inputs for maintenance and normal growth per unit							
Cleaning shed	95	1.0[d]	1.0	1.0[e]	1.0[e]	.9[e]	1.0[c]
Obtaining water	80	.5	.6	.7[f]	.7[f]	.7[f]	1.0[f]
Applying acaricide	0	.0	.1	.2	.2[f]	.2	.4[f]
Supplying forage[g]	65	14.0	14.3	14.4	14.4	11.8	14.4
Total labor for maintenance and normal growth	66-67	15.5	16.0	16.3	16.3	13.6	16.8
Weekly labor inputs for milk production per unit of cow in production period							
Supplying forage[g]	65	1.8	2.3	2.5	2.9	2.3	4.0
Milking[g]	90	1.5	1.7	2.0	2.3	2.3	2.9
Total labor for milk production	76	3.3	4.0	4.5	5.2	4.6	6.9

[a]Interpolated from unit requirements in Table 7.1 unless otherwise noted.

[b]Interpolated between average zebu and the f_2 in mixed herds unless otherwise noted.

[c]Interpolated from Table 7.3 unless otherwise noted.

[d]Regression estimate from Table 7.1.

[e]Regression estimate from Table 7.3.

[f]Taken from Table D-2 in Appendix D.

[g]Taken from Table D-1 in Appendix D.

Labor for breeding and purchasing is insignificant and has been ignored in computing labor requirements. The details of the calculation of average labor inputs are discussed in Appendix D.

Table 7.4 also indicates the percent of labor supplied by women. Cleaning the shed and milking are nearly exclusively female tasks while herding and applying acaricide are almost exclusively male activities. About 75 percent of the labor used to carry grass is supplied by women as is 80 percent of labor for drawing water. For both of these activities males are not reluctant to help when necessary, especially when it involves work on the homestead. However grass gathered from the plains and forest is almost always carried by women and female children. Male children help with herding, but overall, the importance of schools and the smaller size of bundles of forage carried by female children make children's contribution to the total forage and labor supply very small.

B. Other Variable Inputs

Apart from labor, other variable inputs into dairy enterprises in Kilimanjaro are mostly cash inputs. A small amount of labor hired to repair cattle housing is paid in kind. This has been valued at the market wage of 5/50 per day and included with hired labor. Labor expended in gathering soda ash from the mountain was included as a purchasing activity in the previous section.

Table 7.5 shows that for all practical purposes cash inputs into the zebu enterprise are non-existent. The table also demonstrates rather clearly that grade cattle in mixed herds are not cared for as well as those in all-grade herds. The average level of

TABLE 7.5

THE AVERAGE VALUE OF ANNUAL VARIABLE CASH INPUTS FOR ALL-ZEBU, MIXED ZEBU-GRADE AND ALL-GRADE DAIRY ENTERPRISES IN KILIMANJARO; TOTAL AND CATTLE UNIT EXPENDITURES, 1973 (TZ SHILLINGS)

	Enterprise						
	All-Zebu[a]		Zebu-Grade[b]		All-Grade[b]		
						Per C.U.	
Variable Cash Input	Total	Per C.U.	Total	Per C.U.	Total	Average	Superior[c]
Salt and soda ash	4	3	8	3	19	7	14
Grain	0	0	12	4	94	36	95
Milk Replacer	0	0	0	0	0	0	10
Medical supplies	0	0	9	3	22	9	18
Grass and Transport	2	1	15	6	97	41	190
Hired Labor	0	0	1	0	12	6	71
Repairs to Shed	4	3	2	1	11	5	35
Other	0	0	1	0	2	1	8
Total[d]	10	7	48	17	258	106	441
	(1.6)[e]	(1.2)	(12.7)	(4.5)	(45)	(17.2)	
Number of Observations	159	159	54	54	80	80	
Average Number of Cattle Units							
Zebu	1.6		1.3		0		
Grade	0		1.5		2.2		
Total	1.6		2.8		2.2		

[a]Random sample estimates.

[b]Estimated from the composite grade cattle sample.

[c]Estimated based on relationship between superior and average cows.

[d]Totals may not equal column totals due to rounding errors.

[e]Numbers in parentheses are the standard errors of the estimated means.

cash inputs is less than one-fourth that of all-grade enterprises even though grade cattle make up over half of these herds.

For the mixed and the all-grade enterprises cash payments for grass, grain and transport account for 56 and 74 percent of all cash inputs respectively. Greater use of salt, medical supplies and hired labor is also evident in the upgraded herds. On a cattle unit basis, total variable cash expenditures per year amount to 7/= for all-zebu herds, rising to 17/= for mixed herds and 106/= for all-grade herds.

C. Capital Investments by Enterprise Type

1. Housing

Cattle in Kilimanjaro are housed in a wide variety of structures with fewer than 1 percent of the herds being held in an enclosure without a roof. In poorer households cattle, goats and sheep share the same dwelling with household members. The next step in cattle housing as a person's wealth increases is the kitchen, or rarely, sharing a secondary dwelling with younger members of the household. In still wealthier households cattle and other ruminants usually have a dwelling to themselves. Given this progression of housing it is not surprising that the proportion of grade cattle households having separate quarters for livestock is almost twice that of all-zebu households (Table 7.6).

In terms of the type of structure in which cattle are housed, mud and pole walls with tin roof is the most common type for both zebu and grade cattle enterprises, accounting for 43 percent of housing for both types. But where grass roofs or grass walls constitute the next most important types of structures for the zebu enterprise, cement, rock or wood walls—all with tin roofs—are more

TABLE 7.6

LOCATION OF CATTLE HOUSING IN KILIMANJARO BY CATTLE TYPE

Location of Housing	Percent of Housing by Cattle Type		
	Zebu[a]	Grade[b]	All Cattle[a]
Dwelling reserved for animals	39	75	41
Main dwelling of household members	35	16	34
Kitchen	25	9	24
Corral and other	1	0	1

[a]Random sample estimates.

[b]Estimated from composite grade cattle sample. Includes mixed zebu-grade enterprises.

typical of the next most important types of housing for grade cattle. For both types of cattle virtually all housing has a hard floor, usually rocks. Table 7.7 gives the breakdown of housing type by type of enterprise.

There is very little difference in the value of similar types of housing for cattle when comparing those housed in main residences with those housed in separate structures. The reason for distinguishing between where cattle reside is to allocate housing costs between cattle and other uses. To adjust for this we assume that cattle sharing a house with household members sleeping in it occupy half the dwelling while cattle housed in the kitchen occupy two-thirds of that structure. House investment costs are allocated accordingly.

The type of structure in which cattle are housed and the size of the herd also influence housing costs for cattle. Table 7.8 compares both the total cost of housing, adjusted for the proportion of the structure occupied by cattle, and the cost per cattle unit for all-zebu, mixed and all-grade enterprises. Table 7.9 breaks down costs per cattle unit by the size of the herd.

In terms of the cost of the structures themselves, there is little difference in statistical terms in the amount invested in grass, and poles and/or mud structures between the three types of enterprise. However there is a large difference in the amount invested in cement block and rock structures, a difference that is significant at the 99 percent level of confidence if the two grade cattle samples are combined. This supports observations made by Mbaga [1968] and others that grade dairy farmers in Kilimanjaro tend to overinvest in housing for prestige reasons. Not only do many of

TABLE 7.7

TYPE OF STRUCTURE USED AS HOUSING FOR CATTLE IN KILIMANJARO BY TYPE OF CATTLE

Type of Structure		Percent of Total Housing Units			
		By Cattle Type			With Hard floors[a,c]
Walls	Roof	Zebu[a]	Grade[b]	Cattle[a]	
Grass	Grass	29	5	28	98
Poles and/or mud	Grass	16	2	14	96
Poles and/or mud	Tin	43	43	43	99
Cement or rock	Tin	4	15	4	100
Wood or logs	Tin	1	25	4	100
Any	None	0	1	0	---
Other combinations		7	9	7	100
Overall Average					98

[a]Population estimates from random sample.

[b]Composite grade cattle sample, i.e. including mixed zebu-grade enterprises.

[c]Rocks or cement. Overall 96 percent of hard floors consisted of rocks. For grade cattle the percent of hard floors is the same but 15 percent have cement rather than rock floors.

TABLE 7.8

VALUE OF CATTLE HOUSING IN KILIMANJARO BY TYPE OF HOUSING AND TYPE OF ENTERPRISE

(TZ SHILLINGS)

Type of Housing		Type of Enterprise					
		All-Zebu[a]		Zebu-Grade[b]		All-Grade[b]	
Walls	Roof	Total	Per C.U.	Total	Per C.U.	Total	Per C.U.
Grass	Grass	224 (17)[c]	217 (24)[c]	227 (33)[c]	93 (12)[c]	174 (62)[c]	133 (63)[c]
Poles and/or mud	Grass	350 (54)	342 (92)	241 (96)	80 (29)	465 (406)	286 (347)
Poles and/or mud	Tin	580 (36)	436 (38)	672 (113)	312 (72)	657 (51)	351 (45)
Cement or rocks	Tin	995 (211)	659 (172)	2524 (381)	781 (152)	2097 (294)	903 (171)
Wood or logs	Tin	284 (81)	112 (47)	552 (126)	252 (68)	680 (194)	270 (59)
Other combinations		415 (83)	287 (88)	359 (44)	126 (7)	260 (32)	198 (39)
Overall average		437 (25)	348 (26)	681 (103)	274 (43)	816 (93)	404 (51)

[a]Random sample estimates.

[b]Estimated from the composite grade cattle sample.

[c]Numbers in parentheses are the standard errors of the estimated means.

TABLE 7.9

VALUE OF CATTLE HOUSING PER CATTLE UNIT BY TYPE OF ENTERPRISE AND SIZE OF HERD (TZ SHILLINGS)

Number of Cattle Units in Herd	Type of Enterprise		
	All-Zebu	Zebu-Grade	All-Grade
One	433 (37)	540 (362)	612 (161)
Two	227 (23)	305 (71)	336 (58)
Three	140 (18)	217 (45)	353 (60)
Overall Average	348 (26)	274 (43)	404 (51)

SOURCE: Random sample and composite grade cattle sample estimates.

these farmers build structures that are more substantial than those used by most humans on the mountain, but they also build larger ones than are required for efficient management in order to allow for expansion.

On a cattle unit basis the relationship between the figures is more one sided. Except for cement structures,[1] investment per cattle unit is substantially lower for grade cattle than zebu cattle, especially grade cattle in mixed herds, though these differences are not consistently statistically significant. Part of this difference between zebu and grade cattle housing investment costs is due to the fact that the weights used to compute cattle units reflect feed intake rather than space requirements since labor for feeding is by far the largest input. This would tend to increase the number of cattle units of grade cattle relative to zebu cattle in relation to a set of weights designed specifically for housing.

However, the bulk of the difference between average cattle unit costs of housing arises from differences in the average size of the various enterprises. For enterprises of a given size the progression in costs as a herd is upgraded is very much as expected, rising as the proportion of grade cattle increases. The fact that mixed zebu-grade herds are larger and economies of size in housing costs are considerable combine to depress average per unit housing costs for the mixed herds.

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[1]There were only two zebu owners with wood structures.

2. Cattle

The cattle themselves are far and away the single largest component of investment costs for all types of cattle/dairy enterprises. Using the age-sex specific values detailed in Appendix E, Table E.1 for each type of animal, Table 7.10 compares average investments in cattle for the different enterprises. On an adult basis grade cattle, adjusted for their larger size, require two and one half times as much investment in cattle as do zebu animals. The fact that the spread between grade and zebu animals appeared to be widening over the 1972-74 period suggests that farmers found the increased investment worthwhile.

3. Other Cash Investment Costs

Table 7.10 also summarizes other cash investments used for dairy cattle enterprises in Kilimanjaro. As was the case with variable cash costs, cash investment costs for the zebu enterprise, apart from housing and cattle, are virtually nil. Few farmers spray their animals with acaricide or maintain established pasture. Household cooking and eating utensils are used for milking and for marketing what milk is sold. These are mostly calabashes with a small cash value and for which milk related uses are a small part of total use. As was commonly done by farmers, enumerators usually did not value these utensils.

Other cash capital costs are not that high for grade enterprises either. Only the wealthier households have a milk bucket which sold in urban markets for 10/= to 30/=. Most use calabashes as do zebu owners. Average investment in sprayers does rise both

TABLE 7.10

AVERAGE TOTAL AND CATTLE UNIT INVESTMENTS IN CATTLE AND OTHER CASH ITEMS FOR ZEBU, MIXED AND ALL-GRADE DAIRY ENTERPRISES IN KILIMANJARO, 1973
(TZ SHILLINGS)

Capital Investment	Type of Enterprise					
	Zebu[a]		Zebu-Grade[b]		All-Grade[b]	
	Total	Per C.U.	Total	Per C.U.	Total	Per C.U.
Cattle	650	417	1679	616	1793	815
	(28)[c]	(6)	(80)	(16)	(94)	(24)
Other						
Sprayer	1	1	15	6	25	14
Utensils	0	0	3	1	6	3
Pasture	0	0	1	0	1	1
Total[d]	1	1	18	7	32	17
	(.6)[c]	(.8)	(5.7)	(2.2)	(7.3)	(4.1)
Number of observations	159	159	54	54	80	80
Average number of cattle units						
Zebu	1.6		1.3		0	
Grade	0		1.5		2.2	
Total	1.6		2.8		2.2	

[a]Random sample estimates.

[b]Estimated from the composite grade cattle sample.

[c]Numbers in parentheses are the standard errors of the estimated means.

[d]Totals may not equal column totals due to rounding errors.

because more grade cattle owners spray their cattle and purchase the more expensive high pressure type of sprayer recommended by the veterinary service rather than use their coffee sprayers as most cattle owners do. From an animal health point of view the method of applying acaricide is not important as long as it has been mixed to proper strength and the animal is completely drenched. The use of coffee sprayers represents an excellent way of spreading investment costs over multiple enterprises.

CHAPTER VIII

DETERMINANTS OF MILK YIELDS

A. The Model

Using ordinary least squares estimation procedures eight input, two technological, five management and three institutional/ecological variables as well as two variables correcting for measurement error were tested for their ability to explain variation in milk yields as measured by milk production net of calf consumption during the first six months of lactation. The particular variables and their hypothesized relationships to the dependent variable are as follows:

Dependent variable:

Q_m = Liters of milk produced during the first six months of lactation, net of the amount suckled by the calf.

Input variables:

W_f = Number of times per week a cow is given water. The maximum value for this variable is 14, representing twice daily or more frequently. Banana stems are not counted as a source of water. The expected relationship with the dependent variable is positive.

S_f = Number of times per week cow is given salt or soda ash. The maximum value is also 14 and the hypothesized relationship also positive.

L_g = Labor hours expended in acquiring forage, either by gathering grass or herding. In general we would expect this to be one proxy for the quantity of forage fed and to be positively related to milk production. However the long distances some households must go for grass introduces a lot of statistical noise into this variable.

C_g = Cash expenditures for grass and transportation, mostly money paid for purchasing grass, but a small part represents cash expenditures for herding and grazing. The hypothesized relationship is again, positive.

P_b = The proportion of fed forage which comes from bananas. This variable attempts to incorporate a quality dimension of forage. Since banana stems and leaves were not differentiated and the relative importance of each not measured the relation of this variable to milk production is ambiguous.

P_p = The proportion of fed forage which comes from improved grasses planted by the farmer himself. This is another quality variable for roughage from which we would expect a positive association with milk production.

G_f = The number of days per week which the animal grazes. Positive.

G_r = The quantity (kilograms) of grain and feed supplements fed to the cow. Positive.

Technological variables:

B_n = The number of times the cow has given birth. For zebu cows we expect a less positive effect than for grade cows.[1]

B_d = A dummy variable with a value of 1 for grade cows reported to be pure bred as opposed to a cross. No breed variable is included in the zebu model. We hypothesize that higher grade animals produce more milk.

Management-related variables:

W = The household wealth index. This measures both ability to acquire resources as well as access to better advice on the selection and purchase of breeding stock. Its hypothesized influence is positive. In the zebu model the logged form, W_1, provided a better fit. Appendix F details how the index is constructed.

P_g = An index of progressiveness, presumably measuring receptivity to and perception of output increasing practices. Again, positive and detailed in Appendix F.

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[1]Williamson and Payne [1965] report that during their first lactation temperate breed cows usually produce 70-77 percent of the milk they will produce when mature while zebu cows average 90 percent of their production at maturity during their first lactation.

A_h = Age of the head of household. The recent history of grade cattle and the greater amount of risk and work they involve suggests a negative association with milk production for grade cattle. For zebu cattle the association should be negative due to a decreasing ability to carry forage long distances by the wives of older farmers.

E_a = A dummy variable representing permanent employment in a job associated with agriculture or KNCU. This presumably gives an inside track both to acquiring grade animals on credit as well as getting a better selection of those which become available. We would expect, therefore, a positive sign.

E_h = Education of the head of household. In Kilimanjaro this variable is highly correlated with income, though we would expect some positive association in its own right.

Institutional/ecological variables:

A_{sp} = Aspect of the homestead with respect to Kibo, the main mountain peak. This variable is a proxy for different things in the different models. In the zebu model it is a proxy for a complicated set of rainfall, sunlight and temperature interactions which become more favorable for cropping activities (and presumably forage supply) as aspect increases.[1] The expected sign therefore is positive. In the grade model, it is a proxy for veterinary and extension services.

A_{lt} = Altitude of the household. This variable can reasonably have any sign. Households on the upper slopes have more difficult access to purchased inputs and are more removed from the activities of the Kilimo extension centers. On the other hand the closeness of the forest reserve and the generally lower density of coffee and bananas at the higher elevations suggests greater availability of forage.

Variables correcting for measurement error:

E_n = A dummy variable with a value of one when the data was recorded by enumerator three in Appendix A. Differences between this enumerator's recorded responses for milk production and those of other enumerators were significant at the .10 level or lower on the basis of a one factor analysis of variance using only those cattle included in the respective models. For zebu cattle this enumerator's measures were higher. For grade cattle, lower.

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[1]The northern extremity of the survey area had an aspect of 14 and the southwestern extremity, 264.

A_w = Age of calf at weaning. Since the measure of milk production used is net of calf consumption, we would expect a positive association between age at weaning and milk production for zebu cows since they cannot be (are not) milked once the nursing stimulus is removed. For grade cows we expect a negative relationship since the longer the calf nurses the greater is the proportion of total milk production that is not observed and recorded.

Since there is little reason to expect either the intercept or slope coefficients to be similar between zebu and grade herds, determinants of milk production from each type of cow are estimated separately.

The input variables essentially represent dimensions of the variable inputs in a production function for milk, though the functional form of the model does not meet the structural requirements of a production function. The two technological variables are intercept shifters which reflect various technological givens. The management variables are proxies for genetic potential which, in turn, influence the marginal products of the variable inputs. They also measure factors which influence the level of variable inputs used. Because the management variables are essentially instrumental, their introduction into the models should increase explained variation as well as reduce the amount of variation explained by the input variables themselves. The same is true for the institutional/ecological set of variables though these are more difficult to interpret correctly.

We turn now to a consideration of the individual models. Details of the data and summary statistics are given in Appendix G.

B. Zebu Cows

The overall model which includes production, management and error-related variables (equation 3) only explains 31 percent of the variation in milk yields for zebu cows. The final equation for the production-related variables, excluding those which do not add to adjusted R^2, explains 26 percent of the total variation in Q_{mz} and was as follows:

$$(1)\quad Q_{mz} = \underset{(44.6)}{-29.7} + \underset{\underset{**}{(2.07)}}{5.13W_f} + \underset{\underset{***}{(7.58)}}{29.6A_w} + \underset{\underset{***}{(26.0)}}{94.3E_n}$$

where the subscript z refers to zebu cows; numbers in parentheses are the standard errors of the estimated means; and

$R^2 = .26$
$F = 11.9$***
*** = significant at the .001 level
** = significant at the .01 level

None of the six other input variables nor the number of times calved were significant at below the .45 level when added to the above model.[1] At the same time the coefficients for included variables changed less than 10 percent from their present values when these other variables were added.

The signs of all the included variables are as expected. From a statistical point of view, the most significant variable in the model is the age of the calf at weaning (A_w). This reflects the fact that milk production for zebu cows stops as soon as the calf is no longer nursing. Thus reducing calf mortality will have a very direct

[1]It should be pointed out that the variables G_R and E_A did not appear in the model because of a lack of non-zero values for either one. Breed, B_d, of course, refers only to grade cattle and also does not appear in the model for zebu cows.

and immediate positive impact on aggregate milk production from zebu cows.

The enumerator dummy (E_n) is the next most significant variable in the model. The value of the coefficient amounts to 50 percent of the mean value of Q_{mz}, and the variable accounts for 40 percent of explained variation in Q_{mz}. The water variable (W_f) is also significant but, with a maximum value of 14 its impact on milk production is not as great as the other two variables. In fact, the two technical variables ($W_f + A_w$) taken together account for only 3 percent of the difference in average milk production between the top producing 25 percent and average zebu cows when average values for these two subpopulations are compared. This suggests that, apart from reducing calf mortality and shortening the calving interval, there is little that public policy can do to increase milk production from zebu cows in Kilimanjaro.

Even the management factors tested do not add a great deal to explained variation in milk production for the zebu herd, as equation (2) demonstrates.

$$(2) \quad Q_{mz} = \underset{(78.9)}{-75.0} + \underset{\substack{(2.06)\\ **}}{5.48W_f} + \underset{\substack{(7.55)\\ ***}}{31.4A_w} + \underset{\substack{(26.5)\\ ***}}{101E_n} + \underset{\substack{(28.4)\\ *}}{51.6W_l}$$

$$- \underset{(3.75)}{5.76P_g} - \underset{(.63)}{.841A_h}$$

where:

R^2 = .30
F = 7.1***
*** = significant at the .001 level
** = significant at the .01 level
* = significant at the .1 level.

The difference between the R^2's for the two equations is .04. The management variables are considerably less significant than the two technical variables even though the coefficient for the wealth variable is quite high. Not surprisingly for the zebu model, given the low explanatory power of the technical variables, addition of the management variables does not materially alter the values or the significance levels of those variables already included in the model.

The sign on the progressiveness variable is not as hypothesized and is not due to collinearity with the income variable. Since this variable is based largely on agricultural practices rather than animal husbandry practices it could suggest that good crop farmers are not always good livestock farmers.

The age of the head of the household carries a negative sign, as expected, though it is significant only at the .19 level and, substantively, has only a small impact on milk production. The presence of younger members in households headed by older men creates enough statistical noise to dilute the significance of this variable.

Education of the head of household (E_h) was not significant at the .30 level when added to equation (2) because of collinearity with wealth (W_1). Consequently it was dropped in the final model. Its sign was positive as expected.

The addition of aspect (A_{sp}) increases $\bar{R}^2$ and changes the magnitude and significance levels of the other variables only slightly. The sign is negative as can be seen from equation (3) in Table 8.1, though its significance level barely qualifies it for inclusion. Given that the value for the variable varies between 14 and 264, however, the magnitude of its impact on production can be quite substantial.

TABLE 8.1

SUMMARY OF REGRESSION COEFFICIENTS EXPLAINING VARIATION IN MILK PRODUCTION AMONG ZEBU COWS IN KILIMANJARO

Variable Set Entered	Number of Variables Tested	Constant	Variables Retained and Associated Coefficients							Summary Statistics		
			Freq. Water	Age Weaning	Enumerator	Wealth	Progressiveness	Age of Herd	Aspect	R^2	F Ratio	Residual d.f.
			W_f	A_w	E_n	W_1	P_g	A_h	A_{sp}			
1. Inputs, technology and measurement error	10	-29.7 (44.6)[a]	5.1 (2.07) **	29.6 (7.58) ***	94.3 (26.0) ***					.26	11.9	102
2. Management	4	75.0 (78.9)	5.48 (2.06) **	31.4 (7.55) ***	101 (26.5) ***	51.6 (28.4) *	-5.76 (3.75)	-.841 (.630)		.30	7.1	99
3. Ecological/Institutional	3	43.1 (83.2)	5.75 (2.07) **	32.2 (7.56) ***	102 (265) ***	59.2 (29.0) *	-6.77 (3.84) *	-.928 (.633)	-.258 (.217)	.31	6.3	98

[a]Numbers in parentheses are the standard error of the estimated coefficient.

*Significant at the .1 level.

**Significant at the .01 level.

***Significant at the .001 level.

The sign for aspect is not what is hypothesized for the zebu model and raises the question of whether it measures what we think it does. Available grazing becomes more constrained as aspect increases but population density, rainfall and coffee production (and therefore incomes) increase. The excluded variable G_f, the frequency of grazing, had a positive sign but at a very low level of confidence. If A_{sp} were measuring what was expected in the zebu model G_f should be more significant. The fact that it is not suggests that little policy impact can be assigned to this variable.

The three equations representing various components of the zebu model are summarized in Table 8.1.

C. Grade Cows

The model does a much better job of explaining variation in grade cow milk yields especially for Moshi District.[1] Equation (4) presents the results of the technical set for Moshi. The subscript g on Q_{mg} refers to six month milk production for grade cows.

$$(4)\quad Q_{mg} = \underset{\substack{(226)\\ *}}{515} + \underset{(13.1)}{19.4W_f} + \underset{\substack{(8.72)\\ **}}{23.5_f} + \underset{\substack{(52.6)\\ *}}{123G_r} + \underset{\substack{(.375)\\ ***}}{1.25C_g} + \underset{(7.28)}{7.98L_g}$$

$$- \underset{\substack{(344)\\ *}}{694P_b} - \underset{(448)}{525P_p} - \underset{(19.0)}{24.0G_f} + \underset{(51.9)}{64.8B_n} - \underset{\substack{(22.5)\\ *}}{41.3A_w} - \underset{(112)}{152E_n}$$

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[1] The recent introduction of grade cattle into Rombo District generated a high percentage of don't know responses for six month milk production, the dependent variable. As a result the all-Kilimanjaro sample on which the grade cattle regressions were to be based retained only four grade cows from Rombo District out of a total of 72 cows. This, coupled with ecological differences between large parts of both districts suggested that it would be more appropriate to separate the two sets of data. Those observations for Moshi District retained their original weights and give, therefore, a representative picture of the grade cow population in Moshi District.

where:

R^2 = .59
F = 7.3***
*** = significant at the .001 level
** = significant at the .01 level
* = significant at the .1 level.

The variables for the frequency of feeding salt (S_f) and cash expenditures on grass per cattle unit (C_g) are significant at the .01 level with the signs as expected. Kilograms of grain fed (G_n) is significant at the .02 level, and the proportion of the ration coming from bananas, at the .05 level. The sign of the former is as expected but its magnitude is lower than it should be since it implies that 180 kilograms of grain[1] are associated with an increase in milk production by only 123 liters of milk.[2] This is explained partly by the fact that about half of the grain fed to dairy cows is, in fact, bran, with a lower TDN and digestible protein content than concentrates. Recording grain normally fed to cows, as the one visit study did, introduced another source of error since many farmers would not feed this normal quantity continuously, especially when their stores were temporarily depleted or when they were short of cash. Thus the actual quantities of grain consumed were probably much lower than those recorded.[3]

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[1]One kilo per day for six months.

[2]Williamson and Payne [1965] indicate that four pounds of grain (1.8 kgs.) are required to produce one gallon of milk (4.5 kgs.) in tropical breeds, with a higher ratio required at lower production levels. Five hundred grams of grain per liter of milk per day is a good rule of thumb.

[3]Data on cash expenditures confirm that farmers did not purchase as much grain as they reported feeding. Though the two measures do not refer to exactly the same things the average household reported feeding 275 kilograms of feed supplements to its herd over

The sign of the variable representing the proportion of the forage ration coming from bananas is plausible but its magnitude is surprising. It is possible that a high proportion of bananas in the ration indicates an unwillingness to go off the farm for supplemental forage supplies. A more likely explanation is that the ratio of stems to leaves is higher in these rations containing a higher proportion of bananas.[1] Unfortunately these two feedstuffs were not distinguished on the recording instrument so the actual composition of the banana portion of the ration is unknown.

The sign and magnitude of P_p, the proportion of the ration coming from planted grasses is hard to accept, even allowing for the level of significance of the coefficient (.25). It is not clear why a farmer who would take the time and resources to plant grasses would not also ensure that the rest of a cow's forage ration was adequate. Perhaps this suggests, more than anything, that counting bundles is not a sufficiently precise measure of relative forage intake for estimating differences in the quality of the forage ration.

The age of the calf at weaning (A_w) is significant at the .07 level and negative as expected. The frequency of feeding water (W_f) and the number of times given birth (B_n) carry the expected signs but

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the previous year (.29 kilograms per day per animal) and purchasing about 145 kilograms. Some byproducts are acquired from local flour mills and household milling activities and some from beer making residue, some of which may be purchased. This could not account for all of the difference, however. As a rough guess per cow grain consumption is probably overstated by about 50 percent. There is no reason to believe this overstatement is a selective phenomenon.

[1]Banana stems have a much lower TDN and crude protein content than banana leaves.

at .15 and .21 respectively, they are not particularly significant. The same is true of the amount of labor used to gather grass (L_g) which is significant at the .28 level. The coefficient for the enumerator dummy (E_n) is large, though in this case, negative and less significant than in the zebu model.

The frequency of grazing carries a negative sign which was unexpected. This may indicate that grade cows in extensively grazed herds are lower grade f_1's and f_2's rather than more poorly fed animals, and points to the need to carefully interpret all of these variables since the data contain many crosscurrents.

The dummy for pure bred animals, the only technical variable not retained in the final model, had a positive sign but its level of significance was only .50. This is not surprising since this variable suffers from the fact that few farmers know the genetic history of their grade cows.[1]

Introducing the management set of variables into equation (4) for Moshi District increases the R^2 and has a substantial impact both on the magnitude of many of the technical variables as well as their levels of significance. This can be seen from equation (5).

$$(5)\quad Q_{mg} = \underset{(259)}{51.3} + \underset{(12.5)}{11.4W_f} + \underset{\underset{**}{(8.14)}}{22.7S_f} + \underset{\underset{*}{(49.1)}}{120G_r} + \underset{\underset{*}{(.396)}}{.664C_g} + \underset{(6.83)}{10.3L_g}$$

$$- \underset{(337)}{372P_b} - \underset{\underset{*}{(430)}}{851P_p} - \underset{(17.9)}{17.1G_f} + \underset{(49.0)}{40.9B_n} - \underset{(22.3)}{17.0A_w} - \underset{(107)}{151E_n}$$

$$+ \underset{\underset{*}{(15.9)}}{34.7P_g} + \underset{(15.3)}{17.6E_h}$$

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[1]The lack of knowledge about the genetic history of grade cows introduced some enumerator error as well. One of the better

where:

R^2 = .66
F = 7.9
** = significant at the .01 level
* = significant at the .1 level.

Obviously there is collinearity between the management related variables and the level of use of some technical inputs. The increase of .07 in the R^2 is only a minimum estimate of the effect of management on the production relationships. Some of the effects attributed to technical variables, such as the frequency of feeding water and cash expenditures on grass are probably due to the influence of management on the selection of grade cows with above average milk producing potential.

Progressiveness (P_g) is positive and significant at the .03 level. This variable explains the bulk of the variation explained by the management set. The education of the head of the household, again picking up some of the effect of wealth, is positive as expected, but is significant only at the .26 level, barely qualifying it for inclusion in the final estimating equation. It's high collinearity with P_g causes its addition to explain relatively little of the variation not already explained by progressiveness.

Adding the ecological/institutional set of variables brings about major changes in the magnitude, and in the case of banana forage, the sign, of almost all previously included variables. The one variable in this set which is retained, aspect, drives the R^2 up to .76, a .10 increase over the equation including only the technical

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enumerators, knowing full well that many farmers did not know the genetic history of their animals and realizing that truly pure bred animals were rare, recorded all-grade animals as crossbreeds unless the proprietor could convince him otherwise.

and management variables. Part of this increase in explained variation arises from including the age of the head of household (A_h), a variable which does not meet the inclusion criterion when aspect (A_{sp}) is not in the model. Both coefficients are positive with aspect significant at the .001 level and age of the head of household (A_h) at the .06 level.

The positive value of the coefficient for aspect indicates that milk production per cow increases as the location of residence moves from Marangu to Machame and Mashati. This reflects perhaps partly the greater and more evenly distributed rainfall which falls on the southwestern slope of the mountain. But more certainly, this variable measures the historical distribution of veterinary and extension services and the much longer history of caring for grade cattle for farmers on the southwestern slope. Some internal selection has taken place and the existence of a Kilimo extension center and artificial insemination program since the mid 1960's has resulted in substantially greater upgrading than has been possible in areas where farmers rely only on available low-grade bulls. Using six month milk production as a dependent variable removes the effect of the one negative aspect of the A.I. program to date, namely, the low conception rate. It seems likely that using a variable which included the effect of the longer calving interval arising from a low A.I. conception rate, such as annual milk production, would show considerably less effect for this institutional/ecological variable. The values of the coefficients for all three equations are summarized in Table 8.2.

Table 8.2 also summarizes coefficients for all three versions of the model for Rombo District. The data for Rombo are not

TABLE 8.2

SUMMARY OF REGRESSION COEFFICIENTS EXPLAINING VARIATION IN MILK PRODUCTION AMONG GRADE COWS IN KILIMANJARO

Variable Set Entered	Number of Variables Tested	Con-stant	Various Retained and Associated Coefficients								
			Freq. Water	Freq. Salt	Kilos Grain	Purchase Grass	Labor Grass	Prop. Bananas	Prop. Planted	Freq. Grazing	Number Births
			W_f	S_f	G_r	C_g	L_g	P_b	P_p	G_f	B_n
Moshi District											
4. Inputs, technology and measurement error	12	515 (226) *	19.4 (13.1)	23.4 (8.72) **	123 (52.6) *	1.26 (.375) ***	7.98 (7.28)	-694 (344) *	-525 (448)	-24.0 (19.0)	64.8 (51.9)
5. Management	5	51.3 (259)	11.4 (12.5)	22.7 (8.14) **	120 (49.1) *	.664 (.396) *	10.3 (6.83)	-372 (337)	-851 (430) *	-17.1 (17.9)	40.9 (49.0)
6. Ecological/Institutional	3	-1427 (398) ***	220 (11.3) *	12.5 (7.32) *	22.0 (46.9)	.455 (.344)	11.7 (5.89) *	87.7 (303)	-890 (373) *	-52.4 (17.1) **	40.7 (43.3)
Rombo District											
7. Inputs, technology and measurement error	12	849 (198) ***	16.4 (15.4)					-513 (442)	-815 (506)	-63.8 (24.9) **	
8. Management	5	482 (360)	17.8 (14.0)					151 (434)	-676 (461)	-43.2 (23.5) *	
9. Ecological/Institutional	3	2664 (1013) **	22.5 (13.9)					18.1 (426)	-285 (480)	-56.5 (23.8) *	

TABLE 8.2—Continued

Variable Set Entered	Age of Weaning	Enu-merator	Progres-siveness	Education of Head	Age of Head	Agricultural Employment	Wealth	Aspect	Altitude	Summary Statistics		
	A_w	E_n	P_g	E_h	A_h	E_a	W	A_{sp}	A_{lt}	R^2	F Ratio	Resi-dual d.f.
Moshi District												
4. Inputs, technology and measurement error	-41.3 (22.5) *	-152 (112)								.59	7.3	56
5. Management	-17.0 (22.3)	-151 (107)	34.7 (15.9) *	17.6 (15.3)	a					.66	7.9	54
6. Ecological/Institutional	9.6 (19.8)	-119 (91.4)	29.1 (13.8) *	34.1 14.2 *	4.99 (2.63) *			5.77 (1.24) ***		.76	11.0	5[illegible]
Rombo District												
7. Inputs, technology and measurement error										.15	2.6	57
8. Management					-6.06 (3.53) *	459 (180) **	29.4 (13.9) *			.34	4.0	54
9. Ecological/Institutional					-4.01 (3.54)	468 (179) **	31.0 (13.6) *	-9.04 (4.34) *	-.283 (.127)	.40	3.9	52

[a]Retained only when A_{sp} is included in the model.

*Significant at the .1 level.

**Significant at the .01 level.

***Significant at the .001 level.

representative, however, in contrast to those for Moshi District. These results need special care in interpretation.[1]

As can be seen from Table 8.2, the technical variables explain only 15 percent of the variation in six month milk production. The coefficient for water is positive but significant only at the .29 level. Those for the proportion of the forage ration coming from bananas and planted grasses are negative, as in the Moshi model, but significant only at the .25 and .11 levels respectively. The frequency of grazing is again negative but unlike Moshi District, highly significant (.01). The frequency of feeding salt (S_f), kilograms of grain fed (G_n), cash expenditures on grass (C_g) and number of births (B_n) all had positive coefficients but did not increase adjusted R^2 when added to a model containing the retained variables. Age at weaning (A_w) had a negative sign, as in the Moshi model but it too did not increase adjusted R^2. The signs for the enumerator variable (E_n) and labor for gathering grass were reversed from the Moshi model but the low level of confidence associated with the coefficients for

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[1]Because of the high incidence of recent arrivals in the grade cow population of Rombo District we had fewer six month lactation histories. In order to increase the number of observations all households in the Rombo regression models were given an equal weight of one instead of being weighting down to overall population probabilities. This had the effect of increasing sample size from 4 to 62. Since the Rombo sample is a two stage sample drawing ten households in or near each of ten first stage sample units, assigning each observation a weight of one does not correct for the lower efficiency of a two stage sample relative to a simple random sample of the same size. Consequently standard errors are underestimated and significance levels based on them are artificially low. Moreover the reader is reminded that more than three-quarters of all-grade cattle in the Rombo sample were selected purposively rather than randomly. All these factors suggest the results for Rombo be treated with caution and taken as indicative of orders of magnitude only, with an additional need for considerable interpretation.

these variables indicate there is nothing contradictory here from a statistical point of view.

The poor explanatory power of the technical set of variables for Rombo District reflects the very recent nature of the grade cattle industry there. A much higher proportion of farmers have animals acquired from outside the area for which performance variables could not be objectively verified by purchasing farmers as well as they could from a local animal. As a result, large amounts of money have been spent for infertile and low producing animals—obviously not intentionally. These results point out that wealthy progressive farmers and early adopters expose themselves to substantial risk of financial loss. Thus part of the higher returns realized by those who are successful represents a necessary risk premium rather than monopoly profit.

Not surprisingly, the management set of variables explains much more of the variation in milk yields in Rombo District than in Moshi District. Their addition to the technical set raises R^2 to .34 an absolute increase almost three times as large as for Moshi District. The agricultural employment dummy is positive and highly significant (.01), indicating either a better ability to select or more likely, an inside track to information on which animals are better producers. Since animals financed by KNCU usually arrive in groups, persons familiar with veterinarians and others involved in the actual purchase and distribution of the animals are in a good position to get the better animals. Indeed such favoritism is one of the most common complaints of farmers in Kilimanjaro. In Rombo, unlike in Moshi District, the small number of locally born grade cows in relation to the total allows the data to reveal this favoritism.

The influence of wealth (W) is positive and significant at the .04 level in Rombo District while the coefficient for the age of the head of the household (A_h) is negative and significant at the .09 level. Recalling that (A_h) was positive in Moshi District the likely explanation for the switch in signs arises from the inclusion of wealth in the Rombo model. In Moshi the age of the head of the household is probably picking up some of the effect of wealth.

The major change in the management model is in the sign of the coefficient for the proportion of the ration coming from bananas, from negative to positive. This variable became considerably less negative in the Moshi model when the management set of variables were added and positive as well when the age of the head of household was included. This reflects the fact that traditionally bananas have been an important source of livestock roughage and the lower yields associated with feeding bananas reflect lower yields associated with older farmers. Whether these lower yields arise from excessive dependence on bananas per se or simply less human energy available for gathering more distant sources of roughage is a question the data cannot address.

Addition of aspect and altitude, the two ecological/institutional variables, increases R^2 proportionately about as much as in the Moshi model but still leaves overall explained variation at about one-half the level for Moshi. The negative value for aspect and altitude reflects the high concentration of grade cattle in Usseri and Tarakiya and the presence there of an extension agent who is active and well respected by farmers. He has been very successful in helping farmers acquire good breeding stock from Kenya and West Kilimanjaro. There is no A.I. program in Rombo to speak of so this set of variables gives an indication of the potential benefits of a well-organized and well-staffed extension program.

D. Implied Marginal Productivity of Selected Inputs

Only the data relating to grade cows in Moshi District reflect enough stability and explanatory power to be used to estimate the marginal productivity of selected inputs into the grade dairy enterprise. Table 8.3 compares the average value of the dependent variable and each of the independent technical variables for all-grade cows and the 25 percent top producing cows only.[1] Based on the values of the estimated coefficients the increase projected for superior cows is 485 liters versus 680 liters actually found for these animals. Thus the technical variables explain slightly over 70 percent of the variation in milk yields between the two groups when calculated in this way versus the 60 percent found for the model itself when estimated on a much more limited set of data.

The implied marginal productivities of the five technical variables which involve a quantifiable expenditure are also given in Table 8.3. Since linear forms were used for each of these variables the theoretical characteristics of these marginal productivities are not particularly sound but they nonetheless shed some light on the profitability of selected inputs.

[1] Includes all-grade cows in the composite grade cattle sample for both Moshi and Rombo Districts.

TABLE 8.3

INCREASE IN MILK PRODUCTION BETWEEN AVERAGE AND SUPERIOR GRADE COWS EXPLAINED BY TECHNICAL VARIABLES IN THE MILK PRODUCTION MODEL FOR MOSHI DISTRICT WITH THE ASSOCIATED COST OF THE ADDED INPUTS, THE VALUE OF THE ADDED OUTPUT AND THE IMPLIED MARGINAL PRODUCTIVITIES PER UNIT OF EXPENDITURE

Variable	Estimated Coefficients[a]	Average Value of Variable[b]		Increase Projected for Superior Cows (liters)	Shillings of Additional		Implied Return per unit of Expenditure
		All Grade Cows	Superior Cows Only		Input	Output[c]	
Q_{mg} Milk Production[d]		805	1485				
W_f Water[e]	19.4	7.9	10.3	46.6	3[f]	70	21.0
S_f Salt[e]	23.4	8.3	12.0	86.6	11[g]	130	11.8
G_r Grain[h]	123	.58	1.07	60.3	45[i]	90	2.0
C_g Purchased grass[j]	1.26	64	220	196.6	156	295	1.9
L_g Labor for grass[k]	7.98	11.2	8.7	-20.0	-28[l]	-30	1.1
G_f Grazing[e]	-24.0	.96	.18	18.7	n.e.	n.e.	n.e.
P_b Bananas[m]	-694	.266	.300	-23.6	n.e.	n.e.	n.e.
P_p Planted grass[m]	-525	.144	.145	-.5	n.e.	n.e.	n.e.
B_n Number of births	64.8	1.97	2.54	36.9	n.e.	n.e.	n.e.
A_w Age of weaning[n]	-41.3	4.54	3.00	63.6	n.e.	n.e.	n.e.
E_n Enumerator[o]	-152	.127	0	19.3	n.e.	n.e.	n.e.
Total explained				484.5			

[a]Coefficient for Moshi District only.

[b]Includes all cows in the sample, including those observations excluded from the regression analysis because of missing or extreme values.

[c]With milk valued at 1/50 per liter.

[d]Liters during first six months of lactation as reported, unadjusted for enumerator bias and underreporting.

[e]Frequency per week. [f].23 hours for 1.3 cattle units for 26 weeks at .43 shillings per hour.

[g]Average expenditure on salt per grade cow was 24/=. The implied increase in expenditure is then 10.7 shillings ($\frac{3.7}{8.3} \times 24$).

[h]Kilograms per day. [i].49 kilograms for 180 days at 51 cents per kilo. [j]In shillings. [k]Hours per week.

[l]2.5 hours for 26 weeks at 43 cents per hour. [m]Proportion of ration. [n]In months. [o]Dummy variable.

n.e. = not estimated.

The marginal productivity of expenditures on water and salt are too high to be credible given the rather low rates of utilization of each in the average herd. No doubt coefficients for both variables pick up some non-causation correlation between the frequency of these practices and high milk yields.

The figures for grain and cash and labor expenditures on grass are much more believable. Cash expenditures on grain and grass yields around two shillings for each shilling of expenditure. No doubt capital constraints and risk aversion account for the failure to use each at optimal levels, though farmers appear to be operating on a line of least cost combination with respect to the two.

Labor for gathering grass, a relatively abundant input in Kilimanjaro, appears to yield returns only slightly above its opportunity cost. Though the significance level of the coefficient is weak (.28) the implied return is quite believable since milk is only one of three principal outputs of the dairy enterprise, the other two being meat and manure. This input has the greatest impact on production of manure by far and inclusion of the value of manure in the dependent variable would raise the MVP of this input relative to the others.

The purpose of this exercise is not to estimate a production function as much as it is to explain variation in milk yields. Returns to labor and capital for the entire enterprise are computed in a different way in a later section.

E. Summary of Determinants of Milk Yield

Very little of the variation in milk yields among zebu cattle can be explained by either technical or management variables. The two technical variables which were significantly different from zero at the .01 level explain only 3 percent of the difference in average milk production between average and superior (top 25 percent) zebu cows.

For grade cows the results were more as expected, especially for Moshi District where the grade dairy industry is more established. Technical variables kept in the model, exclusive of enumerator bias, explain almost 60 percent of the variation in average milk yields. The coefficients for these variables embody at least some increase more properly attributable to management, especially as management relates to selecting cows capable of superior performance. But in general, the data suggest that feeding water, salt, grain and purchased grass all have a substantial economically positive impact on milk production from grade cows. The return per unit of expenditure on labor for gathering grass and for purchased grass, coupled with the negative coefficient for the proportion of the ration from bananas, suggest that the quantity of forage given to animals is constraining milk production in Kilimanjaro. Thus, efforts aimed at reducing forage constraints will have a positive impact on milk production. As expected milk production by grade cows increases after the first lactation but the relationship is not particularly strong in the data used in this analysis.

The regression analysis also confirms the importance of institutional variables related to the distribution of extension and artificial insemination services and management variables related both to progressiveness and wealth as well as special interest politics.

The grade cattle data confirm that variables over which a well-organized extension and artificial insemination program can have some influence explain at least 70 percent of the variation in six month milk production for grade cows in Kilimanjaro. No doubt much of the unexplained variation arises from genetic differences in grade animals that the A.I. services could address as well. Just how much of this potential can be realized will depend on organizational and implementation issues beyond the scope of this study. We turn now to an examination of the costs and returns of cattle/dairy enterprises in Kilimanjaro.

CHAPTER IX

ENTERPRISE ACCOUNTS AND INCENTIVES FOR UPGRADING THE DAIRY ENTERPRISE

A. Budgeting Techniques

In this chapter simulated capital budgets are prepared and analyzed for eight different types and sizes of cattle enterprises over two different planning horizons. The inputs and outputs used for each of the capital budgets are derived from average values for relevant coefficients or from values which themselves are derived from or otherwise based on those average values. These budgets then serve as the basis for a discussion of the profitability of the various alternatives.

The use of simulated results to analyze the dairy industry in Kilimanjaro was necessitated by the fact that many of the herd performance parameters necessary for calculating the profitability of the cattle/dairy enterprise could not be obtained on an individual herd basis. Age specific mortality rates, calving interval, age at weaning and lactation milk production are only a few of the variables that had to be calculated on a herd basis. This is partly because for an individual household or cow the last occurrence of the event is not a particularly good predictor of the most recent as yet uncompleted occurrence, and partly because many animals, especially grade animals, were recently acquired and had not yet completed a complete reproductive cycle with the farmer now owning it. At the same time the flow of benefits of a cattle enterprise cover many years and depend on a number of chance events such as the sex of the calf and the genetic potential of grade animals purchased in an imperfect market. Further problems in calculating profitability on an individual herd basis arise from the long calving interval and the low percentage of cows actually in milk at the time of the survey, as well as the fact that 1973 was a period of rapidly rising zebu cattle prices in Northern Tanzania[1] and grade cattle prices in Kenya. Finally, the single visit method of data collection, with interviews of various households distributed over time, yields population estimates that are more independent of seasonal variation than the individual household observations.

The enterprise budgets are thus synthetic budgets. Using synthetic budgets of this kind helps overcome unknowns and anomalies in the individual herd data and provides more representative figures for the entire year. Where the distribution of the values of particular coefficients in the sample population is fairly continuous with a clear central tendency this approach poses no problems in interpretation. However where distributions are more dispersed and no central tendency is clear, such as with lactation milk production for grade cows, a question always arises as to the usefulness of the results for predicting farmer behavior.

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[1]Large numbers of cattle were being purchased by Asians and smuggled into Kenya as a way of exporting capital. In 1973 the Tanzanian Government nationalized all rental properties with a value in excess of 100,000 shillings ($14,000) with no compensation to be paid on buildings more than ten years old. This was the last straw for many Asians who sought to export as much of their capital as possible before leaving themselves.

B. Summary of Procedures and Coefficients

Two principles guided the selection of the specific enterprise size/type combinations which are simulated and analyzed in this chapter: the enterprise must represent central tendencies for large groups of farmers or it must represent a reasonably accessible target for existing producers, given the quantity of labor required. There are five basic enterprise size/types. In addition, three of these basic combinations are constrained by the requirement of a minimum proportion of males in the herd in order to assure breeding services. Overall, the eight enterprise size/types which are analyzed include six that are 1.6 cattle units in size and two which are 2.2 units. The 1.6 unit enterprises require roughly the same amount of labor that is currently expended on the average all-zebu herd in the same area, the size of which also averages 1.6 cattle units. The 2.2 unit enterprises reflect the average size of all-grade cattle herds in Kilimanjaro in 1973 and are included to get an idea of the returns to existing grade cattle owners, even though the amount of labor and capital they utilize is considerably greater than that which could be brought to bear by the average household without offsetting changes in the farming system and in expenditure patterns.

All of the capital budgets for the various enterprises assume the purchase in year 0 of a heifer twelve months younger than the average age at first calving for the particular type of heifer in question. Subsequent calves are born at the appropriate average calving interval for each type of cow until such time as the cow is removed from the herd. The age specific mortality rates as detailed in Tables 4.5 and 4.6 and summarized in Table 9.1 are used to

TABLE 9.1

COEFFICIENTS ASSUMED FOR THE ENTERPRISE BUDGETS

Coefficient	Enterprise and Type of Cow					
	Zebu Average	Zebu-Grade		All-Grade		
		F_1	F_2	Average		Superior
a. Average size of enterprise in cattle units	1.6	1.6	1.6	1.6	2.2	1.6
b. Age in months of heifer at purchase	37	na[a]	na	22	22	22
c. Age at first calving in months	49	42	34	34	34	34
d. Calving interval in months	29	25	20	20	20	17
e. Lactation length (months)	8	9	10	10	10	11
f. Production period (months)	11	12	13	13	13	14
g. Milk production per lactation (liters)						
Overall	380	750	1100	1470	1470	2220
First lactation	380	750	1060[b]	1350[c]	1350[c]	2040[c]
Second lactation	380	750	1100[b]	1470[c]	1470[c]	2220[c]
Third and subsequent lactation	380	750	1140[b]	1590[c]	1590[c]	2400[c]
h. Number of cattle units per full grown adult animal	1.0	1.15	1.3	1.3	1.3	1.3
i. Labor inputs (hours per month per cattle unit)						
Normal maintenance and growth	67.1	69.3	70.6	70.6	58.9	70.6
Production period	14.3	17.3	19.5	22.5	19.9	29.9
j. Mortality rates						
Male						
under 1 year	.24	.22	.20	.20	.20	.20
1-<2 years	.21	.16	.10	.10	.10	.10
2-<3 years	.10	.10	.10	.10	.10	.10
3 years and older	.10	.10	.10	.10	.10	.10
Female						
under 1 year	.13	.10	.07	.07	.07	.07
1-<2 years	.10	.09	.07	.07	.07	.07
2-<3 years	.10	.08	.06	.06	.06	.06
3 years and older	.10	.08	.06	.06	.06	.06

[a]Not applicable.

[b]Assuming that increases in milk production for second and third lactations for f_2 zebu-grade crosses are one half as great, in percentage terms, as the increases indicated for grade cows in Table 8.3.

[c]Assuming increases in milk production for second and third lactations are proportional to those found for six month milk production and reported in Table 8.3.

compute interdependent survival probabilities for the initial heifer and all subsequent offspring, according to age and sex.

With the exception of a zebu enterprise in which the first calf is assumed to be a male, internal reproduction is the only way the herd is allowed to grow. The number of animals (or fraction thereof) in the herd rises with new births while both the probability of a birth and the survival probability of individual animals in the herd declines according to mortality probabilities. By year 10, the last year for which herd performance is simulated, some of the herds will have contained as many as 12 animals with survival probabilities of 40 percent or less.

In no year is the size of the herd—adjusted for survival probabilities—allowed to grow beyond a specified maximum permissible size. This limit ensures that the average size of the enterprise between years three and nine—essentially years of full capacity—does not greatly exceed its average size in the population. It also causes substantial fluctuations in herd size from year to year as animals are removed from the herd.

When cattle need to be removed from the herd they are generally sold in the middle of the first year during which the herd size limit would otherwise be exceeded. Animals selected for sale are those adding the lowest increment to total value over the next 12 months. In general this causes male animals to be removed first. In three of the enterprises, however, a minimum proportion of males is required even if retaining a female would add a greater increment to total output.

If any zebu or f_1 cows are removed while still in milk their calves are sold with them since the regression analysis suggests that these animals stop letting down their milk once the nursing stimulus is removed. In those cases where the reduction in value added would be less by selling a nursing calf instead of an adult animal, the calf is valued as a male, regardless of its sex. This presumes such animals are sold for slaughter and reflects the very high mortality rate for calves away from their mothers.

All male animals are sold within six months of reaching their maximum value whether or not the maximum permissible herd size constraint has been exceeded. This gives farmers the service of sexually mature males for about two years while limiting their presence in the herd to the period of increasing weight and value. The herd structure data indicate that this is the practice followed by most farmers.

Animals which are sold are valued using the age-sex specific average prices included in Appendix E. In addition, females are assumed to capitalize one-quarter of the value of a newborn calf if sold when three to six months pregnant and one-half of the value of the calf if sold over six months pregnant. Cows sold within three months of parturition are assumed to capitalize 25 percent of the value of milk production expected for the following lactation, in addition to one-half of the value of the unborn calf.

Animals which die are assumed to generate income equal to their mortality probability times 50 percent of their meat value[1] at the

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[1]Meat value is defined as the sale value of the male animal or if a female animal, the lower of the value of the female animal or a male animal of equal age.

mid-point of the period covered (much of this meat is consumed by the household or retailed at a discount to neighbors). At the same time, variable costs and variable returns such as milk and manure are counted only to the extent indicated by the survival probabilities.

Labor inputs per cattle unit are those detailed in Table 7.4 for normal growth and maintenance and production, converted to a monthly basis. Production inputs are included only over the actual production period for lactating cows, defined as the last three months of pregnancy and the entire lactation period. Each hour of labor is valued at .43 shillings, its average sex specific opportunity cost over the entire year as described in Appendix H. All reproduction coefficients and labor hours assumed for the various enterprise types are summarized in Table 9.1.

Variable cash costs, like labor expenses, are divided into those for maintenance and normal growth and those associated with milk production. Since most grain is fed either to cows or calves, all grain and milk replacer cash expenses as reported in Table 7.5 are assumed to be milk production related expenses and are charged entirely to the production period. The breakdown of variable labor and cash inputs are summarized in Table 9.2 with the details of their derivation explained in the footnotes to the table.

Table 9.2 includes also the value of manure from maintenance and growth converted to a monthly basis on the assumption that production is spread evenly over the relevant production period. Manure has been valued at 75/= per ton with annual manure production amounting to 1200 kilograms per 100 kilograms of body weight. Cattle unit values are used to approximate weights and one cattle unit

TABLE 9.2

SUMMARY OF THE COST OF VARIABLE INPUTS AND THE VALUE OF VARIABLE OUTPUTS PER CATTLE UNIT PER MONTH FOR VARIOUS SIZES OF ALL-ZEBU, ZEBU-GRADE AND ALL-GRADE CATTLE HERDS IN KILIMANJARO UNDER ALTERNATIVE LEVELS OF MANAGEMENT (TZ SHILLINGS)

Input/Variable	Management Level by Enterprise					
	Zebu	Zebu-Grade		All Grade		
	Average	F_1	F_2	Average		Superior
Average number of cattle units in enterprise	1.6	1.6	1.6	1.6	2.2	1.6
Cost of variable inputs (shillings) for maintenance and normal growth						
Labor[a]	29	30	30	30	25	30
Variable cash inputs[b]	1	2[c]	2[c]	6	6	28
For pregnancy and milk production						
Labor[a]	6	7	8	10	9	13
Variable cash inputs[d]	0	1	1	10	10	22
Value of variable outputs						
From maintenance and growth:						
Manure[e]	21	21	21	21	21	21
From production:						
Milk[f]						
First lactation	71	125	159	203	203	278
Second lactation	71	125	165	221	221	303
Third lactation	71	125	171	239	239	327

[a]Values in Table 9.1 multiplied by x.43 to get monthly values in shillings.

[b]Data taken from Table 7.5 and reduced to monthly basis. Variable cash inputs for maintenance and growth do not include grain and milk replacer since these are fed to cows and calves only, usually while the cow is producing milk. Consequently they are treated as a production period expense.

[c]Assuming all increase in cattle unit cash inputs over the levels for zebu cattle are expended on grade cattle in these herds and assuming further that grade cattle make up 50 percent of the herds.

[d]Includes grain and milk replacer costs from Table 7.5, reduced to per month of production period basis for cows. This involves multiplying the annual expenditure for these items from Table 7.5 by the following term

$$\frac{\text{calving interval}}{12 \times \text{production period} \times \text{proportion of cattle units which are cows}}$$

This reduces these annual expenditures to a monthly production period basis for cows only. Values used for each of these variables are listed in Appendix Table D-1.

[e]Assuming one cattle unit weighs 275 kilos, all cattle produce 1.2 tons of manure per year per 100 kilograms of body weight and manure has an economic value of 75 shillings per ton (see Appendix I).

[f]Average monthly milk production @ 1/50 per liter.

produces 3.3 tons of manure having a total value in crop production of 248/= per year. Appendix I explains how the quantities and value of manure production were derived.

Lactation milk production is based on average production for each enterprise type as reported in Table 6.5 and summarized in Table 9.1. Milk yields for the 1.6 unit superior managed herd reflect average grade cow lactation milk production plus the increase in production explained by technical variables in the milk production model for grade cows as reported in Table 8.3. All milk production is assumed to be spread evenly over the entire lactation period. The monthly value of milk production for the different types of cows is also given in Table 9.2.

Milk has been valued at 1/50 per liter, slightly below its weighted average sale value of 1/57 based on 1/65 per liter for fresh milk and 1/43 per liter for sour milk quantities actually sold. The 1/50 figure reflects the fact that most milk consumed on the farm is consumed in the cheaper fermented milk form (69 percent).[1]

Investment costs for the five groups of enterprises are detailed in Table 9.3. Each herd begins with sufficient housing to cover the maximum size the herd will attain before being forced to liquidate an animal in order to stay within its respective labor constraint.

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[1]The actual average price weighted by the 1973 quantities of sweet and fermented sales and on-farm consumption comes to 1/51 per liter.

Given the amount of unmet demand for milk at current prices there is little justification for budgeting a decline in the relative value of milk over the ten year period for which the enterprises are compared. However, problems could arise in such places as Machame and Marangu if government policies continue to favor concentration of production for accumulating surpluses rather than dispersal of production to maximize on-farm consumption as well as the value of production.

TABLE 9.3

SUMMARY OF INITIAL CAPITAL INVESTMENT REQUIRED TO ESTABLISH ONE COW ZEBU AND GRADE CATTLE ENTERPRISES IN KILIMANJARO

(TZ SHILLINGS)

Investment	Enterprise and Management Level				
	Zebu	Zebu-Grade	All-Grade		
			Average		Superior
Herd size in equilibrium (C.U.)	1.6	1.6	1.6	2.2	1.6
Maximum permissible herdsize (C.U.) in enterprise simulations	1.9	1.9	1.9	2.5	1.9
Initial purchase of cattle[a]					
37 month old heifer	360	360	---	---	---
22 month old heifer	---	---	1100	1100	1210
Housing[b]	450	610	670	1010	670
Other purchased items[c]	---	14	34	51	100
Total initial capital investment	810	984	1804	2161	1980

[a]Taken from Appendix E.

[b]Taken from Table 7.9 assuming two C.U. capacity for 1.6 unit enterprises and three C.U. capacity for 2.2 unit enterprises.

[c]Taken from Table 7.10 assuming as in b. Average figures are used on all management levels except superior. A full complement of sprayer and utensils has been assumed for the latter.

Housing values per cattle unit are those summarized in Table 7.9 and are fully depreciated over 10 years.

The cost of zebu and average grade heifers are taken from Appendix Table E.1. The cost of grade heifers in superior herds has been increased by 10 percent in line with the higher average prices farmers reported paying for breeding females of this type. Table 9.3 details the actual costs assumed for the initial purchase of heifers.

The cost of other capital inputs is taken from Table 7.10 using the maximum size of each of the enterprises as a basis for establishing the respective costs and assuming a life of five years with zero salvage value at the end of that period. For superior herds, a full complement of sprayer and utensils has been assumed while those for lower levels of management reflect average values as obtained from the respective samples. Though no farm will have one-half of a sprayer, and in this sense the costs assumed are unrealistic, the effect of spraying as measured in mortality rates and milk production are average effects across users and nonusers. It is appropriate, therefore, to reduce costs to a similar basis.

Since the profitability of the cattle enterprise—especially the grade cattle enterprises—is greatly influenced by the sex of the calf, separate simulations were done according to the sex of the first calf. Subsequent calves then alternate sex and the sex of the first calf of the first female offspring is the opposite of the sex of the first calf of its mother.

These two simulations are then averaged to come up with the computational parameters used in the enterprise capital budgets. The procedure gives an expected outcome across all farms on the assumption that the probability of getting a male and female calf is equal. Appendix J contains details on the simulations for one of the enterprises to give the reader a clearer idea of the steps involved and the procedures used.

C. Enterprise Types and Results

The following eight enterprise size/types are analyzed:

1. An all-zebu enterprise which grows through internal reproduction only. All males are grown out to 54 months before sale and cows are sold after the end of their last lactation preceding their twelfth birthday. No other animals are sold. Because of the rather high mortality rates and long calving interval for zebu cows this enterprise type is unable to attain the average herd size of 1.6 cattle units and averages only 1.39 units between years 3 and 9. This enterprise type represents subsistence farmers who have relatively little involvement with the cash economy apart from coffee sales.
2. A 1.6 unit all-zebu enterprise which adds one additional female heifer in year 4 for the case where the first calf of the initial heifer is a male. This forces sale of a two-month old male calf in year 6 and reduces the proportion of males in the herd from .23 found under the first alternative to .16. This compares to .20 for the entire Kilimanjaro zebu herd. This alternative still represents a primarily subsistence-oriented management system that relies on internal reproduction with the occasional addition of a young heifer to raise herd size to a level that more fully utilizes available labor resources. Data on transactions and herd

composition indicate that both management systems are commonly found among zebu cattle producers.

3. A 1.6 unit mixed zebu-grade enterprise that begins with a zebu heifer and crosses all subsequent offspring to a grade bull. Alternative three requires that a male over two years of age be present in the herd at least half of the time between years 3 and 9. Though this reduces profitability it ensures the availability of males for breeding purposes. Reproduction rates for the f_1 and f_2 are sufficiently high and mortality rates sufficiently low as to force the sale of animals in order to stay within the maximum herd size constraint. At the same time the herd is upgraded such that there is an f_3—by Kilimanjaro standards a high grade animal—in the herd by year 10.

4. Another 1.6 unit mixed zebu-grade enterprise but one that retains males only to the extent to which they are increasing in value and are necessary to bring the herd to its maximum permissible size. Thus the ratio of females is as high as it can be under conditions of natural reproduction only. This enterprise presumes the availability of breeding services from bulls held by other farmers or from artificial insemination. The proportion of male cattle units in the herd between years 3 and 9 is .15 as compared to .16 for the entire Kilimanjaro grade herd, .20 for the zebu herd, and .24 for the previous mixed zebu-grade alternative. Both mixed zebu-grade enterprise types represent systems which are common on the mountain, though at the present time the average size of mixed herds is 2.8 cattle units of which 1.3 units are zebu cattle and 1.5 are grade cattle. The 1.6 unit sizes

analyzed here represent what existing zebu farmers, representing about 57 percent of all farm households on the mountain, can aspire to without major changes in their labor and expenditure patterns.

5. A 1.6 unit all-grade herd under average management. Because of the larger size of adult grade cows it will not be possible for average zebu cattle owners to shift to grade cattle unless they can be assured of breeding services from elsewhere. One cow and one calf under six months represent 1.6 cattle units. Thus except for raising one replacement heifer—perhaps taxing available labor resources for one year and doing without a cow for another—1.6 unit grade herds will be essentially milk producers. Feeder calves and very young heifers will be important by-products.

6. A superior managed 1.6 grade cattle enterprise. This alternative uses non-labor input-output relationships found for the 25 percent top producing cows with respect to six month milk production. Labor inputs are those used for the 1.6 unit average grade herd with adjustments to reflect the increased need for forage and labor for milking during the production period of these higher producing animals. It represents the best that a zebu cattle household can aspire to over the next ten years and then only with a very substantial increase in cash inputs and more sophisticated management than it uses at present.

7. A 2.2 unit all-grade cattle herd under average management with a two-year old male in the herd at least half of the time between years three and nine. Maintaining a male in the herd is easier

and less costly in this larger herd but it does reduce returns over what would be possible if reliable bull services were available elsewhere. The 24 percent of the three to nine year period cattle units in this herd which are male compare with 16 percent in the entire Kilimanjaro herd. Thus this represents what we might call a conservative management strategy for existing grade cattle owners.

8. A 2.2 unit grade cattle enterprise under average management with no requirements for males in the herd. This alternative results in only 10 percent of the cattle units in the herd between years three and nine being male, clearly an aggressive management strategy in relation to the population average and one that is only possible in the context of a smoothly functioning artificial insemination program or a friendly, more risk averse neighbor.

Each of these eight alternatives are manually simulated for ten years. The results of the simulations, when inputs and outputs are appropriately priced, summed and discounted, gives a measure of the returns to new investments in each of the selected enterprise types. These measures are necessarily rough because of uncontrollable fluctuations in herd size from year to year and actual average herd size over the period, which though similar, are not exactly the same.

Because of the time it takes to grow from a single heifer to a 1.6 unit herd the ten year results underestimate the returns to ongoing enterprises. To correct for this, a second set of computations involving only years three through ten was made. For this exercise all animals in the herd in the middle of year three were assumed to have been purchased and their cost treated as a capital cost in the first year of a seven year budget. Cattle unit months of life, cattle unit months of production period and months of milk production were then recalculated for year zero and all other inputs and outputs—with the exception of the salvage value of undepreciated capital inputs—remained the same. The results of these shorter capital budgets then reflect the returns to a fully functioning, ongoing enterprise for each respective size/type examined. Additional details and the ten year summary capital budgets for each of the eight enterprises are given in Appendix K.

D. Incentive for Upgrading the Dairy Enterprise

Table 9.4 summarizes the results of the simulated capital budgets and gives the gross benefit cost ratios and the internal rates of return for each one. It also shows the distribution of undiscounted returns between milk, manure and meat, the latter including sales of live animals, salvage of dead animals and the increase in the value of livestock holdings over the period considered.[1]

Turning first to the all-zebu enterprises we note gross benefit/cost ratio's of below .9 for both types and both time periods. The similarity of results between the two types and the two time periods reflects the fact that returns from meat and manure over the growth phase are almost as high as the returns from milk as long as male animals are still in their growth phase. Shifting the composition of the herd toward fewer males does not appreciably alter the overall

[1]The increase in the value of livestock holdings includes the future value of milk production capitalized into the value of females sold during their production period.

TABLE 9.4

PROPORTION OF UNDISCOUNTED SIMULATED RETURNS ARISING FROM MILK, MANURE AND MEAT PRODUCTION; TWO MEASURES OF INVESTMENT WORTH; AND THE PROPORTION OF CATTLE UNITS IN ONGOING OPERATIONS WHICH ARE MALE FOR EIGHT SIMULATED CATTLE ENTERPRISE SIZE/TYPES UNDER TWO DIFFERENT OPERATING ASSUMPTIONS

	Supplemental Heifer	Male Required	New Investments					Ongoing Enterprises					Proportion of Cattle Units in Enterprise Which Are Male	Average Number of Cattle Units in Herd at Year End in Ongoing Enterprise[b]
			Proportion of Undiscounted Returns Arising From[a]			Measures of Project Worth		Proportion of Undiscounted Returns Arising From[a]			Measures of Project Worth			
			Milk	Manure	Meat	B/C	IRR	Milk	Manure	Meat	B/C	IRR		
1.6 Unit Enterprises														
1. All-zebu	No	Yes[c]	.32	.55	.13	.87	7.9	.31	.54	.14	.88	8.9	23	1.39
2. All-zebu	Yes	No[d]	.33	.54	.13	.88	8.8	.32	.54	.13	.89	8.7	.16	1.59
3. Mixed zebu-grade	No	Yes	.33	.41	.25	.95	17.2	.35	.39	.26	1.01	20.6	24	1.59
4. Mixed zebu-grade	No	No	.37	[illegible]	.23	[illegible]	[illegible]	[illegible]	.38	.23	1.03	22.1	.15	1.59
5. All-grade	No	No	.60	.23	.17	1.36	42.7	.62	.22	.15	1.37	50.1	06	1.62
6. Superior-grade	No	No	.70	.15	.15	1.31	43.5	.70	.15	.14	1.33	55.9	10	1.64
2.2 Unit Enterprises														
7. All-grade	No	Yes	.57	.24	.19	1.40	41.6	.59	.25	.16	1.35	45.4	24	2.25
8. All-grade	No	No	.62	.22	.16	1.47	43.9	.65	.22	.14	1.48	54.7	.10	2.21
Mixed zebu-grade, male required, replacing all-zebu with supplemental female (Alt. 3 replacing Alt. 2)[e]						2.44	34.4				2.90	40.4		
Mixed zebu-grade, no male required, replacing all-zebu with supplemental female (Alt. 4 replacing Alt. 2)[e]						3.16	36.3				4.09	45.0		
Overall sample results														
Zebu Cattle[f]													.20	
Grade cattle[g]													.16	

[a]May not add to 1.0 due to rounding errors.

[b]Excluding the last year since the number of cattle units in the herd is measured at mid-year rather than year end.

[c]Mature males are present in the herd because there are not enough females to force liquidation.

[d]Mature males are present when the first calf is a female because there are not enough females to force liquidation.

[e]Based on differences between the total returns, operating costs and investment costs between the two alternatives.

[f]Random sample results.

[g]Composite grade cattle sample results.

returns per unit of expenditure. Increasing the size of the herd does, however, increase total returns to the enterprise.

The low rate of return explains why the zebu herd has been contracting in recent years, though one might expect a more rapid rate of contraction than that which has been occurring if the numbers are correct. It is possible that the value of manure on cereals underestimates its value on bananas. It is also possible that the opportunity cost of labor during the dry season is somewhat overestimated. Though this presents a problem in comparing returns to resources invested in cattle to returns to those resources invested in coffee and other crops competing for farm resources, it does not present serious problems for the analysis of cattle enterprises since all enterprises use very similar amounts of labor and produce similar amounts of manure. It is also possible that actual labor expenditures for gathering grass are overstated since much of the time spent carrying grass during the maize cultivating season doubles with time spent walking to and from the maize fields.

A second noteworthy aspect of the all-zebu herd is the importance of manure in the total benefit stream, accounting for nearly 55 percent of total benefits. Though valuing this output is necessarily difficult, the order of magnitude suggests that stall feeding zebu cattle probably makes most sense where land pressures force intensification causing measures to maintain soil fertility to become important.

The two mixed zebu-grade enterprises come reasonably close to yielding a return equal to the estimated opportunity cost of the resources employed, ranging between 17 and 22 percent on invested capital. For an ongoing herd, the usual case in Kilimanjaro, the upgrading enterprise can even yield a positive net present value if farmers move to eliminate males from the herd and rely on others for breeding services. Currently, mixed herds are much larger than 1.6 units and many of these farmers do have a sexually mature male. But before smaller farmers can begin upgrading with confidence, a more reliable supply of grade cattle semen will have to be assured.

If one assumes that unmeasured returns or utilities account for the large number of all-zebu herds in the population in spite of the relatively low rates of return indicated by the budgets, then upgrading the zebu enterprise becomes a very attractive alternative indeed. In terms of changes in the flow of costs and returns between the mixed and the all-zebu enterprises the additional costs and returns associated with the mixed enterprises though small in absolute amount, yield internal rates of return in excess of 34 percent on the additional investment. More importantly, the benefit cost ratios are well over two and the highest of all the enterprises studied.[1]

One would expect, therefore, a fairly keen interest in upgrading. This interest is readily apparent in Kilimanjaro where the most frequent complaint voiced by non-grade cattle owning farmers against the artificial insemination service is its failure to respond to requests for service from farmers with only zebu cows. Moreover, as the budgets in Appendix K indicate, the rather small increase in operating costs required for the upgrading enterprise is more than offset

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[1]The gross benefit cost ratio is probably a better measure of investment worth for the average farmer in Kilimanjaro since labor is the principal constraint on expanding the stall feeding enterprise and labor represents over 80 percent of total costs associated with the all-zebu and the mixed zebu-grade alternatives.

by an increase in the value of livestock holdings. Thus farmers investing in this alternative have, in effect, an insurance reserve that grows along with their operating investment.

The 1.6 unit all-grade alternatives, effectively possible for the average farmer only if he can rely on an artificial insemination service or another farmer's bull for breeding his cow, are, from the point of view of returns to capital, the most profitable of all cattle enterprises 1.6 units in size. On the basis of the benefit cost ratios, however, the return to total resources is much lower than upgrading an existing zebu enterprise. In fact, given the impact of the non-continuous nature of the data on the actual results attained, there is probably very little difference in the return per unit of capital between these two sets of alternatives.

Investment for the all-grade alternatives is considerably higher when beginning from scratch and the proportion of returns coming from manure is much smaller than for the mixed enterprises. Grade cattle are, as a result, a much more suitable investment for school teachers and other households with important non-agricultural sources of income who may not be able to realize the full value of the manure. For such households capital would most likely be the most important constraint, especially for purchasing grass and operating inputs, and the internal rate of return no doubt gives a good measure of investment worth. On that basis a 1.6 unit grade dairy enterprise, with an internal rate of return of between 40 and 55 percent, is attractive indeed.

Most surprising of all the findings of the survey is the fact that superior managed herds with 44-56 percent internal rates of return do not yield returns on capital that are measurably higher than those available from average management. In terms of total resources, in fact, returns per unit are lower as evidenced by the lower benefit cost ratios. However the fact that the superior herds use many more capital resources and earn a very high return on them is no doubt a very powerful incentive for using improved management practices among households with large cash reserves.

As would be expected, the 2.2 unit grade enterprise, with no male required, yields returns noticeably higher than the 1.6 unit herd, especially using benefit cost ratios as a measure of investment worth. This is because labor costs per unit are lower in the larger herd. Interestingly, the 2.2 unit herd with a male required, with an internal rate of return of 42-45 percent gives returns very similar to those of the 1.6 unit enterprise where no males were required. This suggests that an efficient artificial insemination service available to all farmers may have a substantial positive equity impact in addition to raising aggregate incomes.

E. Potential of the Various Alternatives for Increasing Milk Production

It is clear from the very weak linkages between management practices and milk production among the zebu cattle herd found in Chapter VIII, coupled with the relatively low returns to the resources employed in such enterprises, that zebu cattle alone do not provide a viable alternative for increasing milk production in Kilimanjaro. It is also quite obvious that the increasing difficulty of obtaining grade cattle from Kenya and the very high prices and associated high risk which they present to farmers will continue to constrain increases in milk production from pure grade animals. Moreover, even if such animals were available in larger numbers and credit was forthcoming, past history suggests that it would be only a few wealthy farmers who would benefit.

There is little doubt that upgrading the zebu herd presents the most viable alternative for rapidly expanding milk production in Kilimanjaro. Over 60 percent of all households in the survey have zebu cattle at a given point in time. Current levels of management are not adequate to assure the survival and efficient exploitation of high grade cattle. But farmers upgrading their herds do show evidence of changing their management practices. Moreover, the return to the additional resources required for upgrading is very high and exceeds that of the all-grade enterprise on a total resource basis. Upgrading also eliminates the economic justification for excluding small farmers from grade dairying because of their limited access to additional resources.

The principal constraint on expanding mixed zebu-grade enterprises is the lack of sufficient numbers of grade bulls or a viable artificial insemination service that meets the needs of the mass of small zebu-owning households. Farmers are using the grade bulls that are available but these are limited in number and frequently are low in quality. Yet, every year large numbers of high grade bulls die or are slaughtered to conserve milk for household use and/or sale. Clearly there is much to work with in formulating a dairy development strategy. What has been missing has been a realistic assessment of government capabilities and structures.

CHAPTER X

EXPANDING SMALLHOLDER DAIRYING IN KILIMANJARO

A. The Political Economy Context

Tanzania has committed itself to promoting self-reliance in rural areas, reducing disparities in opportunities and incomes both within and between urban and rural areas, and disengaging from international linkages which restrain a socialist transformation of its economy. Though such aspirations find many sympathetic ears both within and outside of Tanzania, translating them into practice involves concrete actions, the political consequences of which cannot be ignored. These consequences constrain alternative strategies for developing Kilimanjaro's dairy industry.

1. Returns to Milk Versus Coffee Production

This study has not focused directly on the question of the returns to coffee production on the mountain. Until recently milk production was not seen as a viable alternative to coffee. With the introduction of grade dairy cattle, however, this is beginning to change.

The neo-classical analysis of the returns to alternative milk production systems in Chapter IX shows that upgrading zebu cattle yields net returns to the additional resources employed that are considerably above their opportunity cost. Returns from coffee production constitute a portion of that opportunity cost, but so do returns from bananas, maize, beans and other livestock enterprises as well as the availability of household labor. Only a whole farm analysis that simultaneously considers the entire set of resources available to the farm household and the available production opportunities can determine the impact of substituting forage production for coffee on net farm income. At the time of the survey very few farmers were producing forage on mountain land and the state of the art was crude indeed. Consequently it would have been difficult to draw strong conclusions from a study of such farms. Still, 11 of 140 weighted households in the composite grade cattle sample did plant a quarter acre or more of their mountain land in grasses as a source of livestock feed. This represents about 10 percent of the average kihamba holding and suggests that some farmers, at least, found forage production more profitable than coffee.

Of all the enterprises on the farm, coffee is the one most likely to be replaced by forage. Bananas are an important food staple and source of livestock feed and thus an unlikely candidate for replacement. The maize and bean fields in the lowlands cannot produce forage during the dry season when feed supplies are most constraining. It is possible to produce forage in these fields during the rainy season but storage is a problem given the damp, cloudy climate at that time of the year. Grass grown on the mountain homestead, however, can be cut fresh throughout the year thereby maximizing the quality of feed as well as TDN per acre.

To date, direct competition between coffee and dairying for resources has been avoided because of the limited supply of grade cattle and the availability of labor to cut and carry grass from the forest and plains. As the quality and numbers of grade cattle increase, however, and milk production becomes more responsive to improved feeding and management, we can expect more direct competition between the two enterprises for available land and labor.

The magnitude of the benefit-cost ratios obtained for the grade cattle enterprises suggest that under current relative prices between coffee and milk grade dairying can successfully compete against coffee for available resources when these are valued at their average annual opportunity cost. The reader does need to exercise caution in drawing such conclusions from the analysis in Chapter IX alone. Because of taxes and union levies on coffee, farmers receive only 70 percent of the FOB value of their coffee whereas milk produced on small holdings—essentially a nontraded good—is not taxed. About 15 percent of the total FOB value of coffee reflects cooperative union levies for various services, including processing the parchment, and thus represent legitimate costs of production. However another 15 percent consists of development levies, export taxes and District Council cesses [Mhaville, 1966]. These transfers effectively reduce private returns relative to social returns and cause the social returns to enterprises using the same resources to be overstated when prevailing market prices are used to value inputs and output as we have done in Chapter IX.

The magnitude of the distortion caused by using prevailing market prices is not as great as appears at first glance. In the semi-subsistence economy of Kilimanjaro any increase in cash income quickly translates into higher prices for nontraded locally consumed goods. Milk and banana prices rise and fall with coffee prices, the former because it is clearly a superior good and the latter because it is a principal ingredient of the local banana/millet beer.[1] This means that manure also increases in value. Meat prices rise as well though the extent of such a rise is greatly tempered by the ready supply of cattle from the non-coffee producing areas of the country. Thus the benefit-cost ratios of the grade dairy alternatives, though overstated, are probably not so overstated as to give a misleading picture of underlying economic relationships.

A third factor favoring dairying over coffee is the recent widespread outbreak of Coffee Berry Disease on the mountain. By the 1972-73 crop year KILIMO estimated that 25 percent of the coffee in Moshi and Rombo Districts was being lost due to the disease and the infected area was increasing [Regional Agricultural Development Office, 1973]. Chemicals for controlling the disease are very expensive, ranging from 770/= to over 2000/= per hectare [Bujulu, 1973] versus average gross income from coffee on small holdings of about 1400/= at the farm level and 1900/= at the national level, though yields on plots which are properly sprayed are well above average. The heavy spraying in 1972-73 greatly reduced the extent of infestation and the area covered by the special CBD control program was expanded considerably the following year. However costs of this magnitude greatly reduce the attractiveness of coffee unless intensification of production succeeds in increasing yields enough to offset the increased costs. We can only speculate on the extent to which this is likely

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[1] There is little doubt that consumption of beer is highly elastic with respect to income for the average peasant in Kilimanjaro.

to occur but it seems unlikely that farmers will end up with higher net incomes from coffee than before the outbreak unless these inputs are subsidized.

On balance then, the evidence suggests that as opportunities for producing milk from grade cattle expand, competition with coffee for land resources will intensify, at least until such time as milk prices begin to fall. As we pointed out in Chapter V, this may be quite some time in the future.

2. Macro-Economic Effects of Increasing Milk Production

The macro-economic effects of increasing smallholder milk production in Kilimanjaro will depend on how such an increase is brought about and what efforts are devoted to those crops which compete with dairying for resources. Smallholder coffee yields in Kilimanjaro, for example, average only about one-third those on estates, suggesting substantial room for intensification. There may also be some potential for introducing sources of forage that do not compete so directly with coffee.

In the absence of intensification of coffee production or research on new sources of forage, increasing milk production will probably induce a decline in coffee production. This will lower foreign exchange earnings from coffee dollar for dollar. What it does to milk imports depends on the kind of strategy that is adopted for increasing milk production. Maximum savings in foreign exchange expended on milk imports would be obtained if grade cattle were concentrated on the mountain so surplus milk could be collected, and distributed to urban centers where consumption of imported dairy products is highest. Net foreign exchange savings would be reduced if such milk were first processed since most of the plant, equipment and operating inputs are also imported.

A second approach to expanding milk production would be to prevent the build up of pockets of milk production that is surplus to local consumption needs by promoting a more even distribution of grade cattle over the mountain. This would increase agricultural income from milk production over the concentrated alternative by retarding the build up of supplies of milk that could depress local market prices. At the same time, however, much of this increased production would be consumed by households not now purchasing milk and much higher levels of aggregate milk production would be needed to save equal increments of foreign exchange. Thus the choice is between increased farm income, increased consumption of milk and expanded production/consumption linkages within the national economy on the one hand, versus saving foreign exchange on the other. Were available foreign exchange being used to develop an integrated industrial sector capable of bringing about a true structural transformation of the economy this would be a difficult choice.

Of course nothing suggests that if Tanzania needs foreign exchange for industrialization it shouldn't stop imports of dairy products completely and allow consumers to bid up the price of local supplies. This would shift income away from urban consumers which, the government admits, are favored by current policies, and toward milk producers and capital goods industries. Since the former are mostly small holders and the latter are critical for economic transformation the choice would seem to be obvious. That such a policy has not been taken confirms that development policies are more easily articulated than implemented. Thus the social value to Tanzania of producing milk versus coffee, should the choice come to that, depends on the array of policies that Tanzania envisions as acceptable to it and which the country is willing to implement. Such policies can only be decided in the political arena and are, by and large, beyond the scope of this paper.

3. The Local Context

The structure of political and economic institutions at the local level also have an important bearing on what the effects of particular development strategies are likely to be. In Kilimanjaro three factors stand out for consideration: the cooperative movement, organization of agricultural and veterinary extension services, and the patron-client relationship between government leaders and peasants. All three are interrelated.

a. The Cooperative Movement. Since its early days the cooperative movement in Kilimanjaro has been dominated by a class of larger, more successful, commercial farmers. Membership control is weakened by the patron-client relationship encouraged by cooperative leaders vis a vis the less-educated membership. Fears of witchcraft and the knowledge that some of these leaders will extend a helping hand to a grateful client in time of need lead to a great deal of membership acquiescence to policies that favor these elite farmers. Allocation of cooperative society loans for the purchase of grade cattle (which available evidence suggests go unrepaid) and subsidies of the transport of concentrates are but two examples of the way in which this class of farmers enriches itself at the expense of the broader membership. As long as grade cattle and grade cattle services remain scarce, using the cooperatives as a mechanism for allocating them would leave the mass of middle and lower level peasants as residual claimants. The elite would continue to extract economic rents from their investments in grade cattle while peasants have to be content with zebu cattle until rents on grade cattle are reduced to more normal levels.

b. Organization of Agricultural and Veterinary Extension Services. The organization of Ministry of Agriculture extension services also favors elite farmers and discriminates against peasants. The chronic shortage of budget allocations for petrol, transportation and medicines means that farmers who can transport agents or entertain them with beer and other niceties are more likely to obtain medicines or have their calls for service answered. The essentially unscheduled program of activities for veterinary assistants leaves them free to ignore requests from peasants for service with the excuse that they are too busy. Indeed in such a system much time is consumed simply going from one farm to another in rather helter-skelter fashion. It leaves little scope for peasant supervision and control and any effort to create some would be actively resisted by the agents.

c. The Patron-Client Relationship Between Government and Peasants. In spite of all the talk about self-reliance in Tanzania many government leaders in Kilimanjaro still "bring" development to the people and expect them to be grateful for it. Rather than self-reliance, induced dependency is more common. An alliance between cooperative leaders, elite farmers, local government officials and extension agents is very much in evidence. Green [1974], Mbilinyi

[1975] and others have commented on this and have noted the difficulty of overcoming it. Only a program which places a large amount of control over the work programs of extension agents in the hands of peasants is likely to neutralize this alliance and give peasants broader access to public sector resources.

B. The Technical Context

The analysis of the determinants of milk yields for grade cattle in Chapter VIII confirms that variables over which a well-organized extension service can have some control explain about 70 percent of the variation in milk yields between average and high producing grade cows. Moreover, there is a clear tendency for farmers with both zebu and grade cattle to manage the animals differently. This difference suggests that genetic improvement by itself may generate substantial increases in milk production by appreciably reducing calving intervals for the average farmers' cows.

A reliable and predictable supply of high quality semen is an essential ingredient for any program aimed at upgrading zebu cattle. Zebu cows confined in stalls may not exhibit their oestrus periods openly enough or long enough for farmers to catch them in heat in time to get them bred with artificial insemination. However, the fact that conception rates for zebu cows bred to zebu and grade bulls are high [Zalla, 1974] suggests that the quality of the A.I. semen and the way in which the delivery service is organized may be more of a problem than farmers' ability to identify heat periods in time.

There is the additional problem—reported by farmers and confirmed by some extension agents—of artificial inseminators not responding to calls for service from farmers who do not already have grade cattle. This practice is justified on the grounds that the number of inseminators is insufficient to cover zebu cows and any attention directed to them would cause farmers already having grade cattle to down breed their herds in an effort to get their cows in milk as quickly as possible. There is some truth in this contention given the way the system has been operating, but there is also considerable scope for improving operating efficiency for overcoming such problems.

In addition to breeding, feeding is another problem. This is confirmed by the analysis of yield determinants which show marginal value products in excess of marginal factor costs for grain, cash expenditures on grass, frequency of feeding water and salt to grade cows, as well as for the quantity of labor expended carrying forage—presumably also a measure of the quantity of roughage fed. Grain and salt will have to come from off-farm sources and the cooperative societies provide an excellent structure for obtaining and distributing these items. Additional forage will be more difficult to come by and will probably not be forthcoming in adequate quantities for the average farmer until greater forage production can be incorporated into the existing farming system or researchers demonstrate and farmers perceive a greater return to resources employed in forage production than in coffee production. This will probably be quite some time in the future.

In addition to increasing the availability of inputs, farmers need extension advice on how to care for grade cattle, including spraying, feeding, and care of calves. Given the high price of milk it will probably be necessary to offer financial incentives to farmers with good quality male grade calves in order to bring these animals to maturity for breeding purposes.[1] So far, veterinary officials have encouraged the use of local grade bulls only in remote areas that are not accessible to A.I. However, the time has come to acknowledge the problems with the A.I. program by shifting to a more flexible approach until A.I. can be made to function effectively.

C. A Strategy for Developing the Dairy Industry in Kilimanjaro

The nature of Tanzania's stated political and economic objectives suggests that dairy development efforts in Kilimanjaro center around a broad based effort to increase the number of grade cattle by upgrading zebu cattle across the entire coffee/banana belt of the mountain. Such an approach would maximize the income, nutrition and equity effects of increasing milk production, promote self-reliance in rural areas and promote integrated economic development within the national economy as a whole. It should maximize local value added and create a vast reserve of grade cattle that can eventually be transferred to other suitable areas of Tanzania, such as West Lake and Mbeya regions. When milk surpluses do begin accumulating on the mountain serious consideration needs to be given to legalizing direct sale of fresh and fermented milk in Moshi Town and other urban markets while keeping milk processing plants at a size justified by the spontaneous demand for pasteurized milk.

A potential strategy might consist of the following components:

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[1]High milk prices raise the opportunity cost of milk fed to calves and lead to the slaughter of bull calves in an effort to release more milk for sale.

1. Cash payments to farmers with relatively good quality grade animals to encourage them to grow out male animals for breeding purposes. Guaranteed payments of 1400/= per mature bull would be adequate incentive given current returns to grade dairying.
2. Distribution of these high quality males to selected farmers throughout the mountain who demonstrate good husbandry techniques and a willingness to make the bull available to local farmers for breeding purposes. Such farmers would charge a minimal fee which they could keep, with government guaranteeing some minimum level of income. The enterprise budgets indicate that an income of 900/= shillings per year would assure a return on resources equal to that of a grade cow if these farmers were required to purchase the bulls. This would come to around 25/= per pregnancy if the bull serviced one cow per week. Farmers would be quite willing to pay this if they are reasonably assured of a grade pregnancy.
3. Restructuring the A.I. service around a system of roadside crushes that can be partially serviced on foot if necessary. This will reduce the area that can be covered by one inseminator and will concentrate services more. But it will eliminate the excuse for doing nothing when transportation budgets are exhausted. Consequently, it will increase inseminator time in the field and increase the number of inseminations per month.
4. Reduce the training time for inseminators by concentrating on the technique of insemination and handling semen. Leave diagnosis to veterinary assistants. Allow cooperative societies to send their own candidates for training on the condition that KILIMO will provide material support if the society pays the candidate's salary.

5. Increase the ratio of inseminators to veterinary agents so that the latter can service a larger area than the former. In addition veterinary agents should be required to make regular rounds to central points in the morning with afternoons left for farmer requested house calls. As with the inseminators this should be along routes which can be abbreviated should transportation not be available.
6. Allow cooperative societies and selected rural stores to stock veterinary medicines for cash sale to farmers. This will provide a source of supply when ministry supplies are exhausted.
7. Put each veterinary assistant and artificial inseminator under the supervision of a cooperative society. The society should provide a performance bonus in addition to any regular salary the agents might receive from government.
8. Carry out serious research on native and exotic grasses and legumes in order to identify those with the best production capabilities per hectare of land at various altitudes and those which can be intercropped with coffee or bananas or otherwise be integrated into the farming system. Something like Kudzu, a prolific legume, which can grow along fence rows, on houses and trees, perhaps even on coffee trees and banana pseudostems is an example of what needs to be tested.[1]
9. Conduct research on intercropping nitrogen-fixing leguminous forages with bananas and coffee to identify economic combinations

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[1]The prolific growth of Kudzu that has been such a disaster in the southeastern U.S. would be a major asset in Kilimanjaro because of the scarcity of land.

that can increase farm incomes at various altitudes and levels of rainfall.

10. Study the feasibility of using hungry season tuber reserves normally planted along irrigation furrows as cattle feed in years when crop harvests are adequate.

Eventually a dairy expansion strategy will have to incorporate marketing and pricing considerations. The immediate emphasis, however, should be on maximizing on-farm consumption of milk, inter-farm sales of raw milk and, as a result, farm incomes.

The strategy outlined here addresses the principal problems of the supply of semen and forage and gives farmers more control over veterinary services and the supply of other inputs. It maximizes access to bull services and other inputs and should, as a result, have more favorable equity effects than the current limited access program.

D. Further Research

The study uncovered several areas relating to the cattle enterprise and dairying in Kilimanjaro that should be examined more closely. In addition to the forage research already discussed, controlled studies of the relationship between intake of grain, water, salt and other products and milk production are necessary to evolve recommendations to farmers on economic feeding regimes. Researchers also need to explore more fully the reasons for high male calf mortality. High slaughter rates would not be surprising but just why the animals are allowed to die is not clear.

Much more attention needs to be given to goat milk production in Rombo District. At this point breeding research is more important than economic research on existing local goats. But as soon as a sizable number of improved goats become available their potential role in the farming system should be examined. It is quite possible that a goat dairy enterprise makes better economic sense than a cattle enterprise in Rombo District where dry season feed supplies are of very poor quality.

E. Epilogue

This analysis of the smallholder dairy industry in Kilimanjaro has taken a broader approach than one commonly observes in dealing with farm level agricultural production problems. It recognizes that agricultural production decisions can have important macro-economic and political economy implications. It uses neo-classical market economics to analyze some of those implications but emphasizes the importance of going beyond neo-classical theory into social, political and other institutions which are not static in a real world context. Understanding how these institutions operate is an important step in ensuring that the intended results of agricultural production projects will, indeed, be forthcoming.

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APPENDICES

APPENDIX A

APPENDIX A

DATA COLLECTION AND ESTIMATING PROCEDURES

A. Sampling Methodology

The survey area covers the smallholder coffee-banana zone of Rombo and Moshi Districts from about 3000 to 6000 feet elevation on Mount Kilimanjaro. Topography, rainfall, and agricultural productivity in the area are dominated by the mountain peak with distinct patterns of variation according to altitude and direction of the slope. Rainfall is heaviest on the southern slope, gradually diminishing in a northern direction. The northern slope is dry and uninhabited. However, rainfall varies with altitude on all slopes of the mountain as does temperature. Ridges and hills interrupt these general patterns here and there, giving rise to pockets of more or less rainfall, but the overall pattern is remarkably continuous.

A two stage probability sample was employed for the study. The 1967 census enumeration areas served as first stage sample units, being systematically selected with probability proportional to their 1967 household populations. From each selected first stage unit within each of the districts an independent constant size sub-sample of individual households was drawn systematically. From a practical standpoint the systematic sampling procedure adopted can be taken as yielding a representative random sample to which conventional two stage estimating procedures apply.

The systematic sampling procedure used for selecting first stage sample units took account of the continuous variation in rainfall and altitude in the survey area. As a first step the survey area was divided into 12 zones of roughly equal household population ($N_Z = 6364 \pm 19$). Each zone consisted of a vertical slice of the mountain running from the lower boundary of the survey area to the upper boundary (see map on next page). Then beginning at the top of the first zone and moving toward the bottom, all census enumeration areas were listed and a cumulative household listing constructed. After listing all first stage units in zone 1 the listing process continued into zone 2, working from the bottom of the zone toward the top. Zones 1, 3, 5, 7, 9 and 11 were listed from top to bottom and zones 2, 4, 6, 8, 10 and 12 from bottom to top.

The listing procedure ensured that a systematic sample with a systematic sampling interval equal to 1/36 of the household population would include high, medium and low altitude variations within each of the 12 zones. Listing being opposite for contiguous zones, the expected value of the k systematic samples was the mean of the respective systematic sampling interval regardless of where on the 1 to k systematic sampling interval the sampling process began.

Actual selection of the first stage units was done in normal systematic fashion. A random number between 1 and $k = 2121$ was taken and the first stage sample units were those which included the i^{th}, $i + k^{th}$, $i + 2k^{th}$. . . , $i + 36k^{th}$ households as indicated from the cumulative household population listing. Once identified by enumeration area number, maps of the selected first stage units were obtained from census records and the areas delineated on the ground.

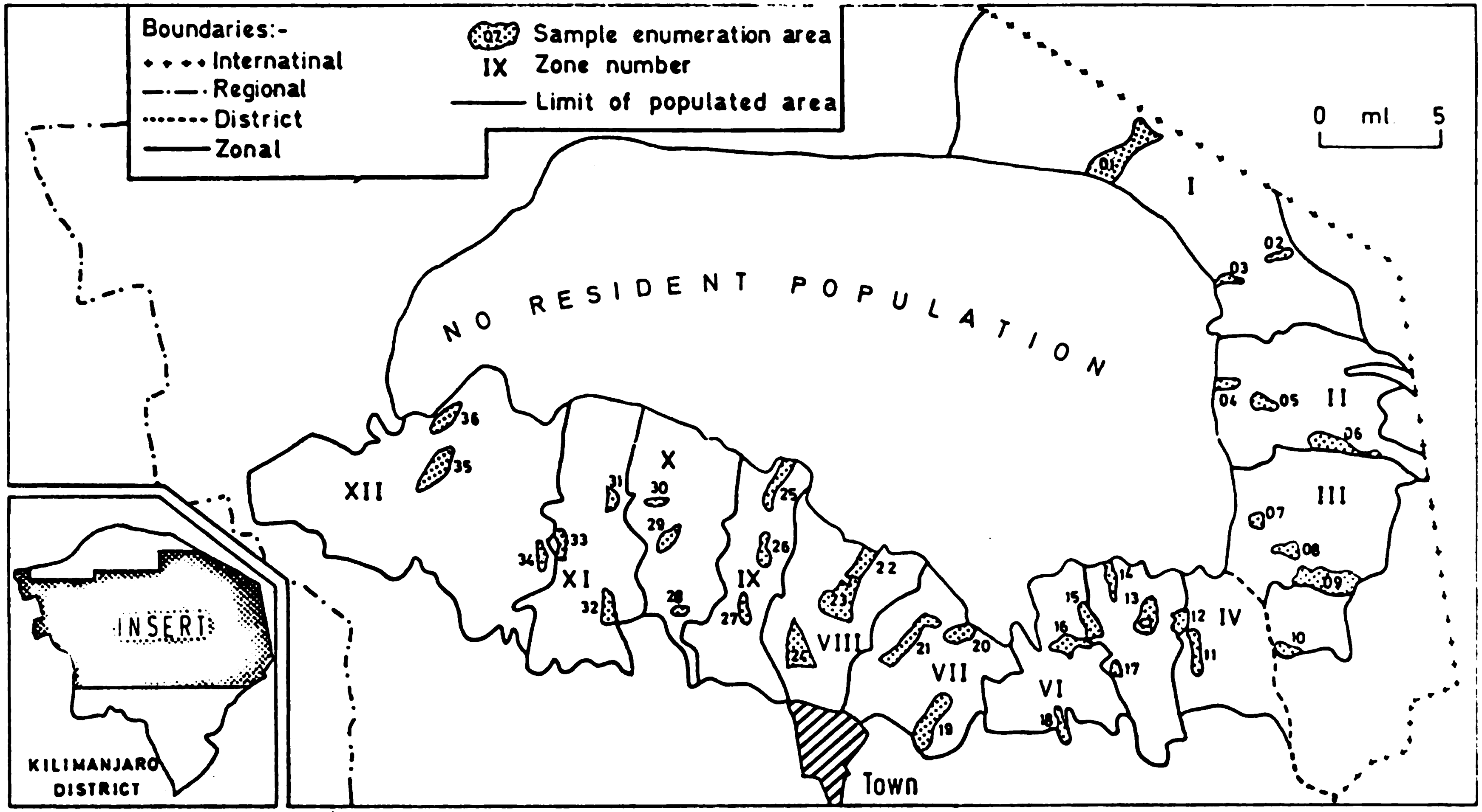

FIGURE A-1

MAP OF SURVEY AREA

All households within each of the 36 selected areas were then randomly listed by ten-cell unit.[1] An independent systematic subsample was drawn from each with the systematic sampling interval given by $\frac{Mi}{m}$, where Mi is the household population listed in the selected enumeration area and m is the desired subsample size, constant within a given district.

Actually there were as many as three separate samples taken from or near each first stage unit. The first, sample A, was a random sample picked systematically as described above. Excluding alternates, it included 8 households in each of the 26 first stage sample units in Moshi District, and 20 households in each of the 10 first stage units of Rombo District—giving roughly 200 households per district.[2]

A second sample, sample B, consisted only of those households in the enumeration area having grade cattle but not drawn in the random sample. The frame for this sample was obtained from ten-cell leaders at public meetings held in each of the selected first stage units. A variable number of households per first stage unit was selected systematically from this list so that a total of at least five grade cattle owners per first stage unit in Moshi District, and

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[1]A local political subdivision including every self-sustaining household. They range in size from 3-30 households but have an expected value of about 10. Each unit has a leader who is the link between the people and the local level administrative structure.

[2]The larger number sampled per first stage unit in Rombo District was in response to a request for district level estimates made by government officials after the listing process had been completed. At that time Moshi and Rombo Districts were created out of the former Kilimanjaro District. It was not possible to increase the number of first stage units because of prior commitments.

10 per first stage unit in Rombo District, would constitute a composite AB sample of grade cattle owners.

A third sample of grade cattle owners, sample C, was drawn in all first stage units where fewer than the 5-10 grade cattle-owning households desired for the grade cattle survey were found. Ten-cell leaders were asked to identify those owners of grade cattle living nearest to the sample area until the desired 5-10 households were obtained.

Only the first of the three samples, sample A, was truly random. This sample is used to provide population estimates and descriptive statistics for local cattle and the area in general. Sample B, the sample of grade cattle owners living in the first stage unit but not selected in the random sample, is random but the sampling frame from which it was drawn appears to have been biased. The third sample, sample C, is clearly biased toward better known, wealthier, presumably more progressive farmers. Unlike for sample B, this was expected. It was intended to provide households with superior management practices and to identify problems faced by innovators who receive little governmental support. As it turned out, samples A, B and C were combined in order to derive estimates for grade cattle. The reasons for this are explained later.

B. Data Collection

Field data were gathered simultaneously from group discussions and individual farm interviews. In each of the selected first stage units one or more group meetings were held with ten-cell leaders, the selected farmers, and any others wishing to attend. The local

T.A.N.U. secretary or ward chairman was usually present at the meeting but there was little evidence of a feeling of intimidation on the part of farmers. The meetings consisted of a brief presentation of the research objectives followed by a question and answer dialogue in which special problems, concerns or constraints relating to the dairy industry in the area were discussed. At the end of the meeting farmers were asked for their approval to conduct the interviews. In Moshi and Rombo Districts no first stage units refused to participate.[1]

The farm survey consisted of a single visit to the sampled households with a follow-up visit to take blood samples from the cattle. Enumerators gathered data on household membership, income indicators, food consumption, cattle management practices, and detailed individual cattle records. The interview lasted 30-45 minutes for households having no cattle and about 1-1/2 hours for households with cattle. Information was provided almost entirely on a recall basis with the recall period varying from one to two days for household consumption and milk production data to as long as several years for cattle records. In general, the length of the recall period required was offset by the significance of the information asked so that reliable answers could be expected. Only for cash inputs did the recall period present serious problems. These could not always be related to a well-defined time period or change in work

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[1] In a companion study in Arusha District about 20 percent of the first stage units refused to participate. These were mostly Waarusha areas where farmers were more reluctant to divulge information on livestock.

schedule. Often the person answering the questions and handling the cattle was not the one who made the purchase.

The survey team consisted of four to six enumerators and one supervisor, apart from the author. The entire team interviewed within each first stage unit before moving on to the next, leaving one or two enumerators to follow up persons not at home and non-respondents. Care was taken to ensure that each enumerator interviewed a cross-section of the combined sample so that subsequent analysis of variance could evaluate enumerator bias. This was a rather costly exercise but absolutely necessary because of continuing problems with supervision in other farm surveys in Tanzania.

The survey was carried out over the period February-June, 1973, with a scattering of repeat and follow-up visits throughout July and August. This corresponded with the period immediately preceding, during and immediately following the long rains. During about half the period ground cover was relatively scarce and during the other half, relatively plentiful. For seasonally-sensitive items measured for the day or week preceding the survey, sample averages should roughly approximate annual averages. For the regression analyses, however, variables for the time of the year during which the survey took place were included.

C. Data Quality

About 15 percent of all farms sampled were checked for enumerator arrival, thoroughness and accuracy. Another 10 percent were reinterviewed by another enumerator either as a follow up of a previous omission or as an intentional check on enumerator error. In

Moshi and Rombo Districts no cases of falsification of questionnaires were found. There was only one case of completing a questionnaire after the fact and one of falsification of itinerary. However, frequent discrepancies (±20 percent or more) in numbers of animals reported, calving and breeding months occurred.

A good deal more discrepancy occurred in milk production on the day preceding the survey and at key points during the lactation period (at one, three, and six months after parturition and at the end of lactation). There was considerable evidence that many farmers were not being honest in reporting milk yields. Where the analysis of the data indicates serious inconsistencies this has been noted in the text and attempts at adjustment have been made.

To check for enumerator bias a one-way analysis of variance was performed on 15 important variables. The results are presented in Table A-1. Six of the variables show statistically significant differences at the 95 percent confidence level. Eleven of the 15 are significantly different at or near the 80 percent level. As a general pattern enumerators one and four consistently fall on the extremes. For enumerator one this is not surprising since this is a composite of several enumerators who worked for brief periods only. Normally they would have been assigned to the more literate and wealthier grade cattle owners until they established their interviewing skills. Their estimates merely reflect this tendency and do not suggest bias.

Enumerator four is generally an outlier. In general, mean estimates for this enumerator reflect his rather timid, unassuming personality. In contrast, enumerator three had a very aggressive,

TABLE A-1

ANALYSIS OF THE VARIANCE IN ENUMERATOR RECORDING PATTERNS

Variables	Unweighted Estimated Means and Standard Errors of Enumerator Recordings						Significance of F Test	Degrees of Freedom
	Unweighted Composite Sample Mean	Enumerator					$(Pr: \bar{X}_1 = \bar{X}_2 = \bar{X}_3 = \bar{X}_4 = \bar{X}_5)$	
		1[a]	2	3	4	5		
Household Variables								
1. Household type income indicator[b]	5.71 (.11)[c]	5.56 (.44)	5.67 (.21)	5.58 (.21)	6.00 (.27)	5.75 (.21)	.8086	667
2. Household possession income indicator[d]	4.9 (.07)	4.8 (.27)	4.7 (.15)	4.9 (.14)	5.1 (.16)	4.9 (.14)	.4568	665
3. Index of progressiveness[e]	9.11 (.13)	9.90 (.67)	9.33 (.29)	8.79 (.23)	9.60 (.30)	8.83 (.21)	.1062	664
4. Calories consumed as a percent of requirements[f]	1.22 (.021)	1.22 (.092)	1.22 (.039)	1.47 (.049)	1.02 (.034)	1.10 (.034)	.0000	623
5. Grams of protein consumed[f]	396 (3)	398 (50)	401 (17)	442 (15)	340 (15)	379 (16)	.0028	629
6. Amino-acid score of diet[g]	149 (3.4)	138 (16.1)	155 (7.6)	172 (7.3)	136 (7.3)	130 (5.1)	.0001	628
7. Man days of labor hired by household[h]	23.9 (2.9)	12.9 (5.8)	24.2 (6.1)	32.2 (6.7)	11.1 (2.8)	23.9 (5.1)	.2222	667
8. Hours of labor per week allocated to dairy enterprise by households with cattle	31.2 (0.8)	37.7 (6.5)	28.4 (1.5)	33.9 (1.2)	23.6 (1.5)	34.6 (1.7)	.0000	511
9. Liters of milk obtained yesterday from all cows by households with cattle[i]	1.18 (.13)	1.76 (.65)	1.64 (.40)	.90 (.14)	.69 (.17)	1.14 (.19)	.1354	512
Cattle Variables								
10. Average age of all cattle (years)	3.31 (.10)	3.94 (.51)	3.57 (.21)	3.42 (.23)	3.44 (.21)	2.80 (.17)	.0239	1008
11. Average age of grade cattle	2.48 (.13)	3.15 (.69)	2.57 (.23)	2.46 (.29)	2.63 (.34)	2.26 (.22)	.6673	407

TABLE A-1—Continued

Variables	Unweighted Estimated Means and Standard Errors of Enumerator Recordings						Significance of F Test ($Pr: \bar{X}_1=\bar{X}_2=\bar{X}_3=\bar{X}_4=\bar{X}_5$)	Degrees of Freedom
	Unweighted Composite Sample Mean	Enumerator						
		1	2	3	4	5		
Cattle Variables (cont.)								
12. Lactation milk prod of Zebu cows (liters)[i]	237 (13)	142 (71)	242 (28)	222 (24)	313 (25)	229 (24)	.1724	241
13. Lactation milk prod of grade cows (liters)[i]	1101 (69)	1584 (494)	1217 (146)	987 (139)	722 (143)	1152 (104)	.2050	114
14. Daily milk yield of grade cows at three months post-parturition (liters)[i]	4.35 (.20)	4.61 (1.16)	4.80 (.39)	4.27 (.47)	3.27 (.34)	4.23 (.31)	.3179	196
15. Proportion of roughage fed to grade cattle as banana leaves	.231 (.006)	.185 (.021)	.229 (.011)	.259 (.015)	.189 (.013)	233 .010	.0149	545
Sample Size								
All households	671	32	183	179	93	184		
With cattle	517	21	144	134	75	143		
With grade cattle	261	9	76	66	36	74		

[a]Enumerator one is a composite of several enumerators who worked for brief periods of time.

[b]Scaled from 1-10. See Appendix F.

[c]Number in parentheses is the standard error of the estimate based on that enumerator's results.

[d]Scaled from 1-8. See Appendix F.

[e]Scaled from 0-23. See Appendix F.

[f]Consumed on the day prior to the interview.

[g]Lowest of the ratios of milligrams supplied over milligrams required for the eight essential amino acids.

[h]In the preceding twelve months.

[i]Net of calf consumption.

perhaps too quick, manner. Both these characteristics come out most strongly on questions relating to food consumption and sensitive areas such as use of hired labor. However, using the composite mean as a standard, these two biases offset each other somewhat. Using the same standard, other enumerators offset the extreme tendencies of enumerator four for other variables. Partly for this reason, partly because it is not always clear which, if any, of the enumerator subsample means are unbiased, and partly because of the impracticality of adjusting different variables for the various enumerator biases reflected in the estimates, all observations have been kept. Dummy variables adjust for enumerator bias in the regression analysis. For population estimates no adjustments for enumerator bias have been made other than for lactation milk production.

D. Sampling Bias

The sampling procedure adopted for the farm survey introduced two sources of bias which are of practical concern for statistical inference: the weights used in selecting first stage sample units; and the quantitative and qualitative difference between grade cattle-owning households included in samples A, B and C. These are discussed in turn.

Two stage estimates from samples in which the first stage sample units are selected with probability proportional to an estimate of size require a correction for the difference between the actual size of the selected first stage unit (1973 household population) and the measure of size used in sampling (1967 household population). In order to avoid introducing a bias it is imperative that the area be precisely defined at both points in time. This was not possible with the census enumeration areas.

Enumeration areas were mapped using footpaths, roads, hollows, forests, the name of household heads, etc. as boundaries. In trying to relocate those boundaries from the census maps we sometimes had considerable difficulty. In a number of cases we were not able to identify the boundaries at all and had to select one ourselves. In others we chose the wrong boundary, a fact which usually became evident only after the field survey team became very familiar with the area in the course of their interviews. As a result of this the areas defined in 1973 are not sufficiently precise to give meaning to the correction factor, $\frac{Mi}{Zi}$,

where Mi = the number of elementary units actually included in the i^{th} first stage unit, and

Zi = the selection probability associated with the i^{th} first stage unit.

A less biased, more efficient and, in fact, more appropriate estimator given the stratification effect of the systematic sampling procedure would be the probability proportional to actual size model, even though 1967 sizes rather than 1973 sizes were used.

Clearly the 1973 population of the sample area is greater than the 1967 population. There also have been internal population shifts as families continue to move from the mountain toward the lower slopes in search of land. But how these shifts affect given Mi is not possible to determine except in a very broad sense. It would be possible to use the systematic sampling procedure to stratify the sample after the fact so that estimates could be calculated and

weighted separately by high, medium and low altitude strata with 12 first stage sample units each. Normal two stage probability proportional to size estimates would then be no more biased for household estimates than the particular strata weights employed. This has not been done, however. The added computational complexity, the small bias which overlooking this population shift introduces[1] and the spurious accuracy such an adjustment would imply given the substantial non-sampling errors reflected in the data all support this simplifying oversight.

A second source of bias is introduced by aggregating grade cattle households from samples A, B and C to derive population estimates relating to grade cattle. Several factors suggest that these samples do not reflect the same underlying populations. On the basis of the random sample, sample A, the estimated proportion of households having grade cattle is .10 (±.02). Yet according to the name lists provided by the ten-cell leaders only 6.6 percent (±1.2 percent) of the households in the survey area have grade cattle. Although this difference is significant only at the 16 percent level, the very small proportions involved coupled with differences in other variables suggest that the two groups do not reflect the same underlying populations. Table A-2 demonstrates this quite clearly.

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[1]A realistic assumption would be that one-half of the population increase occurring in the overcrowded medium and high altitude strata moved to the less densely settled, lower stratum over the six-year period 1967-73. As a result population distribution would shift from the 33-1/3 - 33-1/3 - 33-1/3 percent for the high, medium and low strata implied by the sampling frame to about a 32 - 32 - 36 percent distribution in 1973. It would take very large differences in means and totals for such a shift to have much impact on population estimates.

TABLE A-2

ANALYSIS OF THE MEANS AND VARIANCES OF SEPARATE GRADE CATTLE SAMPLE POPULATIONS

Variable	Estimated Means and Standard Errors of the Mean of Grade Cattle Samples				Significance of F Test ($Pr: \bar{X}_a = \bar{X}_b = \bar{X}_c$)	Degrees of Freedom[a]
	Composite Sample a+b+c	A	B	C		
		Random (Weighted)	Listed Within FSSU (Weighted)	Listed Outside FSSU (Unweighted)		
Household Variables						
1. Household type income indicator	7.59 (.17)[b]	6.71 (.49)	7.75 (.25)	7.67 (.26)	.1424	231
2. Household possession income indicator	5.94 (.10)	5.73 (.25)	5.69 (.15)	6.30 (.15)	.0119	229
3. Index of progressiveness	10.5 (.24)	8.4 (.45)	9.5 (.31)	12.3 (.36)	.0000	230
4. Calories consumed as percentage of requirement	1.26 (.03)	1.10 (.09)	1.27 (.05)	1.29 (.05)	.1789	216
5. Grams of protein consumed	448 (14)	378 (30)	393 (16)	532 (25)	.0000	218
6. Amino acid score of diet	179 (7.3)	137 (15.0)	201 (12.2)	166 (9.4)	.0083	217
7. Man days of labor hired by household	43.0 (5.7)	16.0 (10.7	45.1 (7.5)	48.8 (10.4)	.1953	231
8. Hours of labor/week allocated to dairy enterprise	34.6 (1.2)	32.2 (3.7)	31.5 (1.8)	38.8 (1.8)	.0175	231
9. Liters of milk obtained yesterday from all cows	2.06 (.28)	1.57 (.48)	1.55 (.20)	2.72 (.60)	.1217	225
Cattle Variables						
10. Average age of all cattle (years)	2.85 (.13)	3.13 (.35)	2.78 (.19)	2.81 (.20)	.8410	506
11. Average age of grade cattle (years)	2.40 (.13)	2.53 (.4[illegible])	2.40 (.17)	2.35 (.20)	.9110	367
12. Lactation milk production of Zebu cows	233 (21)	255 (61)	266 (33)	190 (29)	.2325	64
13. Lactation milk production of grade cows (liters)	1106 (66)	1393 (34[illegible])	1129 (105)	1050 (83)	.6572	116
14. Daily milk yield of grade cows at three months post parturition	4.36 (.21)	4.57 (.6[illegible])	4.44 (.36)	4.27 (.30)	.8991	179
15. Kilos of grain fed to grade cow per day	.60 (.058)	.83 (.27[illegible])	.41 (.081)	.71 (.081)	.0612	206

TABLE A-2—Continued

Variable	Estimated Means and (Standard Errors of the Mean) of Grade Cattle Samples				Significance of F Test ($Pr:\bar{X}_a=\bar{X}_b=\bar{X}_c$)	Degrees of Freedom[a]
	Composite Sample a+b+c	A Random (Weighted)	B Listed Within FSSU (Weighted)	C Listed Outside FSSU (Unweighted)		
Cattle Variables (cont.)						
16. Age of grade cow at first parturition (years)	2.85 (.10)	2.77 (.18)	2.96 (.19)	2.77 (.12)	.8340	86
17. Number of months since grade cow last gave birth	11.9 (1.0)	9.3 (2.3)	10.9 (1.0)	13.1 (1.8)	.6428	203
18. Length of last lactation (months) for grade cows	10.1 (.4)	11.5 (2.1)	10.2 (.7)	9.9 (.5)	.8336	118
19. Age of last calf at weaning (months) for grade cows	5.52 (.31)	5.86 (1.05)	5.14 (.42)	5.81 (.48)	.7601	136
20. Months between last parturition and first insemination for grade cows	8.5 (.64)	11.0 (3.87)	7.7 (.86)	8.9 (.92)	.3647	91
Household Sample Size						
Actual	261	38	126	97		
Weighted[a]	234	29	108	97		

[a]Weighted samples are used in the above analysis. Differences between weighted household sample size and degrees of freedom are primarily due to the number of cattle per household, the number of cattle having the characteristic in question or don't know responses.

[b]Numbers in parentheses are the standard error of the estimated mean.

Subsample A is weighted in proportion to the occurrence of grade cattle households in the random sample and subsample B in proportion to the number of cattle-owning households indicated by the ten-cell leader listings. Subsample C is not weighted. For each of the nine household variables listed in Table A-2 the differences between the subsample means are significant at the 20 percent level; five of them at the 5 percent level. For five of them the means indicate little difference between subsamples A and B. The means of the other four suggest greater similarity between subsamples B and C, both being quite different from subsample A. In general the data indicate that the level of wealth and sophistication of the subsample populations increase as they become less random—as would be expected.

Interestingly enough, the socioeconomic differences in the respective subsamples does not appear to carry through to cattle management performance variables. The small number of degrees of freedom involved, especially for subsample A, contributes to the insignificance in the difference between the subsample means. But quite apart from this, the means themselves are strikingly similar. Both for this reason and because sample A by itself is too small to yield meaningful results, grade cattle from samples A, B and C have been combined to derive population estimates relating to the cattle themselves. The combined sample is then weighted in proportion to the number of households possessing grade cattle in each of the first stage sample units as suggested by the combined random sample and ten-cell leader listings. Table A-3 indicates that the bias introduced by this procedure is minimal and, in any case, not statistically significant. The differences between subsample A and the

TABLE A-3

COMPARISON OF THE MEANS AND THEIR STANDARD ERRORS FOR ELEVEN CATTLE VARIABLES AS ESTIMATED FROM RANDOM SAMPLE A AND A COMPOSITE GRADE CATTLE SAMPLE

Variable	Sample Means and Their (Standard Errors)		Degrees of Freedom[a]	Significance[b] Pr: $\bar{X}_a = \bar{X}_{com}$
	A	A+B+C		
1. Average age of all cattle (years)	3.13 (.35)	2.98 (.17)	382	.70
2. Average age of grade cattle (years)	2.53 (.41)	2.64 (.18)	282	.80
3. Lactation milk production for Zebu cows (liters)	255 (61)	270 (31)	46	.83
4. Lactation milk production for grade cows (liters)	1393 (349)	1206 (104)	65	.61
5. Daily milk yield of grade cows at three months post-parturition (liters)	4.57 (.64)	4.33 (.27)	117	.73
6. Kilos of grain fed to grade cows per day	.83 (.27)	.58 (.08)	135	.38
7. Age of grade cow at first parturition (years)	2.77 (.18)	2.84 (.11)	76	.74
8. Number of months since grade cow last gave birth	9.3 (2.30)	10.3 (.96)	132	.69
9. Length of last lactation for grade cows (months)	11.5 (2.1)	10.3 (5.7)	66	.58
10. Age of last grade cow calf at weaning (months)	5.86 (1.05)	5.17 (.36)	80	.54
11. Months between last parturition and first insemination for grade cows	11.0 (3.9)	9.0 (.9)	56	.62
Household Sample Size				
Actual	38	261		
Weighted[c]	29	144		

[a]Assuming equal variance. Differences between degrees of freedom and weighted household sample size are primarily due to the number of cattle per household, the number of cattle having the characteristic in question or don't know responses.

[b]Normal approximation.

[c]Weighted samples are used in above analysis.

composite means are generally 10 percent or less with the varying directions of the differences suggesting equal management capabilities between the two sample populations.

E. Statistical Inference

Systematic sampling of first stage units is equivalent to sampling without replacement with probabilities proportional to size. Computation of the variance for estimates derived from this type of sample are complex and impractical for more than two first stage units. Sukhatme [1954] suggests that using the appropriate estimate for two stage sampling with replacement at the first stage, and introducing the usual finite multiplier may be sufficiently satisfactory.

Taking first the general case of sampling first stage units with replacement using probabilities proportional to size, Cochran [1963] gives the following unbiased estimate for population means:[1]

(1) $\hat{\bar{\bar{Y}}} = \frac{1}{n} (\bar{y}_1 + \bar{y}_2 \dots + \bar{y}_n)$

where $\hat{\bar{\bar{Y}}}$ = the estimated population mean derived from a sample of first stage sampling units selected with probability proportional to size;

n = member of the N first stage units in the population included in the sample;

which is simply the mean of the first stage sample unit means. For the case of cattle means where the distribution of cattle does not

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[1]Most of the notation used herein follows, with slight modification, that of Cochran [1963] in his discussion of stratified and two stage sampling.

approximate the distribution of households, the first stage means need to be weighted giving the biased but efficient estimate:

$$(2)\quad \hat{\bar{\bar{Y}}}_c = \frac{\sum_{i=1}^{n} w_{ci}\bar{y}_{ci}}{\sum_{i=1}^{n} w_{ci}}$$

where the subscript c refers to estimates relating to cattle and w_{ci} = the number of cattle type c per household in the i^{th} first stage unit.

For zebu cattle w_{ci} is defined as:

$$w_{ci} = \frac{\sum_{j=1}^{m_j} c_{ij}}{m_j}$$

and for grade cattle:

$$w_{ci} = p_i \frac{\sum_{g=1}^{m_g} g_{ij}}{m_g}$$

where c_{ij} = the number of zebu cattle of type c in the j^{th} household of the i^{th} first stage unit;

m_j = the number of households randomly sampled in the i^{th} first stage unit;

p_i = the proportion of households in the i^{th} first stage unit having grade cattle as indicated by the ten-cell leader listings;

g_{ij} = the number of grade cattle of type g in the j^{th} grade cattle household in the i^{th} first stage unit;

m_g = the number of grade cattle-owning households sampled in the i^{th} first stage unit.

The extent of bias in equation (2) is proportional to the error in the w_{ci}. For zebu cattle, the estimates of the w_{ci} are derived from the random sample and equation (2) is assymptotically unbiased. For grade cattle the estimate would be assymptotically unbiased if the p_i were estimated on the basis of the random sample rather than the combined random sample and grade cattle listings provided by the ten-cell leaders as they are. However, the sample size per first stage unit is sufficiently small in 26 of the first stage units ($n \doteq 9$) and the distribution of grade cattle sufficiently narrow and clustered so estimates of the p_i derived from a random sample of this size would no doubt be highly unstable. For this reason we define

$$p_i = P_{gli} \cdot \frac{P_{gr}}{P_{gl}}$$

where P_{gli} = the proportion of households having grade cattle in the i^{th} first stage unit, according to the combined random sample and ten-cell leader listings;

P_{gr} = the proportion of households in the population having grade cattle based on the random sample;

P_{gl} = the proportion of households in the population having grade cattle based on the combined random sample and ten-cell leader listings.

This should improve considerably the accuracy of the estimates of population totals over either the unadjusted P_{gli} or the first stage unit proportions actually found in the random sample.

The variance of (1) is given by

$$(3) \quad V(\hat{\bar{\bar{Y}}}) = \frac{1}{n} \sum^{N} \frac{M_i}{M_o} (\bar{Y}_i - \bar{\bar{Y}})^2 + \frac{1}{n} \sum^{N} \frac{M_i}{M_o} \frac{1-f_{2i}}{m_i} S^2_{2i}$$

where M_i = the number of elements in the i^{th} first stage unit;

M_o = the number of elements in the population;

$\bar{Y}_i$ = the population mean of the i^{th} first stage unit;

f_{2i} = the second stage sampling fraction in the i^{th} first stage unit;

and

$$S_{2i}^2 = \frac{\sum_{j=1}^{M_i} (y_{ij} - \bar{Y}_i)^2}{(M_i - 1)}$$

An unbiased estimate of (3) is given by:

$$(4) \quad v(\hat{\bar{\bar{Y}}}) = \frac{(1-\frac{n}{N})}{n\,(n-1)} \sum^{n} (\bar{y}_i - \hat{\bar{\bar{Y}}})^2$$

where $(1-\frac{n}{N})$ is the finite population connection factor for first stage sample units.

For cattle, the variance of equation (2) is approximately:

$$(5) \quad V(\hat{\bar{\bar{Y}}}_c) \doteq \frac{1}{nC_o^2} \sum^{N} \frac{C_i^2}{z_i} (\bar{Y}_{ci} - \bar{\bar{Y}}_c)^2 + \sum^{N} \frac{1}{m C_o^2} \frac{C_i(1-f_{2ci})\, S_{2ci}^2}{z_i m_{cj}}$$

where C_i = the number of cattle of type c in the i^{th} first stage units;

C_o = the number of cattle of type c in the population;

z_i = the probability of selecting the i^{th} first stage unit.

An estimate of equation (5), slightly biased, is given by Yates:[1]

$$(6)\quad v(\hat{\bar{\bar{Y}}}_c) = \frac{(1-\frac{n}{N})\, n \sum_{i=1}^{n} w_{ci}^{2} (\bar{y}_{ci} - \bar{Y}_c)^2}{(n-1)\,(\Sigma w_{ci})^2}$$

which is simply the formula for the variance of the weighted mean of a random sample applied to first stage unit means. This is appropriate given the small sampling fraction employed at the first stage (6.3 percent).

F. Computational Compromises

Only a few variances are calculated using the above procedures. Because of the computational complexity introduced by using grade cattle weights which are not derived from the sample itself, weighted random sample estimators were calculated instead. Using fractional counters to weight individual cases in the file, the weighted random sample procedure yielded mean estimates identical to the two stage procedure. Variances, however, would be larger or smaller depending on the absolute value of the relative weights assigned. In an attempt to approximate the two stage estimate of the variance the random sample of 448 households was weighted down to 8 cases per first stage unit for a total of 288. The combined grade cattle sample of 261 was weighted down to 4 per first stage unit for a total of 144 households. Table A-4 compares the results of this procedure to the more appropriate two stage estimators.

[1] Yates, 1960, p. 197.

TABLE A-4

COMPARISON OF WEIGHTED RANDOM AND TWO STAGE ESTIMATES OF THE STANDARD ERROR OF SELECTED POPULATION ESTIMATORS

Variable	Estimated Population Mean	Estimated Standard Error of the Mean: Weighted Random Estimate[a]	Estimated Standard Error of the Mean: Two Stage Estimate[a]
Household Variables			
1. Household type income indicator	5.12	(.141)	(.198)
2. Household possession income indicator	4.56	(.103)	(.136)
3. Index of progressiveness	8.10	(.162)	(.138)
4. Calories consumed as a percent of requirements	1.18	(.030)	(.028)
5. Grams of protein consumed	363	(11.7)	(11.4)
6. Amino score of diet	147	(5.2)	(5.3)
7. Man days of labor hired by household	17.9	(4.1)	(3.7)
8. Hours of labor per week allocated to diary ent. by households with cattle	27.9	(1.24)	(1.31)
9. Liters of milk obtained yesterday from all cows by households with cattle	.46	(.088)	(.096)
Cattle Variables			
10. Average age of all cattle	3.55	(.179)	(.129)
11. Lactation milk production of Zebu cows (liters)	237	(18.3)	(16.1)
12. Average age of grade cattle	2.64	(.177)	(.227)
13. Lactation milk production of grade cows (liters)	1206	(104)	(140)
14. Daily milk yield of grade cows at three months postparturation	4.33	(.267)	(.397)

[a]See the text for a definition of the two methods.

For the nine household variables included in Table A-4, the weighted random sample estimates of the standard error of the mean average slightly smaller than the two stage estimators. Still, the variation is substantial for individual estimates. The cattle variables reflect a much greater variation between two estimates. The weighted random sample estimates relating to all cattle or zebu cattle (derived from the random sample along with the household variables) are about 25 percent larger than the appropriate two stage estimates. Those relating to grade cattle only appear to be about 25 percent smaller than the two stage estimates. Thus standard errors relating to zebu cattle or total cattle are overestimated while those relating to grade cattle are underestimated.

G. Conclusion

In hindsight, there are two areas where the sampling procedure could have been improved which would no doubt have been worth the cost. It would have been preferable to list separately the first stage units in each of the 36 strata defined by the 12 zones and the systematic sampling interval and then draw independent two stage samples from each strata. A great deal more theoretical rigor and flexibility would have been possible in estimating variances. From a practical point of view, however, there is no evidence that it would have made any difference in the results.

A more substantive improvement would have been to conduct a census interview of 150 randomly selected households in the selected first stage sample units (including contiguous units if there were not 150 households in the selected unit). Since the boundaries are not in any case identifiable, the use of census enumeration areas as first stage sample units does little more than serve as a vehicle for identifying a cluster of households more or less representative of the stratum anyway. A census sample of this size, asking nothing more than cattle holdings, would have yielded much more accurate herd size estimates than relying on the ten-cell leaders and selected farmers in the area as we did. The cost would have been substantial, it is true, increasing farmer contact and data collection time by about 50 percent. But it would have made only a marginal addition to tabulation and analysis time which, in the final analysis is where the bulk of survey costs actually fall. It also would have provided an unbiased sample frame from which unbiased estimates relating to grade cattle could have been derived.

APPENDIX B

APPENDIX B

ADJUSTMENTS TO REPORTED LACTATION MILK PRODUCTION

Actual reported lactation milk production net of calf consumption was 239 ($\pm$18) liters for zebu cows and 1,207 ($\pm$104) liters for grade cows on the basis of reported yields at one month, three months, and six months after parturition as well as at the end of lactation. These reported yields embody three types of error. As was noted in Chapter V lactation milk production is probably underestimated by around 28 percent. Partly this is due to underreporting by farmers. But part of the discrepancy arises from the way in which lactation production itself was calculated. Part also arises from enumerator bias.

The formula used to estimate lactation milk yields is as follows:

$$Q_L = 90\left(\frac{Q_1 + Q_3}{2}\right) + 90\left(\frac{Q_3 + Q_6}{2}\right) + 30\,(M_L - 6)\left(\frac{Q_6 + Q_E}{2}\right)$$

where Q_L = lactation milk production (liters)

Q_1 = daily milk production at one month after parturition (liters)

Q_3 = daily milk production at three months after parturition (liters)

Q_6 = daily milk production at six months after parturition (liters)

Q_E = daily milk production at the end of the lactation (liters)

M_L = length of lactation in months

If M_L was less than three or six then appropriate adjustments in the first two terms were made to reflect the fact that the lactation did not last six months. For cows which had not yet completed their most recent lactation the missing production and lactation length figures were taken from the previous lactation. Since cows generally produce less milk in their first one or two lactations and given that a high proportion of cows had calved only once or twice, this procedure exerts an obvious downward bias on estimated lactation milk production.

This bias is probably greater for grade cows than zebu cows since the analysis of yield determinants in Chapter VIII shows the number of times calved not to be significant for zebu cows. However an analysis of variance shows a clear upward trend in mean values for first, second and third lactations for zebu cows, though the number of observations limits the significance of the differences to the 20 percent level.

Turning to an analysis of the variance in lactation milk production as recorded by different enumerators we find one enumerator with an average six month milk production for zebu cows that is over 60 percent higher than the average of all other enumerators, a difference that is significant at the .003 level. For grade cattle the same enumerator recorded an average six month milk production that is only about half that recorded by other enumerators. This difference is significant at the .07 level.

The regression analysis of determinants of six month milk production in Chapter VIII yields values for the enumerator dummy variable which permit adjustment for enumerator bias. Assuming the magnitude of adjustment required in estimated lactation milk production is proportional to the adjustment required for six month milk production the revised estimate for average lactation milk production for zebu cows would decline by about 6 percent to 225 liters per lactation and that for grade cattle would increase by about 3 percent to 1,240 liters to correct for enumerator bias.

On an aggregate production basis the amount by which zebu lactation milk yields are overestimated more or less offsets the amount by which grade cattle milk yields are underestimated. Thus the estimate of annual milk production in Kilimanjaro based on lactation histories as reported in Table 5.1 remains as reported. Only the division of that production between zebu and grade cattle changes.

To get an idea of the adjustment in reported yields necessary to correct for the 28 percent underestimate in overall lactation milk production as discussed in Chapter V, Table B-1 compares estimated annual milk production based on reported production for the day preceding the survey, with that based on reported lactation histories and that based on lactation milk production adjusted for enumerator bias. From the table it is clear from the similarity in estimates for grade cattle that underreporting was more serious for zebu cattle owners. This is not surprising since grade cattle owners are more educated and progressive as a group and less suspicious of researchers. Using the highest estimate for either breed and comparing it to an estimated annual milk production of 12 million liters we get an

TABLE B-1

COMPARISON OF VARIOUS ESTIMATES OF ANNUAL MILK PRODUCTION FROM CATTLE IN KILIMANJARO IN 1973
(1,000 LITERS)

	Total Annual Milk Production	
Basis of Estimate \ Breed	Zebu	Grade
Production on day preceding interview	5856 (893)	4177 (422)
Reported lactation histories	4239 (347)	4293 (345)
Reported lactation histories adjusted for enumerator bias	4000	4400
Estimated actual production	6800	5200
Implied average lactation milk production per cow	380	1470

average shortfall of about 15 percent. Adjusting the already enumerator-adjusted lactation milk production figure, gives an estimated production of 380 liters per lactation for zebu cows and 1,470 liters for grade cows.

The revised figure for zebu cows is not far from what one would expect from zebu cattle selected for milk production and protected from many of the disease outbreaks that ravage extensively grazed herds. The figure for grade cattle is also within the range of expected values considering it represents an aggregation of poorly managed first crosses as well as better managed higher grade animals.

APPENDIX C

APPENDIX C

CATTLE UNITS AND ASSOCIATED LIVEWEIGHTS

Data on the approximate consumption of dry matter by zebu cattle of various weights is given by Pratt and Gwynne [1977] and used to interpolate appropriate age specific values in Table C-1. Estimated liveweights for zebu cattle as reported in Wilson and Clarke [1976] for Sudan, and Miles [c1968] for Kadjiado District in Kenya are also included in the table to establish feeding requirements by age group. No specific weights for zebu cattle held by the Chagga on Kilimanjaro are available. By popular observation the most common type of zebu cattle on the mountain is a dwarf variety, noticeably smaller than the average East African Shorthorn Zebu. However there is continuous movement into the area of cattle from the plains as farmers seek replacements for dead or slaughtered animals. As a result one finds greater than normal size variation among zebu cattle on the mountain.

The size of grade cattle is equally varied. Initially most grade cattle on the mountain were Jerseys. Currently, however, pure Jerseys account for only 19 percent of grade cattle, with Jersey crosses accounting for another 30 percent. Ten percent are Friesian crosses and 35 percent other unidentified (and in many cases unidentifiable) crosses. Chagga farmers do, however, make it a point to avoid large grade animals since such animals are too difficult to

TABLE C-1

AVERAGE LIVEWEIGHT OF ZEBU CATTLE
IN EAST AFRICA BY AGE GROUP

Age of Animal	Average Live Weight (Kilograms)	Approximate Consumption of Dry Matter (Kilograms)[a]
3 months	39[b]	1.2[c]
6 months	65[b]	2.0[c]
0-12 months	66[d]	2.0[c]
none specified	100	3.0
12-23 months	132[d]	3.6[c]
18 months	140[b]	3.8[c]
none specified	150	4.0
24-35 months	189[d]	5.0[c]
none specified	200	5.3
36 months	240[b]	6.3[c]
none specified	250	6.5
over 36 months	274[d]	6.9[c]
48 months	290[b]	7.1[c]
none specified	300	7.3
none specified	350	8.0
none specified	400	8.7
none specified	450	9.3
none specified	500	9.8

[a]Pratt and Gwynne [1977]. Some entries have been interpolated.

[b]Wilson and Clarke [1976].

[c]Interpolated.

[d]Miles [c. 1968].

control when moving them for breeding and other purposes. Moreover, the less than optimal feeding regime restricts average weight gains for grade cattle below their full genetic potential.

In Table C-2 we lay out the average weights assumed for zebu, zebu-grade first crosses and grade cattle by age groups of one year. The average weight for an adult zebu is set at 275 kilograms, the weight reported by Miles [c1968] for adult cattle in the nearby plains. Though Chagga cattle are, on the average, smaller than plains cattle, they are usually better fed and probably attain similar weights. No distinction is made between the weight of male and female animals.

The average weight for grade cattle is imputed based on the relationship between the value of male grade cattle and male zebu cattle as reported in Appendix E. We have assumed that 80 percent of the difference in prices for male animals in the same age category reflects differences in their value as producers of meat while 20 percent is a premium for their breeding potential. Adult weights are still less than 90 percent of those commonly found among Jersey cows in the U.S.

From the estimated and imputed weights in Table C-2 we calculate average consumption of dry matter per day. On the basis of relative differences in this variable, then, we assign relative weights to each age/breed category, counting the adult zebu as a unit of one. Values for the zebu-grade first cross are simply interpolated between the two. The resulting adult zebu equivalent units (referred to in the text as cattle units) are then used to calculate per unit housing,

TABLE C-2

AVERAGE LIVEWEIGHTS, APPROXIMATE CONSUMPTION OF DRY MATTER AND ADULT ZEBU EQUIVALENT CATTLE UNITS ASSUMED FOR ZEBU AND GRADE CATTLE IN KILIMANJARO

Months of Age	Average Liveweight (kgs)		Approx. Cons. Dry Matter Per Day (kgs)		Adult Zebu Equivalent Cattle Units		
	Zebu	Grade	Zebu	Grade	Zebu	F_1 Cross[a]	Grade
.01-<6	40	70	1.5	2.1	.20	.25	.30
6-<12	85	160	2.5	4.3	.35	.45	.60
12-<24	135	270	3.7	6.8	.50	.75	1.00
24-<36	190	390	5.0	8.5	.70	.95	1.20
36+	275	410	6.9	8.8	1.00	1.15	1.30

[a]Equals one-half of value for zebu animal plus one-half of value for grade animal.

labor and input costs. They are also used to estimate the quantity of manure produced by animals in the various age/breed groups.

APPENDIX D

APPENDIX D

DERIVATION OF UNIT LABOR INPUTS FOR VARIOUS SIZES OF ALL-ZEBU, ZEBU-GRADE AND ALL-GRADE DAIRY ENTERPRISES

The labor data in Tables 7.1-7.3 are averages for all animals including cows in milk, young stock, etc. An important part of this labor arises from carrying grass for cows in their production period, i.e. the last three months of pregnancy and the period of lactation. This labor should be allocated to cows specifically since this is, in effect, a variable cost of producing offspring and milk.

Morrison [1956] has published standards for feeding pregnant and lactating cows. Using the lowest of these (318 kgs.) for zebu cows and the actual weight assumed for grade cows in Appendix C, we calculate the ration for milk production and that for pregnancy and express these as a proportion of the maintenance ration. These proportions are then used to deduce the proportion of unit labor inputs for supplying forage which arise from herd maintenance and the proportion arising from pregnancy and milk production for cows. To this we then add labor for milking, expressed on a production period basis (lactation length in months plus three) and get total labor for milk production. In the budgets these coefficients are then accumulated for each cow for the production period and the production period only. The remainder of the time the cows are fed only a maintenance and growth ration and labor coefficients for this are used. The formula for deducing the maintenance and growth component of the ration expressed in hours of labor per week is as follows, using the line letters in Table D-1 for notation:

$$E = J + \frac{(\frac{C}{D} \cdot I \cdot \frac{H}{100} \cdot J)}{B} + \frac{(\frac{3}{D} \cdot I \cdot \frac{G}{100} \cdot J)}{B}$$

$$= J \left[1 + \frac{I(CH + 3G)}{100\ BD} \right]$$

since pregnancy and production requirements are expressed as a percent of maintenance for a whole cow, not a cattle unit. Rearranging and transposing we get as labor for maintenance and growth:

$$J = \frac{E}{1 + \frac{I(CH + 3G)}{100\ BD}} \quad .$$

After solving for J we compute labor for milk production as follows:

$$K = \frac{JI(CH + 3G)}{100\ BD} \quad .$$

Then $K \cdot \frac{D}{L} = M$ allocates labor for production evenly over only the production period. Finally, adding to M the labor required to milk one unit of cow (N)—also spread over the entire production period (O)—we get P, the total hours of milk production labor per week over the entire production period.

The resulting amount of labor required to feed one cattle unit a maintenance ration of forage (J) reflects, as would be expected, considerable similarity between enterprises of the same size. However, cash expenditures for transportation and grass are higher for all-grade than mixed herds and are zero for zebu herds. As a result, the amount of forage supplied per cattle unit in the all-grade

TABLE D-1

COEFFICIENTS USED IN CALCULATING MAINTENANCE AND PRODUCTION PERIOD LABOR FOR ENTERPRISE BUDGETS

	Enterprise and Type of Cow					
	All-Zebu	Zebu-Grade		All-Grade		
Description	Average[a]	F_1[b]	F_2[c]	Average[d]		Superior[e]
A. Number of cattle units in herd	1.6	1.6	1.6	1.6	2.2	1.6
B. Number of cattle units per cow	1.0	1.15	1.3	1.3	1.3	1.3
C. Lactation length (months)	8	9	10	10	10	11
D. Calving interval (months)	29	25	20	20	20	17[f]
E. Total hours per week required for supplying forage	14.7	15.4	16.0	16.3[g]	13.3	17.7[h]
F. Mix production per lactation (liters)[i]	380	750	1100	1470	1470	2220[j]
G. Percent increase in TDN due to pregnancy (3 months only)[k]	73	73	73	73	73	73
H. Percent increase in TDN due to milk production (lactation length only)[k]	25	34	41	54	54	74
I. Proportion of cattle units in herd which are cows	.37	.41[l]	.45	.45	.45	.49[m]
J. Implied weekly labor requirement for supplying forage for maintenance	14.0	14.3	14.4	14.4[n]	11.8	14.4[o]
K. Implied weekly labor requirement for production (hours)	.7	1.1	1.6	1.9	1.5	3.3
L. Production period (C + 3)	11	12	13	13	13	14
M. Labor required for production per week of production period (hours)	1.8	2.3	2.5	2.9	2.3	4.0
N. Labor hours required for milk production per week in milk[p]	2.0	2.3	2.6	3.0	3.0	3.7
O. Allocated over production period $(\frac{NC}{L})$	1.5	1.7	2.0	2.3	2.3	2.9
P. Total hours of milk production labor per week for production period (M + O)	3.3	4.0	4.5	5.2	4.6	6.9

[a]Based on random sample unless otherwise stated.

[b]In general, interpolated between average zebu and f_2 cows.

[c]Average composite grade cattle estimates adjusted for a 1.6 cattle unit herd size unless otherwise noted.

[d]Average composite grade cattle sample estimates unless otherwise stated.

[e]Top producing 25% of grade cows. The figures are adjusted to reflect the smaller herd size. Unless otherwise noted these estimates are based on the 25% highest producing cows in the composite grade cattle sample.

[f]Composite grade cattle sample gave 17 months as the calving interval for superior cows. However this is still quite long and calving intervals much shorter than this are common in many herds.

[g]Computed by adding to the maintenance requirement of the f_2 in mixed herds, itself based on a regression estimate from sample data for grade cattle, implied weekly labor required for production (K).

[h]Computed by adding to the maintenance requirement of the average grade cow implied weekly labor required for production (K).

Footnotes to Table D-1—Continued

[i]Taken from Table 6.5 unless otherwise noted.

[j]This includes only the increased production that is explained by technical variables in the grade cattle regression model given average values for these variables between average and superior grade cows as indicated in Table 8.3 and given average lactation milk production for the two levels of management as indicated in Table 6.5

[k]Taken from Morrison [1956] and expressed as a proportion of the maintenance ration.

[l]Interpolated between the f_2 and the average zebu herd.

[m]Imputed based on reduced calving interval.

[n]Same value as for f_2 since herd is same size and the figure for the f_2 is a regression estimate from the grade cattle data in Table 7.3.

[o]Same value as for 1.6 unit average grade cow enterprise since herd is same size.

[p]Imputed based on labor hours reported for households actually milking a cow and level of milk production.

enterprise is actually about 1.3 hours higher than in zebu herds if those expenditures are divided by the value imputed to family labor.

In addition to labor for grass, labor for carrying water and spraying acaricide needs to be imputed for the superior herds. Appendix Table D-2 compares average values for labor inputs for these two activities for each of the types and sizes of enterprises described in Table 7.4. Some adjustment in labor for carrying water for the f_2 and the average grade enterprise has been made to eliminate anomalies in the data.

TABLE D-2

LABOR INPUTS PER CATTLE UNIT FOR CARRYING WATER AND APPLYING ACARICIDE FOR VARIOUS TYPES AND SIZES OF CATTLE ENTERPRISES IN KILIMANJARO

Variable	Enterprise and Management Level					
	Zebu	Zebu-Grade		All-Grade		
	Average[a]	F_1[b]	F_2[c]	Average[d]		Superior[e]
Number of C.U. in enterprise	1.6	1.6	1.6	1.6	2.2	1.6
Frequency of feeding water per week	4.9	5.8	6.6	7.0	7.0	10.3
Frequency of feeding salt per week	4.4	4.6	4.7	8.4	8.4	12.0
Frequency of dipping per month	0.3	1.0	1.7	2.6	2.6	4.0
Hours of labor expended per week per cattle unit						
Carrying water	.5	.6	.7[f]	.7[f]	.7[f]	1.0[f]
Spraying and dipping	.0	.1	.2	.2	.2	.4[g]

[a]Taken from random sample.

[b]Interpolated between average zebu and f_2 in mixed herd.

[c]Average value for grade cattle in mixed herds unless otherwise stated.

[d]Average value for grade cattle in all-grade herds unless otherwise stated.

[e]Average value for 25% of top producing cows in composite grade cattle sample unless otherwise noted.

[f]Imputed based on frequency of feeding water in relation to zebu since figures in Table 7.3 are not reasonable.

[g]Imputed based on frequency of practice since separate estimate not available.

APPENDIX E

APPENDIX E

CATTLE VALUES BY AGE, SEX AND BREED

Prices for cattle as detailed in Appendix Table E-1 were derived from sale, acquisition and disposition data gathered from both the random and the grade cattle sample households. Most prices refer to an event that occurred over the previous twelve months. However prices for cattle, especially grade cattle were rising rapidly at this time and only aggregations substantially less detailed than those in Table E-1 yield consistent patterns in prices between age groups. For this reason the numbers in the table have been smoothed and interpolated in order to eliminate anomalies and cover gaps.

TABLE E-1

1973 CATTLE VALUES IN KILIMANJARO BY AGE, SEX AND BREED (TZ SHILLINGS)

Age in Years	Zebu Male	Zebu Female	Grade Cross[a] Male	Grade Cross[a] Female F_1	Grade Cross[a] Female F_2	Grade Pure Male	Grade Pure Female Average	Grade Pure Female Superior
.01- .20	80	80	150	200	250	150	350	385
.21- .33	110	160	225	220	275	225	375	415
.34- .50	140	215	275	260	325	275	425	470
.51- .75	150	220	300	360	450	300	550	605
.76- 1.00	160	245	350	440	550	350	650	715
1.00- 1.25	170	260	375	520	650	375	850	935
1.26- 1.50	180	270	400	560	700	400	950	1045
1.51- 2.00	200	280	450	640	800	450	1100	1210
2.01- 2.50	225	290	550	680	850	550	1200	1320
2.51- 3.00	275	330	600	760	950	600	1350	1485
3.01- 4.00	340	360	650	800	1000	650	1350	1485
4.01- 5.00	400	360	650	800	1000	650	1350	1485
5.01- 6.00	400	360	650	760	950	650	1250	1375
6.01- 9.00	400	350	650	680	850	650	1150	1265
9.01-12.00	375	325	600	560	700	600	900	990
12.01-30.00	350	300	550	480	600	550	700	770

[a] F_1 females are valued at 80 percent of the F_2. F_1 males are valued the same as F_2 males.

APPENDIX F

APPENDIX F

CONSTRUCTION OF PROGRESSIVENESS AND WEALTH INDICES

A. Progressiveness Index

The purpose of the progressiveness index was to identify progressive farmers. Because only two-thirds of all households had cattle the index was constructed from data on seven agricultural practices relating to manure, coffee, maize and beans. (At least 94 percent of all farmers grew at least some coffee, 89 percent some maize and 87 percent some beans.) For farmers who had either no coffee or no maize the value of the index was set at the higher of its calculated value or the mean value for the random sample. Such an adjustment was required for 4 percent of the households in the random sample.

In constructing the index, if a farmer had ever purchased manure the index was incremented by two. For each of the remaining six practices, the index was incremented by one if a farmer had ever used it. If he used it or expressed a clear intention to use it during the current season the index was incremented by two. However, if the farmer expressed a conditional intention to use the practice during the current season the index was incremented by only one. Finally if he had a good agronomic reason for not using it the increment was two. Thus for six of the seven practices one point was added if the practice were ever tried and another one to two points were added depending on whether the farmer used or intended to use the practice this season or had a good reason not to use it.[1]

The seven practices and the maximum number of points related to each were as follows:

Practice	Maximum Increment
Purchase manure	2
Plant improved beans	3
Plant hybrid maize	3
Apply chemical fertilizer to maize	3
Apply chemical fertilizer to coffee	3
Prune coffee	3
Apply copper fungicide to coffee	3
Apply insecticides to coffee	3

Thus the index is weighted most heavily toward coffee and practices which are common and less heavily toward planting improved beans and purchasing manure, practices which are much less common.

The maximum value the index could have was 23. Its average value in the random sample of all households was 8.3 and its maximum

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[1]Good reasons included such things as not planting hybrid maize because a particular field did not receive sufficient rainfall for it to do as well as local varieties or not spraying coffee with copper fungicide because it reduced resistance to the new strain of CBD.

was 18. In the composite grade cattle sample some households attained an index of 23 and the average in that sample was slightly over 10. Overall, the index as constructed did not do a very good job of discriminating farmers as can be seen from Appendix Table F-1. This was due to the low incidence of non-coffee practices for which information was solicited and widespread sophistication in caring for coffee.

B. Wealth Index

The wealth index is a composite of two separate indices, one relating to household possessions and one relating to house type. The index relating to house type used data on the type of roof, type of walls, type of floor, and type of outside finish on the main dwelling of the household. The index relating to household possessions used a Guttman scale to identify a set of possessions that were effective in discriminating the population, and then attached an equal weight to each of the components. The two indices were then added together after adjusting each index to a base of 10, giving equal weight to each in the overall wealth index.

1. Housing Index

The housing index was constructed by incrementing the index as follows:

Component	Increment
Type of roof	
Tin sheets	2
Scrap tin or tar paper	1
Grass in whole or part	0

TABLE F-1

PERCENTAGE OF RANDOM SAMPLE POPULATION HAVING A PROGRESSIVENESS OR WEALTH INDEX OF THE VALUE SPECIFIED

Index Value	Percent of Population: Progressiveness Index	Percent of Population: Wealth Index
1-2	2	1
3-4	3	5
5-6	12	11
7-8	56	11
9-10	8	27
11-12	14	17
13-14	4	10
15-16	0	9
17-18	1	5
19-20	0	4
20+	0	-
	100	100

Component	Increment
Type of walls	
Cement or rock	3
Wood or mud and poles with cement plaster	2
Mud and poles	1
Grass or dirt	0
Type of floor	
Cement	2
Wood	1
Dirt	0
Type of finish	
Paint or cement	2
Manure	1
None	0

The total index calculated in this way could range from zero to nine. The very large proportion of houses with tin roofs, mud and pole walls, dirt floors and a manure finish on the exterior reduced the ability of this variable to discriminate between large numbers of farmers.

2. Household Possession Index

The set of possessions used in this index had a coefficient of reproducibility of .92 and a coefficient of scalability of .69 using Guttman scaling techniques. The index was constructed by adding one point for each of the following possessions: two or more blankets, one or more chairs, one or more tables, one or more lanterns, one or more metal beds, one or more foam mattresses, and one or more easy chairs. It thus had a range of 0-7 and was quite effective in discriminating the population.

3. Wealth Index

To create the household wealth index (W) the house type index (H) was combined with the possession index (P) in the following way:

$$W = (H + 1) + (P + 1) \cdot 1.2$$

This generated a wealth index of 1-20. This index had a mean value of 10.6 in the random sample and ranged from 2-20. As can be seen from Appendix Table F-1, it gave a reasonably good spread of farmers, especially as compared to the progressiveness index.

APPENDIX G

APPENDIX G

MEAN VALUES, STANDARD DEVIATIONS AND SUMS OF SQUARES FOR THE ZEBU AND GRADE CATTLE MILK PRODUCTION MODELS

Not all sample observations could be used to estimate the milk production model. For many cows, no milk production figure was available. For some, mean values for age of calf at weaning and cash expenditures on grass had to be imputed in order to increase the number of observations. All households for which labor used for acquiring grass, cash purchases of grass or amount of grain fed exceeded the mean value for these variables by three standard deviations or more were removed. In the zebu model cows whose milk production exceeded the population average by the same amount were removed. Outliers were not a problem with other variables. Table G-1 gives mean values and standard deviations for the zebu model. Table G-2 gives them for both Rombo and Moshi Districts' grade models. Table G-3 gives the summary statistics for all three models.

TABLE G-1

MEAN VALUES AND STANDARD DEVIATIONS FOR VARIABLES EXPLAINING VARIATION IN MILK PRODUCTION DURING THE FIRST SIX MONTHS OF LACTATION FOR ZEBU COWS

	Variable	Mean	Standard Deviation
Q_{mz}	Milk production (liters)	172.6	112.7
S_f	Frequency feeds salt (times/week)	4.91	5.20
W_f	Frequency feeds water (times/week)	4.18	4.65
A_w	Calf age at weaning (months)	5.59	1.27
E_n	Enumerator dummy	.163	.371
C_g	Expenditures on grass (shillings)	.95	3.78
P_b	Proportion from bananas	.335	.195
P_p	Proportion planted (grass)	.043	.076
G_f	Frequency of grazing (times/week)	.948	2.25
G_r	Kilos of grain	0	0
B_n	Times given birth	2.08	.851
L_g	Labor for grass (hours/week)	13.5	8.10
P_g	Progressiveness (1-23)	8.30	2.71
W_l	Wealth (1-20)	2.39	.356
A_h	Age of household head (years)	50.6	15.5
E_h	Education of household head (years)	2.62	2.75
E_a	Agricultural employment dummy	0	0
A_{lt}	Altitude (meters)	4568	774
A_{sp}	Aspect (degrees)	166	45.7
$A_{sp}2$	Aspect (squared)	29667	14931

TABLE G-2

MEAN VALUES AND STANDARD DEVIATIONS FOR VARIABLES EXPLAINING VARIATION IN MILK PRODUCTION DURING THE FIRST SIX MONTHS OF LACTATION FOR GRADE COWS BY DISTRICT

	Variable	Moshi		Rombo	
		Mean	Standard Deviation	Mean	Standard Deviation
Q_{mz}	Milk production (liters)	751	480	687	432
S_f	Frequency feeds salt (times/week)	8.15	5.70	7.98	5.23
W_f	Frequency feeds water (times/week)	6.85	3.41	7.06	3.54
A_w	Calf age at weaning (months)	4.66	1.99	4.51	1.73
E_n	Enumerator dummy	.187	.393	.065	.248
C_g	Expenditures on grass (shillings)	81.2	135	29.2	54.6
P_b	Proportion from bananas	.231	.141	.269	.129
P_p	Proportion planted grass	.127	.109	.103	.112
G_f	Frequency of grazing (times/week)	1.20	2.43	.871	2.12
G_r	Kilos of grain	.572	.921	.429	.606
B_t	Times given birth	1.97	.856	1.97	.758
L_g	Labor for grass (hours/week)	11.1	6.26	10.4	6.10
B_d	Breed	.157	.367	.307	.465
P_g	Progressiveness (1-23)	10.1	3.61	12.1	4.18
W	Wealth (1-20)	15.0	4.07	14.2	3.74
A_h	Age of household head (years)	52.2	17.0	50.7	14.5
E_h	Education of household head (years)	5.23	3.65	5.02	3.57
E_a	Agricultural employment dummy	.069	.255	.081	.275
A_{lt}	Altitude (meters)	4626	570	4958	597
A_{sp}	Aspect (degrees)	185	37.7	103	18.6
A_{sp}^2	Aspect (squared)	35604	14096	10951	3782

TABLE G-3

SUMMARY STATISTICS FOR ZEBU AND GRADE COW MILK PRODUCTION MODELS

Statistic/Description	Model and Incremental Variable Set								
	Zebu			Grade					
				Moshi			Rombo		
	Technical	Management	Institutional	Technical	Management	Institutional	Technical	Management	Institutional
R^2	.26	.30	.31	.59	.66	.76	.15	.34	.40
Adjusted R^2	.24	.26	.26	.51	.57	.69	.09	.26	.30
Regression degrees of freedom	3	6	7	11	13	15	4	7	9
Residual degrees of freedom	102	99	98	56	54	52	57	54	52
Regression mean square	115649	66887	59230	829331	780361	783802	435151	558147	510564
Residual mean square	9686	9430	9391	113189	98455	71235	169302	138588	130687
F ratio	11.9	7.1	6.3	7.3	7.9	11.0	2.57	4.0	3.9
Significance of the F ratio	.000	.000	.000	.000	.000	.000	.047	.001	.001

APPENDIX H

APPENDIX H

DERIVATION OF THE OPPORTUNITY COST OF FAMILY LABOR IN KILIMANJARO

The farming system in Kilimanjaro has evolved in such a way that coffee, bananas and cereals compete more for land than labor. Except in the northern half of Rombo District, representing about 10 percent of the population of the survey area, and the western quarter of Moshi District, also representing about 10 percent of the population, cereals are not serious competitors with coffee and bananas in the well-watered middle belt. On this portion of the slopes coffee and bananas do better and represent the highest valued use of land. Cereals do better in the drier lowlands where land is also more abundant.

The labor requirements for coffee, bananas and cereals are such that the period of peak labor demand for each occurs at a different time of the year. For cereals it is planting and weeding, occurring during April and May on the southern slope and about three months earlier on the northeast slope. For coffee it is picking time occurring from mid-September to mid-November and somewhat earlier on the northeastern slope. Coffee pruning and banana thinning and trashing are undertaken during the slack periods between the two peaks.

Labor for cattle cuts across all other activity periods and lowers the amount of labor available for each. However, since available land is the principal constraint in Kilimanjaro, cattle provide year-round employment which integrates well with cereals, coffee and bananas. Since farmers must walk to their cereals fields in the plains anyway, the marginal cost of cutting a bundle of grass while there is small. Similarly, since cattle eat banana stems and leaves, the marginal cost of carrying banana feedstuffs to cattle is quite small since the coffee-banana groves usually surround the homestead where the cattle are kept. The same applies to mulching coffee since the same materials are used for mulch and roughage.

Unlike the cattle enterprise, labor inputs for cereals are more equally balanced between men and women. These fields are generally worked as a family. Land cleaning, land preparation, planting, weeding and harvesting are all family activities, though use of tractors for plowing is common in the area. Spraying can be done by either males or females but threshing is primarily a women's and children's activity. Where hybrid maize is grown it is not uncommon for the man to take primary responsibility for the maize and the women for beans.

Coffee and bananas are more the responsibility of males than any other enterprise. Men plant and prune coffee and plant and thin bananas, the most strenuous tasks. Coffee-banana fields are sometimes lightly broken up to make room for beans, cocoyams and other garden crops during the rainy season and this work is usually a joint activity as is weeding and harvesting. But spraying insecticides and fungicides is almost always done by males. Pulping coffee is commonly done by children, if available, or by the man and wife together. Drying and grading is an adult activity, again with no obvious sex-based specialization.

The major determinant of the agricultural wage in Kilimanjaro appears to be coffee income, not just because coffee competes for labor at picking time but also because higher coffee incomes provide the means of substituting hired labor or tractor power for family labor on cereal crops, thereby reducing family drudgery. In other words, the marginal propensity to consume leisure from increments in income is positive and substantial.

Data gathered on daily wage rates showed little difference between rates for land preparation, weeding and other uses. Rather, farmers vary the number of hours worked in a day. Most commonly, however, wages in Kilimanjaro are based on a piece rate system that makes reduction to a least common denominator difficult. At the same time, the amount of time spent getting to and returning from cereals fields can be a substantial portion of the total amount of time (as much as 35 percent) expended by a hired laborer. Normally the laborer himself bears thic cost but it can't help but be a factor in negotiation.

The average daily wage for males as reported in the random sample was 5.46 shillings ($\pm$.10) and for females 4.16 ($\pm$.54). Weighting the average labor inputs for maintenance and production detailed in Table 7.4 by the time for which each input is required and the proportion supplied by women gives an average of 67 percent for the all-zebu and 70 percent for the superior all-grade herds as the proportion of total labor supplied by women. Assuming that:

1) Adult males and females are fully employed in agriculture for six months of the year with an opportunity cost equal to the average daily wage for each.

2) The opportunity cost of male and female labor during the rest of the year is only one-half as great as during the agricultural production season.

3) Overall 70 percent of all labor for the cattle enterprise is supplied by women:

then the weighted average daily wage for the cattle enterprise can be computed as follows:

$$\text{weighted average wage} = \frac{\sum_{i=1}^{2} \sum_{t=a}^{n.a} W_i P_i R_{ti}}{2}$$

where W = daily wage for labor during the agricultural season

i = sex, one if male and two if female

P = proportion of total labor supplied by i with $\Sigma P_i = 1$

R = opportunity cost of labor relative to the agricultural season where the limit t=a refers to the agricultural season and n.a to the non-agricultural season.

This gives a weighted average daily wage of 3/41 shillings or 43 cents per hour assuming an eight hour day. Since labor inputs do not vary substantially over the year this value is then imputed to all family labor used in the cattle enterprises with no further regard to its sexual composition or temporal distribution.

APPENDIX I

APPENDIX I

THE ECONOMIC VALUE OF MANURE

Stout and Loudon [1976], Rose, Loudon and Stout [1979], Laak [1970], Turk and Weideman [1945], and Bene _et al_. [1961] cite data from various sources indicating that dairy cattle fed under American conditions produce around 27 metric tons of manure per 1,000 kilograms of liveweight per year while beef cattle produce approximately 22 tons. The moisture content of fresh cattle manure ranges from 78-86 percent, the lower bound more frequently cited for beef cattle. About 30 percent of total manure is excreted as urine which contains almost 50 percent of the total plant nutrients in the manure.

The amount of bedding provided to absorb excess moisture is an important determinant of the proportion of total nutrients which can be salvaged for agricultural use. Turk and Weideman [1945] show that the ability of bedding materials to absorb moisture varies widely, ranging from 4-7 times its weight for peat to 2-3 times its weight for straw and cornstalks. Moreover, on a pound for pound basis, most straw and grasses used as bedding materials have more pounds of plant food per ton than are contained in average farm manure. Assuming: (1) nutrients in the bedding mixed with manure offset nutrients lost due to drainage of excess urine; (2) the more restricted feeding regimes of cattle in Kilimanjaro reduce manure production per kilogram of liveweight by one quarter in comparison to standards for

American beef cattle, and (3) one quarter of nutrients available in manure are lost through poor handling techniques; then cattle in Kilimanjaro produce the equivalent of 12 tons of first quality manure per 1,000 kilograms of body weight.

The value of manure as a fertilizer varies greatly depending on storage conditions and application procedures. From the point of view of major nutrients, one ton of manure is equivalent to 50 kilograms of 10-2-10, though the value of increased yields from the application of manure often exceeds the fertility value of the manure [Bene et al., 1961]. At the same time, manure exposed to rain and sunlight for six months may lose more than half its fertilizer value [Turk and Weideman, 1945].

Turk and Weideman [1945] report an increase of 115 kilograms of grain per metric ton of manure applied on a Michigan sandy loam preceding corn in a three year rotation of corn, barley and wheat when manure was applied at a rate of 17 tons per hectare. In another Michigan experiment Bene et al. [1961] report an average increase of 21 kilograms of small grains and row crops per metric ton of manure when manure was applied at the rate of 22 tons per hectare preceding the small grain crop in a two year rotation. In this experiment 225 kilos per hectare of superphosphate each year were added to the manure, so the increase in grain production is not just due to the manure.

In an experiment in Northern Cameroon IRAF [1976] reports a 2.87 tons per hectare increase in maize and a 2.18 tons increase for sorghum over control plots when manure was applied at the rate of 50 tons per hectare. This comes to 57 kilograms of maize or 44 kilograms of sorghum per ton of manure. In addition to increases in grain yields, the IRAF experiment obtained an average increase in straw yields over control plots of three tons for maize and 7.5 tons for sorghum. It should be noted that this experiment took place during an exceptionally dry year. Though this accentuates differences between manured and non-manured plots, it also points to the important role played by manure as a risk-reducing, output-increasing method of coping with rainfall uncertainties.

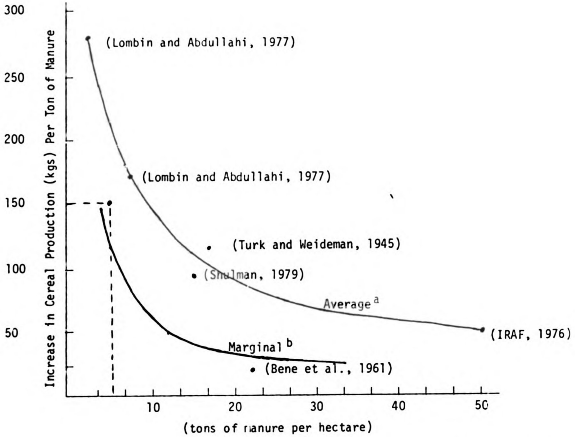
In Northern Nigeria, Lombin and Abdullahi [1977] report average increases of 278 kilograms of sorghum per metric ton of manure when applied at the rate of 2.5 tons per hectare over a 15-year period and 170 kilograms per ton when applied at a 7.5 tons per hectare rate. This same experiment showed that these differences widened with the passage of time as yields on manured fields increased while those on control fields declined, especially at the higher rate of application. During the last three years of this experiment, for example, the 2.5 ton rate of application gave an increase of 494 kilograms of sorghum per ton of manure over the control while the 7.5 ton rate gave an increase of 360 kilograms per ton over the control. These large increases are attributable at least in part to the fact that manure was incorporated deeply into the soil at the time of application, thus avoiding nitrogen losses due to volatilization of ammonia gas.

Shulman [1979] reports a seven year experiment in Mali which gave an increase in cotton, sorghum and peanut production of 93 kilograms per ton of manure when applied at a 15 tons per hectare rate preceding cotton in a cotton, sorghum, peanuts and fallow rotation.

The results of these studies are plotted in Figure I-1. The upper curve in Figure I-1 traces out the average increase in cereal production per ton of manure at various levels of application, though clearly, the parameters of each experiment are different. The lower curve essentially traces out the marginal physical product of manure and is deduced from the average curve. The experiment cited by Bene et al. [1961] appears to lie outside a more theoretically-shaped, manually-approximated average increase curve, possibly due to higher fertility of both the test plot and the control plot. Though not carried out under soil, climate and cropping conditions similar to Kilimanjaro, these data provide clear evidence of the economic value of manure. Overall they suggest that farm level cereal production increases of 150 kilograms per ton of manure when applied at rates below five tons per hectare over a period of time are quite reasonable. This is the general rate of application in Kilimanjaro.

In Kilimanjaro manure is used on bananas, not maize. Coffee, which is almost always intercropped with bananas, benefits both from residual nutrients from the manure as well as from the greater volume of banana stems which are used as mulch for both bananas and coffee. Cattle benefit as well from their own manure supplies since they and small ruminants consume a good part of the banana leaves. Obviously, more vigorous banana stem growth generates more readily available cattle forage.

Like cereals, a steady supply of nitrogen is essential for optimum yields of bananas [Acland, 1971]. Acland indicates that four ounces of ammonium sulfate per stool have been shown to be an economic application. Nitrogen is also the most important element in coffee



[a]The average increase referred to here is not an average physical product curve since it is defined as the $\Delta y/q_m$ where Δ_y refers to the change in output and q_m is the total quantity of manure applied. Only if output were zero in the absence of manure would this curve equate with an average physical product curve.

[b]The marginal increase referred to here depicts the marginal physical product of manure in producing cereals. It describes the $\Delta y/\Delta q_m$ at various levels of q_m. This curve reflects a total physical product curve that is in Stage II of the production function.

FIGURE I-1

AVERAGE AND MARGINAL INCREASES IN CEREAL PRODUCTION PER TON OF MANURE AT VARIOUS RATES OF APPLICATION AS INDICATED BY SEVERAL EXPERIMENTS IN MICHIGAN AND AFRICA nutrition. Requirements vary between 90 and 155 kilos of nitrogen per hectare per year, depending on yields. Like bananas, coffee benefits most from a more evenly distributed flow of nitrogen than do cereals. It also benefits greatly from mulching.[1]

Since we have no available data on the actual yield response of intercropped bananas and coffee to applications of manure under farm conditions we can only speculate on the value of manure to the Kilimanjaro farming system. One thing is clear, however, though many farms in Kilimanjaro have maize plots near their cattle sheds, few, if any, apply the manure to their maize. This would suggest that the economic value of manure applied to bananas is greater than when applied to maize. It does not seem unreasonable, therefore, to use the economic value of 150 kilograms of maize as a minimum estimate of

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[1]Acland [1976] reports that most experiments have shown that applications of organic manures to established coffee give no positive responses except in unusual circumstances. Wallace [1968] summarizes results of experiments carried out at the Lyamungu coffee research station in Kilimanjaro which shows rather sharp decreases in coffee yields as the density of banana stools increases. These experiments were carried out under estate conditions, however, and concerned the impact of intercropping on coffee yields rather than the economic output of intercropping coffee and bananas together. Sykes [1959], on the other hand, showed that in spite of declining coffee yields, farmers increased total income by intercropping coffee and bananas. The agronomic interactions between coffee, bananas and manure in Kilimanjaro are very complex. Rainfall varies with altitude, as does sunlight. As the manure trials from the Cameroon show, manure provides some protection against shortages of rainfall which occur more frequently on the lower slopes of the mountain. So does the density of bananas since bananas provide shade and mulching materials, though they may well increase evapotranspiration. In the middle and upper belts the lower amount of sunshine turns shade from an asset to a liability as far as coffee is concerned. Still, from an economic perspective this does not rule out bananas, it only raises their opportunity cost in terms of coffee. At the same time, banana yields are highest where coffee yields are also highest due to the abundant rainfall. Undertaking field trials to determine the effect of all these variables under farm conditions would be a formidable task indeed.

the value of one ton of cattle manure applied on a continuous basis to banana groves in Kilimanjaro when applied at rates below five tons per hectare. On this basis, using the average maize price prevailing in local markets in each of the 36 first stage sample units in 1973, the value of one ton of manure in Kilimanjaro is 75/=. This is the value used in the analysis.

APPENDIX J

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APPENDIX J

SAMPLE ENTERPRISE SIMULATION

Using the reproduction and mortality coefficients detailed in Table 9.1 the growth of each herd was projected out ten years. The probability of a calf being born was simply the probability of its mother being alive at the time of its expected birth. The probability of being alive, or survival probability as we refer to it, is equal to one minus the probability of having died by the date in question. The probability of having died is simply the product of the annual mortality rates or probabilities according to the age, sex and breed of the animal, and the probability of the animal being alive at the beginning of the year in question.

Apart from the mortality and survival probabilities, cattle unit months of life and cattle unit months of production period are calculated for each month for each animal using the unit value appropriate for its age/breed category as listed in Appendix Table C-2. The monthly values in a given year are summed for each animal. These are then multiplied by the animal's survival probability for the year and further summed across all animals in the herd to get cattle unit months of life and cattle unit months of production period in a given year for the herd. Months of milk production are also multiplied by the individual cow survival probabilities and summed across the herd to get the actual months of milk production for the particular year in question.

To calculate the value of animals which have died we multiply the mortality probability for a given animal in a given year by its survival probability the preceding year. This yields a mortality realization probability which is then multiplied by the average meat value[1] of the animal for the year in question. One half of this value, then, is assumed to be value realized from the consumption or sale of meat from dead animals.

Finally, animals which are sold are valued in the year of sale at the value appropriate to their age, sex and breed as listed in Appendix Table E-1, multiplied by their survival probability up to the period of sale.

As discussed in Chapter IX, two simulations were made for each enterprise, one assuming the first calf was a female and another assuming the first calf was a male. The results of each was then transferred to a summary sheet from which the average of the two simulations are derived to get the actual computational parameters found in the budget summaries in Appendix K. Appendix Table J-1 summarizes the results of the simulations for one of the mixed zebu-grade enterprises. Tables J-2 and J-4 list the individual animals for the herds representing a female calf first and a male calf first respectively while Tables J-3 and J-5 show how the salvage value of animals which died under each assumption were derived.

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[1]Average meat value is defined as the value of an equivalent aged male animal, or the value of the female animal if it is less than this, at the midpoint of the time period for which the mortality realization probability applies, usually the midpoint of the year.

TABLE J-1

SUMMARY SHEET FOR A SIMULATED, 1.6 UNIT, MIXED ZEBU-GRADE CATTLE ENTERPRISE WITH REQUIRED PRESENCE OF A MATURE MALE IN THE HERD

DESCRIPTION			YEAR 0	1	2	3	4	5	6	7	8	9	10
Total Cattle Units in Herd at Year End	FCF[a]		1.00	1.13	1.42	1.60	1.84	1.70	1.43	1.87	1.48	1.29	1.47
	FCM[b]		1.00	1.13	1.34	1.46	1.74	1.13	1.38	1.66	1.86	1.78	1.56
$(\sum_{f=1}^{3}\sum_{i=1}^{n} CUVEOY_{fi} \times SPFY_{fi})$[c]			1.00	1.13	1.38	1.53	1.79	1.42	1.41	1.77	1.67	1.54	1.52
Total Cattle Unit Months of Life	FCF	Zebu	6.0	10.8	9.7	8.7	7.9	7.1	3.2	-	-	-	-
$(\sum_{i=1}^{n} CUMOL_{fi} \times SPFY_{fi})$[d]		f_1	-	1.4	5.8	7.7	11.1	10.8	9.2	11.1	8.1	5.4	2.6
		f_2	-	-	-	-	-	3.5	6.3	9.4	12.5	9.7	4.3
		f_3	-	-	-	-	-	-	-	-	-	.1	.9
	FCM	Zebu	6.0	10.8	9.8	8.7	7.9	7.1	6.4	5.7	5.2	2.3	-
		f_1	-	1.4	5.1	6.2	9.6	8.6	7.4	10.0	10.2	12.0	5.6
		f_2	-	-	-	-	-	-	-	1.2	4.7	6.6	4.2
		f_3	-	-	-	-	-	-	-	-	-	-	.4
Total Cattle Unit Months of Production Period	FCF	Zebu	-	8.1	1.6	2.9	4.6	0	2.7	-	-	-	-
$(\sum_{i=1}^{n} CUMOL_{fij} \times SPFY_{fi})$[e]		f_1	-	-	-	-	2.3	6.5	1.3	6.1	0	2.4	2.6
		f_2	-	-	-	-	-	-	-	-	-	2.3	3.3
	FCM	Zebu	-	8.1	1.6	2.9	4.6	0	5.3	.5	2.6	1.9	-
		f_1	-	-	-	-	-	-	-	5.6	1.0	4.3	1.3
		f_2	-	-	-	-	-	-	-	-	-	-	3.0
Total Months of Milk Production	FCF	Zebu	-	5.4	1.6	.7	4.6	0	1.1	-	-	-	-
$(\sum_{i=1}^{n} MOMP_{fi} \times SPFY_{fi})$[f]		f_1	-	-	-	-	-	5.6	0	4.8	0	.8	2.2
		f_2	-	-	-	-	-	-	-	-	-	.5	2.6
	FCM	Zebu	-	5.4	1.6	.7	4.6	0	3.7	.5	1.3	1.9	-
		f_1	-	-	-	-	-	-	-	3.4	.9	2.5	1.2
		f_2	-	-	-	-	-	-	-	-	-	-	1.2

TABLE J-1—Continued

DESCRIPTION		YEAR 0	1	2	3	4	5	6	7	8	9	10
Sales of Live Animals (Shillings)	FCF						227	229		330	233	187
	FCM						311				116	202
Salvage of Dead Animals (Shillings)	FCF	0	18	30	31	54	39	49	38	48	42	29
	FCM	0	18	49	39	41	42	23	43	45	46	45
		0	18	40	35	48	41	36	41	47	44	37
Salvage Value of Investment (Shillings)	FCF											1199
	FCM											1220

[a]FCF - first calf is a female.

[b]FCM = first calf is a male.

[c]Where f refers to the generation, i refers to the individual cattle within a generation, $CUVEOY_{fi}$ refers to the cattle unit value on December 31 of the year t for the i^{th} animal in the f^{th} generation, and $SPFY_{fi}$ refers to the survival probability for the year t and is defined as: $(1-MPFY_t) \cdot SPFY_{t-1}$ for each of the fi animals. $MPFY_t$ is the mortality probability for the year t for the fi^{th} animal. The mortality probabilities are taken from Table 9.1.

[d]Where $CUMOL_{fi}$ refers to cattle unit months of life for the fi cattle. This is defined as: $CUMOL_{fi} = \sum_{j=1}^{12} M_j \cdot CU_j$ for each of the fi animal where M refers to the month of the year and CU refers to the cattle unit value of the animal during month j.

[e]Where $CUMOL_{fij}$ refers to the CUMOL for each of the j months of the year during which the cow is in her production period.

[f]Where MOMP refers to the number of months during which a cow is in milk.

TABLE J-2

SIMULATED HERD FOR A 1.6 UNIT MIXED ZEBU-GRADE CATTLE ENTERPRISE WITH REQUIRED PRESENCE OF A MATURE MALE IN THE HERD AND FIRST CALF IS FEMALE

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	Salvage Value Unadjusted for Survival Probability	Survival Adjusted Sale/ Salvage Value
Purchase 37 Month Old Heifer, July 1													
Mortality Probability for Year ($MPFY_1$)[a]	0	.10	.10	.10	.10	.10	.10						
Survival Probability for Year ($SPFY_1$)[b]	1.0	.900	.81	.729	.656	.590	.531					432	229
End of Year Age ($EOYA_1$)[c]	43	55	67	79	91	103	109						
Months of Life in Year ($MOLIY_1$)[d]	6	12	12	12	12	12	6						
Cattle Unit Value at End of Year ($CUVEOY_1$)	1.0	1.0	1.0	1.0	1.0	1.0	(1.0)						
Cattle Unit Months of Life ($CUMOL_1$)	6	12	12	12	12	12	6						
Month of Parturition (MOP_1)[e]		JULY		DEC			MAY						
Cattle Unit Months of Production Period ($CUMOPP_1$)	0	9	2	4	7	0	5						
Months of Milk Production ($MOMP_1$)	0	6	2	1	7	0	2						
F_{11} Born July 1, Year 1; Female													
$MPFY_{11}$		0	.10	.09	.08	.08	.08	.08	.08				
$SPFY_{11}$		.900	.810	.737	.678	.624	.574	.528	.486			680	330
$EOYA_{11}$		6	18	30	42	54	66	78	84				
$MOLIY_{11}$		6	12	12	12	12	12	12	6				
$CUVEOY_{11}$		.25	.75	.95	1.15	1.15	1.15	1.15	(1.15)				
$CUMOL_{11}$		1.5	7.2	10.2	12.6	13.8	13.8	13.8	6.9				
MOP_{11}						JAN		FEB					
$CUMOPP_{11}$		0	0	0	3.45	10.35	2.3	11.5	0				
$MOMP_{11}$		0	0	0	0	9	0	9	0				

TABLE J-2—Continued

DESCRIPTION	0	1	2	3	4	YEAR 5	6	7	8	9	10	Salvage Value Unadjusted for Survival Probability	Survival Adjusted Sale/ Salvage Value
F_{12} Born December 1, Year 3; Male													
$MPFY_{12}$				0	.22	.093							
$SPFY_{12}$				.699	.545	.495						450	227
$EOYA_{12}$				1	13	19							
$MOLIY_{12}$				1	12	6							
$CUVEOY_{12}$				.25	.75	(.75)							
$CUMOL_{12}$				.25	4.7	4.5							
F_{13} Born May 1, Year 6; Female													
$MPFY_{13}$							0	.09	.09	.080	.093		
$SPFY_{13}$							.542	.493	.449	.413	.374	831	311
$EOYA_{13}$							8	20	32	44	50		
$MOLIY_{13}$							8	12	12	12	6		
$CUVEOY_{13}$							.45	.75	.95	1.15	(1.15)		
$CUMOL_{13}$							2.4	7.8	10.5	13.0	6.9		
MOP_{13}										NOV			
$CUMOPP_{13}$										5.75	6.9		
$MOMP_{13}$										2	6		
F_{21} Born Jan. 1, Year 5; Male													
$MPFY_{21}$						0	.20	.10	.10	.15			
$SPFY_{21}$						.651	.521	.469	.422	.359		650	233
$EOYA_{21}$						12	24	36	48	54			
$MOLIY_{21}$						12	12	12	12	6			
$CUVEOY_{21}$						.6	1.0	1.2	1.3	(1.3)			
$CUMOL_{21}$						5.4	12.0	14.4	15.6	7.8			

TABLE J-2—Continued

DESCRIPTION	0 - 1	2	3	4	5	6	7	8	9	10	Salvage Value Unadjusted for Survival Probability	Survival Adjusted Sale/ Salvage Value
					YEAR							
F_{22} Born Feb. 1, Year 7; Female												
$MPFY_{22}$							0	.07	.07	.085		
$SPFY_{22}$							.547	.509	.473	.433	1119	484
$EOYA_{22}$							11	23	35	41		
$MOLIY_{22}$							11	12	12	6		
$CUVEOY_{22}$							.6	1.0	1.2	(1.3)		
$CUMOL_{22}$							4.8	11.6	14.2	7.7		
MOP_{22}									DEC			
$CUMOPP_{22}$									4.8	7.7		
$MOMP_{22}$									1	6		
F_{23} Born Nov. 1, Year 9; Female												
$MPFY_{23}$									0	.047		
$SPFY_{23}$									.388	.370	450	167
$EOYA_{23}$									2	8		
$MOLIY_{23}$									2	6		
$CUVEOY_{23}$									.3	(.6)		
$CUMOL_{23}$									.6	2.4		
F_{31} Born Dec. 1, Year 9; Female												
$MPFY_{31}$									0	.041		
$SPFY_{31}$									.449	.431	550	237
$EOYA_{31}$									1	7		
$MOLIY_{31}$									1	6		
$CUVEOY_{31}$									.3	(.6)		
$CUMOL_{31}$									.3	2.1		

[a] Taken from Table 9.1.

[b] In the year of acquisition or year of birth the survival probability for the year (SPFY) is equal to the probability of being born, the latter being simply an interpolation of the probability of the mother being alive at the time of birth.

[c] Age of the animal on December 31 in year t.

[d] Total months during which animal was alive during year t.

[e] Cow gives birth on the first day of this month.

TABLE J-3

DERIVATION OF THE SALVAGE VALUE OF DEAD ANIMALS FOR A 1.6 UNIT MIXED ZEBU-GRADE CATTLE ENTERPRISE WITH THE FIRST CALF A FEMALE (SHILLINGS)

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10
Initial Heifer											
Mortality Probability for the Year ($MPFY_1$)	0	.10	.10	.10	.10	.10	.10				
Mortality Realization Probability (MRP_1)[a]		.10	.09	.081	.073	.066	.059				
Average Meat Value in Year ($AMVIY_1$)[b]		360	360	360	350	350	350				
F_{11}											
$MPFY_{11}$		0	.10	.09	.08	.08	.08	.08	.08		
MRP_{11}			.09	.073	.059	.054	.050	.046	.042		
$AMVIY_{11}$			300	450	600	650	650	650	650		
F_{12}											
$MPFY_{12}$				0	.22	.093					
MRP_{12}					.154	.051					
$AMVIY_{12}$					300	400					
F_{13}											
$MPFY_{13}$							0	.09	.09	.080	.093
MRP_{13}								.049	.044	.036	.038
$AMVIY_{13}$								350	550	650	650
F_{21}											
$MPFY_{21}$						0	.20	.10	.10	.15	
MRP_{21}							.130	.052	.047	.063	
$AMVIY_{21}$							350	550	650	650	
F_{22}											
$MPFY_{22}$								0	.07	.07	.085
MRP_{22}									.038	.036	.040
$AMVIY_{22}$									350	550	650
F_{23}											
$MPFY_{23}$										0	.047
MRP_{23}											.018
$AMVIY_{23}$											225

TABLE J-3—Continued

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10
F_{31}											
$MPFY_{31}$										0	.041
MRP_{31}											.018
$AMVIY_{31}$											225
Value of Animals which Died[c]	0	36	59	62	107	79	99	76	95	84	59
Salvage Value of Animals which Died[d]	0	18	30	31	54	39	49	38	48	42	29

[a] $MRP_t = MPFY_t \cdot SPFY_{t-1}$ where SPFY = survival probability for year.

[b] Define as the value of a male animal of equivalent age and breed at the midpoint of the period to which the mortality realization probability (MRP) apply.

[c] $\sum_{f=1}^{3} \sum_{i=1}^{n} MRP_{fi} \cdot AMVIY_{fi}$

[d] One-half of the value of animals which have died.

TABLE J-4

SIMULATED HERD FOR A 1.6 UNIT MIXED ZEBU-GRADE CATTLE ENTERPRISE WITH REQUIRED PRESENCE OF A MATURE MALE IN THE HERD AND FIRST CALF IS A MALE

DESCRIPTION[a]	YEAR 0	1	2	3	4	5	6	7	8	9	10	Salvage Value Unadjusted for Survival Probability	Adjusted Sale/ Salvage Value
Purchase 37 Month Old Heifer, July 1													
$MPFY_1$	0	.10	.10	.10	.10	.10	.10	.10	.10	.10			
$SPFY_1$	1.00	.90	.81	.729	.656	.590	.531	.478	.430	.387		300	116
$EOYA_1$	43	55	67	79	91	103	115	127	139	145			
$MOLIY_1$	6	12	12	12	12	12	12	12	12	6			
$CUVEOY_1$	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	(1.0)			
$CUMOL_1$	6	12	12	12	12	12	12	12	12	6			
MOP_1		JULY		DEC			MAY		OCT				
$CUMQPP_1$	0	9	2	4	7	0	10	1	6	5			
$MOMP_1$	0	6	2	1	7	0	7	1	3	5			
F_{11} Born July 1, Year 1; Male													
$MPFY_{11}$		0	.22	.16	.10	.10							
$SPFY_{11}$		.900	.702	.590	.531	.478						650	311
$EOYA_{11}$		6	18	30	42	48							
$MOLIY_{11}$		6	12	12	12	6							
$CUVEOY_{11}$		.25	.75	.95	1.15	(1.15)							
$CUMOL_{11}$		1.5	7.2	10.2	12.6	6.9							
F_{12} Born Dec. 1, Year 3; Female													
$MPFY_{12}$				0	.10	.09	.08	.08	.08	.08	.047		
$SPFY_{12}$				.699	.629	.572	.527	.485	.446	.410	.391	680	266
$EOYA_{12}$				1	13	25	37	49	61	73	79		
$MOLIY_{12}$				1	12	12	12	12	12	12	6		
$CUVEOY_{12}$				.25	.75	.95	1.15	1.15	1.15	1.15	(1.15)		
$CUMOL_{12}$				.25	4.7	9.2	11.6	13.8	13.8	13.8	6.9		
MOP_{12}								JUNE		JULY			
$CUMOPP_{12}$								11.5	2.30	10.4	3.45		
$MOMP_{12}$								7	2	6	3		

TABLE J-4—Continued

DESCRIPTION	0	1	2	3	4	YEAR 5	6	7	8	9	10	Salvage Value Unadjusted for Survival Probability	Adjusted Sale/ Salvage Value
F_{13} Born May 1, Year 6; Male													
$MPFY_{13}$							0	.22	.16	.10	.10		
$SPFY_{13}$							.542	.423	.355	.320	.288	650	187
$EOYA_{13}$							8	20	32	44	48		
$MOLIY_{13}$							8	12	12	12	4		
$CUVEOY_{13}$							.45	.75	.95	1.15	(1.15)		
$CUMOL_{13}$							2.4	7.8	10.6	13.0	4.6		
F_{14} Born Oct. 1, Year 8; Female													
$MPFY_{14}$									0	.10	.068		
$SPFY_{14}$									.421	.379	.353	640	226
$EOYA_{14}$									3	15	21		
$MOLIY_{14}$									3	12	6		
$CUVEOY_{14}$									.25	.75	(.75)		
$CUMOL_{14}$									.75	5.7	4.5		
F_{21} Born June 1, Year 7; Female													
$MPFY_{21}$								0	.07	.07	.065		
$SPFY_{21}$								.506	.471	.438	.409	1278	523
$EOYA_{21}$								7	19	31	37		
$MOLIY_{21}$								7	12	12	6		
$CUVEOY_{21}$								.6	1.0	1.2	(1.3)		
$CUMOL_{21}$								2.4	10.0	13.4	7.3		
MOP_{21}											APRIL		
$CUMOPP_{21}$											7.3		
$MOMP_{21}$											3		

TABLE J-4—Continued

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	Salvage Value Unadjusted for Survival Probability	Adjusted Sale/ Salvage Value
F_{22} Born July 1, Year 9; Male													
$MPFY_{22}$										0	.22		
$SPFY_{22}$										.425	.332	350	116
$EOYA_{22}$										6	12		
$MOLIY_{22}$										6	6		
$CUVEOY_{22}$										.3	(.6)		
$CUMOL_{22}$										1.8	3.6		
F_{31} Born April 1, Year 10; Male													
$MPFY_{31}$											.055		
$SPFY_{31}$											.395	225	89
$EOYA_{31}$											3		
$MOLIY_{31}$											3		
$CUVEOY_{31}$											(.3)		
$CUMOL_{31}$											.3		

[a] For a definition of neumonics see footnotes to Tables J-1 and J-2.

TABLE J-5

DERIVATION OF THE SALVAGE VALUE OF DEAD ANIMALS FOR A 1.6 UNIT MIXED ZEBU-GRADE CATTLE ENTERPRISE WITH THE FIRST CALF A FEMALE
(SHILLINGS)

DESCRIPTION[a]	YEAR 0	1	2	3	4	5	6	7	8	9	10
Cow_1											
$MPFY_1$	0	.10	.10	.10	.10	.10	.10	.10	.10	.10	
MRP_1		.10	.09	.081	.073	.066	.059	.053	.048	.043	
$AMVIY_1$		360	360	350	350	350	325	325	325	325	
F_{11}											
$MPFY_{11}$	-	0	.22	.16	.10	.10					
MRP_{11}			.198	.112	.059	.053					
$AMVIY_{11}$			300	450	600	650					
F_{12}											
$MPFY_{12}$				0	.10	.09	.08	.08	.08	.08	.047
MRP_{12}					.070	.057	.046	.042	.039	.036	.019
$AMVIY_{12}$					300	450	600	650	650	650	650
F_{13}											
$MPFY_{13}$							0	.22	.16	.10	.10
MRP_{13}								.119	.068	.036	.032
$AMVIY_{13}$								350	550	650	650
F_{14}											
$MPFY_{14}$									0	.10	.068
MRP_{14}										.042	.026
$AMVIY_{14}$										300	400
F_{21}											
$MPFY_{21}$								0	.07	.07	.065
MRP_{21}									.035	.033	.026
$AMVIY_{21}$									350	550	650

TABLE J-5—Continued

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10
F_{22}											
$MPFY_{22}$										0	.22
MRP_{22}											.094
$AMVIY_{22}$											275
F_{31}											
$MPFY_{31}$											.055
MRP_{31}											.023
$AMVIY_{31}$											150
Value of Animals which Died	0	36	98	79	82	83	47	86	91	92	90
Salvage Value of Animals which Died	0	18	49	39	41	42	23	43	45	46	45

[a]For a definition of neumonics see footnotes to Table J-3.

APPENDIX K

APPENDIX K

ENTERPRISE BUDGET SUMMARIES

For each year, cattle unit months of life, cattle unit months of production period and months of milk production as simulated for the separate enterprises are used to calculate costs and benefits for the various alternatives considered. The monthly value of manure on the returns side, and labor and cash inputs for normal growth and maintenance on the cost side are then multiplied by cattle unit months of life in each year to get returns from manure and operating inputs for maintenance and normal growth. Cattle unit months of production period are multiplied by the monthly value of labor and cash inputs to get the cost of each for production. Sales of live animals and the salvage value of animals which have died and of livestock in the herd at the end of the investment period are taken from the simulation summary sheet for each enterprise.

Tables K.1 through K.8 present the ten year budget summaries for the eight enterprises analyzed.

TABLE K-1

TEN YEAR CAPITAL BUDGET FOR A SIMULATED, 1.6 UNIT, ALL-ZEBU CATTLE ENTERPRISE WITH PURCHASE OF INITIAL HEIFER ONLY

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	TOTALS
Computational Parameters												
Cattle Units in Herd at Year End	1.0	1.08	1.18	1.31	1.51	1.27	1.52	1.44	1.49	1.20	1.24	
Cattle Unit Months of Life in Year	6.0	11.9	13.5	13.4	15.7	15.8	15.3	16.9	16.9	15.4	6.3	
Cattle Unit Months of Production Period in Year	0	8.10	1.60	2.90	4.60	2.30	6.35	1.65	5.85	1.90	2.05	
Months of Milk Production in Year	0	5.40	1.60	0.70	4.60	1.45	4.80	0.25	4.55	1.90	0.50	
Returns (Shillings)												
Milk	0	383	114	50	327	103	341	18	323	135	36	1830
Manure	126	250	284	281	330	332	321	355	355	323	132	3089
Sales of Live Animals	0	0	0	0	0	86	0	0	55	126	50	317
Salvage of Dead Animals	0	18	29	26	31	30	27	34	25	29	18	267
TOTAL RETURNS	126	651	427	357	688	551	689	407	758	613	236	5503
Costs (Shillings)												
Operating												
Maintenance and Growth												
Labor	174	345	392	389	455	458	444	490	490	447	183	4267
Cash Inputs	6	12	14	13	16	16	15	17	17	15	6	147
Production												
Labor	0	49	10	17	28	14	38	10	35	11	12	224
Cash Inputs	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL OPERATING COSTS	180	406	416	419	499	488	497	517	542	473	201	4638
Capital Investment												
Housing	450										0	450
Cattle	360										(501)	(141)
Equipment	0										0	0
TOTAL INVESTMENTS	810										(501)	309
TOTAL COSTS	990	406	416	419	499	488	497	517	542	473	(300)	4947
Net Returns (Shillings)	(864)	245	11	(62)	189	63	192	(110)	216	140	536	556

TABLE K-2

TEN YEAR CAPITAL BUDGET FOR A SIMULATED, 1.6 UNIT, ALL-ZEBU CATTLE ENTERPRISE WITH PURCHASE OF ONE HEIFER IN YEAR ZERO AND ANOTHER HEIFER IN YEAR FOUR WHEN FIRST CALF IS A MALE

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	TOTALS
Computational Parameters												
Cattle Units in Herd at Year End	1.0	1.08	1.18	1.31	1.61	1.72	1.72	1.65	1.75	1.39	1.43	
Cattle Unit Months of Life in Year	6.0	11.9	13.5	13.4	17.4	19.3	19.0	19.3	19.9	18.4	7.3	
Cattle Unit Months of Production Period in Year	0	8.10	1.60	2.90	4.60	2.75	8.85	1.60	7.15	1.85	3.55	
Months of Milk Production in Year	0	5.40	1.60	0.70	4.60	1.45	6.45	0.25	5.55	1.85	1.30	
Returns (Shillings)												
Milk	0	383	114	50	327	103	458	18	394	131	92	2070
Manure	126	250	284	281	365	405	361	405	418	386	153	3434
Sales of Live Animals	0	0	0	0	80	0	108	0	55	167	50	460
Salvage of Dead Animals	0	18	29	25	33	35	35	36	29	43	34	318
TOTAL RETURNS	126	651	427	357	805	543	962	459	896	727	329	6282
Costs (Shillings)												
Operating												
Maintenance and Growth												
Labor	174	345	392	389	505	560	551	560	577	534	212	4799
Cash Inputs	6	12	14	13	17	19	19	19	20	18	7	164
Production												
Labor	0	49	10	17	28	17	53	10	43	11	21	259
Cash Inputs	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL OPERATING COSTS	180	406	416	419	550	596	623	589	640	563	240	5222
Capital Investment												
Housing	450				0						0	450
Cattle	360				145						(579)	(74)
Equipment	0				0						0	0
TOTAL INVESTMENTS	810				145						(579)	376
TOTAL COSTS	990	406	416	419	695	596	623	589	640	563	(339)	5598
Net Returns (Shillings)	(864)	245	11	(62)	110	(53)	339	(130)	256	164	668	684

TABLE K-3

TEN YEAR CAPITAL BUDGET FOR A SIMULATED, 1.6 CATTLE UNITS, MIXED ZEBU-GRADE CATTLE ENTERPRISE WITH PRESENCE OF MATURE MALE IN HERD NOT REQUIRED

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	TOTALS
Computational Parameters												
Cattle Units in Herd at Year End	1.00	1.13	1.38	1.53	1.79	1.42	1.41	1.77	1.67	1.54	1.52	
Cattle Unit Months of Life in Year												
Zebu	6.0	10.8	9.8	8.7	7.9	7.1	4.8	2.9	2.6	1.2	-	
f_1 cross	0	1.4	5.5	7.0	10.4	9.7	8.3	10.6	9.2	8.7	4.1	
f_2 cross	0	0	0	0	0	1.8	3.2	5.3	8.6	8.2	4.3	
f_3 cross	0	0	0	0	0	0	0	0	0	0.1	0.7	
Cattle Unit Months of Production Period in Year												
Zebu	0	8.10	1.60	2.90	4.60	0	4.00	0.25	1.30	.95	-	
f_1 cross	0	0	0	0	1.15	3.25	0.65	5.85	0.50	3.35	1.95	
f_2 cross	0	0	0	0	0	0	0	0	0	1.15	3.15	
Months of Milk Production in Year												
Zebu	0	5.40	1.60	.70	4.60	0	2.40	0.25	0.65	0.95	0	
f_1 cross	0	0	0	0	0	2.80	0	4.10	0.45	1.65	1.70	
f_2 cross: first lactation	0	0	0	0	0	0	0	0	0	0.25	1.90	
second lactation	-	-	-	-	-	-	-	-	-	-	-	
third lactation	-	-	-	-	-	-	-	-	-	-	-	
Returns (Shillings)												
Milk	0	383	114	50	327	350	170	530	102	313	515	2854
Manure	126	256	321	330	384	391	342	395	428	382	191	3546
Sales of Live Animals	0	0	0	0	0	269	115	0	165	175	195	919
Salvage of Dead Animals	0	18	49	39	41	42	23	43	45	46	45	391
TOTAL RETURNS	126	657	484	419	752	1052	650	968	740	916	946	7710
Costs (Shillings)												
Operating												
Maintenance and Growth												
Labor	174	355	449	462	541	551	484	561	609	545	273	5004
Cash Inputs	6	14	21	23	29	30	28	35	38	36	21	281
Production												
Labor	0	49	10	17	36	23	29	42	11	38	39	294
Cash Inputs	0	0	0	0	1	3	1	6	1	5	5	22
TOTAL OPERATING COSTS	180	418	480	502	607	607	542	644	659	624	338	5601
Capital Investment												
Housing	610										0	610
Cattle	360										(1210)	(850)
Equipment	14					14					0	28
TOTAL INVESTMENTS	984					14					(1210)	(212)
TOTAL COSTS	1164	418	480	502	607	621	542	644	659	624	(872)	5389
Net Returns (Shillings)	(1038)	239	4	(83)	145	431	108	324	81	292	1818	2321

TABLE K-4

TEN YEAR CAPITAL BUDGET FOR A SIMULATED, 1.6 CATTLE UNITS, MIXED ZEBU-GRADE CATTLE ENTERPRISE WITH PRESENCE OF MATURE MALE IN HERD NOT REQUIRED

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	TOTALS
Computational Parameters												
Cattle Units in Herd at Year End	1.0	1.13	1.38	1.53	1.59	1.42	1.41	1.72	1.68	1.77	1.76	
Cattle Unit Months of Life in Year												
Zebu	6.0	10.8	9.8	8.7	7.9	7.1	6.4	5.7	3.9	1.2	0	
f_1 cross	0	1.4	5.5	7.0	10.0	8.6	8.3	10.6	10.8	11.8	4.9	
f_2 cross	0	0	0	0	0	1.6	1.5	1.9	5.3	7.1	4.2	
f_3 cross	0	0	0	0	0	0	0	0	0	0.1	0.6	
Cattle Unit Months of Production Period in Year												
Zebu	0	8.10	1.60	2.90	4.60	0	5.30	0.50	1.30	0.95	0	
f_1 cross	0	0	0	0	1.15	3.25	0.65	5.85	0.80	6.15	1.95	
f_2 cross	0	0	0	0	0	0	0	0	0	1.15	3.15	
Months of Milk Production in Year												
Zebu	0	5.40	1.60	0.70	4.60	0	3.70	0.50	0.65	0.95	0	
f_1 cross	0	0	0	0	0	2.80	0	4.10	0.45	3.65	1.70	
f_2 cross: first lactation	0	0	0	0	0	0	0	0	0	0.25	1.90	
second lactation	-	-	-	-	-	-	-	-	-	-	-	
third lactation	-	-	-	-	-	-	-	-	-	-	-	
Returns (Shillings)												
Milk	0	383	114	50	327	350	263	548	102	563	515	3215
Manure	126	256	321	330	376	363	340	382	420	424	204	3542
Sales of Live Animals	0	0	0	0	92	156	98	0	70	107	101	624
Salvage of Dead Animals	0	18	39	35	41	36	37	38	43	42	43	372
TOTAL RETURNS	126	657	474	415	836	905	738	968	635	1136	863	7753
Costs (Shillings)												
Operating												
Maintenance and Growth												
Labor	174	355	449	462	529	512	480	540	596	605	291	4993
Cash Inputs	6	14	21	23	28	28	26	31	36	40	22	275
Production												
Labor	0	49	10	17	36	23	36	44	13	58	39	325
Cash Inputs	0	0	0	0	1	3	1	6	1	7	5	24
TOTAL OPERATING COSTS	180	418	480	502	594	566	543	621	646	710	357	5617
Capital Investment												
Housing	610										0	610
Cattle	360										(1351)	(991)
Equipment	14					14					0	28
TOTAL INVESTMENTS	984					14					(1351)	(353)
TOTAL COSTS	1164	418	480	502	594	580	543	621	645	710	(994)	5264
Net Returns (Shillings)	(1038)	239	(6)	(87)	242	325	195	347	(11)	426	1857	2489

TABLE K-5

TEN YEAR CAPITAL BUDGET FOR A SIMULATED, 1.6 CATTLE UNITS, ALL-GRADE CATTLE ENTERPRISE WITH NO MALE REQUIRED IN HERD

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	TOTALS
Computational Parameters												
Cattle Units in Herd at Year End	1.20	1.50	1.53	1.58	1.52	1.75	1.61	1.76	1.52	1.59	1.55	
Cattle Unit Months of Life in Year	6.8	15.6	18.5	18.9	18.6	19.1	20.0	20.3	19.7	18.3	9.0	
Cattle Unit Months of Production Period in Year	0	10.50	5.70	12.80	5.10	7.60	9.75	7.70	7.00	10.85	2.40	
Months of Milk Production in Year												
First lactation	0	5.60	3.50	0	0	0	3.45	1.25	2.35	2.30	0	
Second lactation	0	0	0	8.20	0	0	0	1.30	1.80	2.20	0.50	
Third and subsequent lactations	0	0	0	0	1.60	5.90	2.05	1.30	1.20	2.30	0.55	
Returns (Shillings)												
Milk	0	1137	711	1812	382	1410	1190	852	1162	1503	242	10401
Manure	143	328	389	397	391	401	420	426	414	384	189	3882
Sales of Live Animals	0	0	284	152	186	0	644	97	497	119	0	1979
Salvage of Dead Animals	0	19	37	26	40	27	27	33	35	27	33	304
TOTAL RETURNS	143	1484	1421	2387	999	1838	2281	1408	2108	2033	464	16566
Costs (Shillings)												
Operating												
Maintenance and Growth												
Labor	204	468	555	567	558	573	600	609	591	549	270	5544
Cash Inputs	41	94	111	113	112	115	120	122	118	110	54	1110
Production												
Labor	0	105	57	128	51	76	98	77	70	109	24	795
Cash Inputs	0	105	57	128	51	76	98	77	70	109	24	795
TOTAL OPERATING COSTS	245	772	780	936	772	840	916	885	849	877	372	8244
Capital Investment												
Housing	670										0	670
Cattle	1100										(1752)	(652)
Equipment	34					34					0	68
TOTAL INVESTMENTS	1804					34					(1752)	86
. TOTAL COSTS	2049	772	780	936	772	874	916	885	849	877	(1380)	8330
Net Returns (Shillings)	(1906)	712	641	1451	227	964	1365	523	1259	1156	1844	8236

TABLE K-6

TEN YEAR CAPITAL BUDGET FOR A SIMULATED, 1.6 CATTLE UNITS, ALL-GRADE CATTLE ENTERPRISE WITH NO MALE REQUIRED IN HERD AND WITH SUPERIOR MANAGEMENT

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	TOTALS
Computational Parameters												
Cattle Units in Herd at Year End	1.20	1.50	1.40	1.82	1.48	1.84	1.64	1.70	1.64	1.34	1.56	
Cattle Unit Months of Life in Year	6.8	15.6	17.0	17.4	18.8	18.8	19.6	19.5	20.3	18.1	9.0	
Cattle Unit Months of Production Period in Year	0	10.50	10.30	10.70	11.10	8.60	8.05	12.40	9.95	9.70	6.05	
Months of Milk Production in Year												
First lactation	0	5.60	4.40	0	0	0	0	3.20	1.75	1.65	1.55	
Second lactation	0	0	0.45	8.20	0	0	0	0	1.50	1.70	1.55	
Third and subsequent lactations	0	0	0	0	6.20	4.40	5.50	4.55	1.80	1.70	1.55	
Returns (Shillings)												
Milk	0	1557	1360	2485	2027	1439	1799	2377	1530	1530	1407	17511
Manure	143	328	357	365	395	395	412	410	426	380	189	3800
Sales of Live Animals	0	0	443	0	610	0	244	595	445	366	0	2703
Salvage of Dead Animals	0	19	36	35	24	34	41	26	37	34	26	312
TOTAL RETURNS	143	1904	2196	2885	3056	1868	2496	3408	2438	2310	1622	24326
Costs (Shillings)												
Operating												
Maintenance and Growth												
Labor	204	468	510	522	564	564	588	585	609	543	270	5427
Cash Inputs	190	437	476	487	526	526	549	546	568	507	252	5064
Production												
Labor	0	137	134	139	144	112	105	161	129	126	79	1266
Cash Inputs	0	231	222	235	244	189	177	273	219	213	133	2136
TOTAL OPERATING COSTS	394	1273	1342	1383	1478	1391	1419	1565	1525	1389	734	13893
Capital Investment												
Housing	670										0	670
Cattle	1210										(2019)	(809)
Equipment	100					100					0	200
TOTAL INVESTMENTS	1980					100					(2019)	61
TOTAL COSTS	2374	1273	1342	1383	1478	1491	1419	1565	1525	1389	(1283)	13954
Net Returns (Shillings)	(2231)	631	854	1502	1578	377	1077	1843	913	921	2907	10372

TABLE K-7

TEN YEAR CAPITAL BUDGET FOR A SIMULATED, 2.2 CATTLE UNITS, ALL-GRADE CATTLE ENTERPRISE WITH REQUIRED PRESENCE OF MATURE MALE IN HERD

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	TOTALS
Computational Parameters												
Cattle Units in Herd at Year End	1.20	1.50	1.96	2.22	2.25	2.47	1.97	2.31	2.18	2.35	2.37	
Cattle Unit Months of Life in Year	6.8	15.6	21.6	24.9	26.1	27.4	26.9	26.1	23.7	26.3	13.4	
Cattle Unit Months of Production Period in Year	0	10.50	5.70	12.80	10.35	11.30	11.45	5.85	8.30	13.65	3.40	
Months of Milk Production in Year												
First lactation	0	5.60	3.50	0	3.05	0.70	3.45	0	1.20	4.50	0	
Second lactation	0	0	0	8.20	0	0	3.35	1.30	1.60	0	0	
Third and subsequent lactations	0	0	0	0	1.60	5.90	0	1.25	2.30	4.55	1.10	
Returns (Shillings)												
Milk	0	1137	711	1812	1002	1552	1441	586	1147	2001	263	11652
Manure	143	328	454	523	548	575	565	548	498	552	281	5015
Sales of Live Animals	0	0	0	272	56	0	1374	0	293	149	0	2144
Salvage of Dead Animals	0	19	41	35	41	52	42	39	65	51	49	434
TOTAL RETURNS	143	1484	1206	2642	1647	2179	3422	1173	2003	2753	593	19245
Costs (Shillings)												
Operating												
Maintenance and Growth												
Labor	170	390	540	623	653	685	673	653	593	658	335	5973
Cash Inputs	41	94	130	149	157	164	161	157	142	158	80	1433
Production												
Labor	0	95	51	115	93	102	103	53	75	123	31	841
Cash Inputs	0	105	57	128	104	113	115	59	83	137	34	935
TOTAL OPERATING COSTS	211	684	778	1015	1007	1064	1052	922	893	1076	480	9182
Capital Investment												
Housing	1010										0	1010
Cattle	1100										(2396)	(1296)
Equipment	51					51					0	102
TOTAL INVESTMENTS	2161					51					(2396)	(184)
TOTAL COSTS	2372	684	778	1015	1007	1115	1052	922	893	1076	(1916)	8998
Net Returns (Shillings)	(2229)	800	428	1627	640	1064	2370	251	1110	1677	2509	10247

TABLE K-8

TEN YEAR CAPITAL BUDGET FOR A SIMULATED, 2.2 CATTLE UNITS, ALL-GRADE CATTLE ENTERPRISE WITH NO MALE REQUIRED IN HERD

DESCRIPTION	YEAR 0	1	2	3	4	5	6	7	8	9	10	TOTALS
Computational Parameters												
Cattle Units in Herd at Year End	1.20	1.50	1.96	2.22	2.13	2.16	2.40	2.42	2.24	2.04	2.09	
Cattle Unit Months of Life in Year	6.8	15.6	21.6	24.5	25.1	25.1	28.3	30.6	28.1	24.5	11.7	
Cattle Unit Months of Production Period in Year	0	10.50	5.70	12.80	10.35	11.25	16.85	10.05	15.40	13.65	3.40	
Months of Milk Production in Year												
First lactation	0	5.60	3.50	0	3.05	0.70	3.45	0	1.20	4.50	0	
Second lactation	0	0	0	8.20	0	0	3.35	1.30	1.80	0	0	
Third and subsequent lactations	0	0	0	0	1.60	5.90	4.10	3.85	6.05	4.55	1.10	
Returns (Shillings)												
Milk	0	1137	711	1812	1002	1552	2421	1207	2087	2001	263	14193
Manure	143	349	454	515	527	527	594	643	590	515	246	5103
Sales of Live Animals	0	0	0	89	239	199	127	350	809	379	0	2192
Salvage of Dead Animals	0	19	37	35	40	44	33	49	48	42	40	387
TOTAL RETURNS	143	1505	1202	2451	1808	2322	3175	2249	3534	2937	549	21875
Costs (Shillings)												
Operating												
Maintenance and Growth												
Labor	170	390	540	613	628	628	708	765	703	613	293	6051
Cash Inputs	41	94	130	147	151	151	170	184	169	147	137	1521
Production												
Labor	0	95	51	115	93	101	152	90	139	123	31	990
Cash Inputs	0	105	57	128	104	113	169	101	154	137	34	1102
TOTAL OPERATING COSTS	211	684	778	1003	976	993	1199	1140	1165	1020	495	9664
Capital Investment												
Housing	1010										0	1010
Cattle	1100										(2180)	(1080)
Equipment	51					51					0	102
TOTAL INVESTMENTS	2161					51					(2180)	32
TOTAL COSTS	2372	684	778	1003	976	1044	1199	1140	1165	1020	(1685)	9696
Net Returns (Shillings)	(2229)	821	424	1448	832	1278	1976	1109	2369	1917	2234	12179