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An Interregional Study of Kenya's Livestock Sector Using Linear Programming

Zakayo Joseph Mwangi
Utah State University

AN INTERREGIONAL STUDY OF KENYA'S LIVESTOCK SECTOR USING LINEAR PROGRAMMING

by

Zakayo Joseph Mwangi

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Zakayo Joseph Mwangi

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABSTRACT

An Interregional Study of Kenya's Livestock Sector Using Linear Programming

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Zakayo Joseph Mwangi, Master of Science

Utah State University, 1981

Major Professor: Herbert H. Fullerton
Department: Agricultural Economics

The major purpose of this study was to determine the least-cost method of producing red meat in Kenya. Linear programming was used in the study. A simulated reduction of grazing land available in one of the settlement areas was carried out to indicate what effect this had on the overall regional production pattern of meat in the country.

Kenya was divided into eleven livestock producing and consuming regions. 1979 was used as the base year, and the demand projection was based on the 1979 population. Input and output coefficients, livestock unit requirements, and market prices were developed. A linear programming model was then used to generate the optimal production and marketing of both cattle and small stock.

(116 pages)

CHAPTER I

INTRODUCTION

The government of the Republic of Kenya has emphasized the development of the livestock sector since 1963. Earlier, livestock development was synonymous with either dairy improvement or commercial ranch establishments in the high potential areas leaving much of the traditional pastoral areas and systems unaffected. The Range Management Division within the Ministry of Agriculture was created in 1963 to address problems concerning or relative to Kenyan rangelands. The livestock sector continues to attract government attention as evidenced by the creation of a Ministry of Livestock Development in 1979.

Kenya is primarily an agricultural country. The agricultural sector has contributed much towards the country's industrialization. Most industries are concerned with food processing, paper and printing, textiles, beverages, wood products and furniture, footwear, and printing. There are no known major mineral deposits. This heavy dependence on agriculture is despite the fact that less than 11 percent of Kenya's total land area receives more than 34 inches of rainfall and is classified as high potential for agricultural production. There is 5.5 percent classified as medium potential, leaving more than 75 percent of the country suitable primarily for livestock grazing.

Background of the Problem

Beef production in Kenya has received much more emphasis in recent years due to several factors. Average quality beef can be produced more cheaply by grazing. In the early years, the major concern was to make the pastoral people self-sufficient in food (meat/milk) production and, thus, relieve the government of the costs of famine relief supply that were all too common during the 1960s.

Several other factors emerged in the 1970s requiring much more emphasis on the development of the rangelands. A rapid population growth together with rapidly increasing incomes created a higher local demand for meat and other livestock products. Incomes of the neighboring oil-rich, Middle East Countries have also been rising rapidly, creating a market for either livestock or processed livestock products. The change in the life patterns of the European Economic Community, creating a demand for fast foods, has also meant a ready market for range-fed beef from disease-free zones. These export markets are not restricted to the Middle East and Europe only. Several rich African countries, e.g., Libya, Nigeria, Egypt, etc., indicate large future projected import demand of livestock products.

In the past, most of the Kenyan beef has been consumed in the areas it is produced. As a result, most of the urban beef supply originated mainly from the large commercial ranches in the former "white highlands." The growing scarcity of arable land has resulted in either government resettlement of Kenyans or the purchase of these commercial agricultural enterprises. The end result has been subdivision of the farms into units far too small for beef production.

The above developments have resulted, therefore, in a greater emphasis on range development as well as calling for better veterinary and animal husbandry practices in all livestock-producing zones of the country.

The Kenyan economy, the population pressure, and the world livestock markets are, therefore, shifting production of different agricultural products to areas where they have a comparative advantage. These advantages or disadvantages of regions in growing specific products result from differences in such factors or resources as water, climate, soil fertility, human labor, capital requirements, distances to markets, and similar production inputs.

Problem and Purpose of Study

One of Kenya's livestock problems is how to make the livestock operators in the major pastoral areas produce for the market. Grazing provides the major feed input in livestock production since production of grains is limited to human consumption or to exports where the market price is higher. Failures in the country's feedlot enterprises have occurred as a result of high feed costs.

In order to examine the pastoral areas that have comparative advantage in converting forage to beef for the market, a suitable model was selected and applied as the central effort in this study. This model will be used to identify potential producing areas as well as potential markets. In addition, it should indicate the effects of seasonal variations in forage availability and livestock production.

Presently, livestock development projects are, perhaps, spread too thinly in all the livestock-producing zones. The national emphasis is centered on disease prevention and control, range management, and livestock marketing. Seasonal variations in forage production has at times left livestockmen wondering what to do next in a country where hay or silage production, or any other livestock feed, is relatively unavailable. In the last few years, livestock supply to the major slaughter plants has been very poor, resulting in the closure of some plants and the rest running at below capacity. While some of this can be blamed on the price and marketing systems, most of the blame can be attributed to lack of sufficient knowledge leading to policies on where to lay emphasis on livestock developments.

This study will help broaden the understanding of the livestock production potential in the different regions of the country. The information gathered will help the policy makers assess the necessity and the sufficiency of the present stock routes. It will also help the pastoralists identify the potential markets for their livestock.

Objectives

The specific objectives of this study are:

1. To identify the areas with potential production of red meat products.

2. To identify where and to what extent the dry seasons have adverse effects on livestock production in Kenya.

3. To determine whether the nation's stock routes are outdated

or do they still serve the purpose they were intended for in relation to meat demand and potential supply areas.

4. To recommend a course of action that will be helpful to governmental agencies presently engaged in the Kenya livestock development project.

CHAPTER II

THEORETICAL FRAMEWORK

It is necessary to understand interregional competition and the application of linear programming so as to be able to interpret the results of the model. These two concepts are briefly covered in this chapter. A review of literature related to application of linear programs in the U. S. agricultural sector as well as studies in the Kenyan livestock sector is included.

Interregional Competition

Trade is a common phenomenon either on an international scale or on a local scale. The early primitive agriculturalist is known to have bartered his vegetable crops for meat and animal skins with the hunters. In many parts of Africa, many pastoral communities still trade their livestock for grains grown in the high rainfall areas. Those high rainfall areas are often surrounded by low plains inhabited by the pasturalists. Kenya, with Nairobi as a major market center, is such a case.

The low plains support large populations of livestock and wild animals. These regions have Nairobi urban area as their major livestock demand market and, therefore, have to compete for this market. Where such a competition exists, involving different regions producing similar products, it is called interregional competition (Mighell and Black 1951). Comparative advantage, locational theory, specialization,

general equilibrium analysis, and lack of trade barriers dictate inter-regional competition.

Specialization and Comparative Advantage

Trade is based on the concept of specialization. This was first proposed by Adam Smith (1776), and it guided the growth and success of such sectors as the British textile industries between 1850 and 1946 (Kindleberger 1969). Specialization allows an area or firm to devote most of its resources to producing a given commodity using the cheapest possible technology available in the field. Specialization leads to competitive advantage in trade.

Similar commodities will often be produced under different conditions in many regions within a country. However, various regions will be more endowed in producing the given commodity by virtue of better communications, well-distributed rainfall, better management, fertile soils, etc. While the physical factors determine the regional limits of production, the economic factors determine what is actually produced.

The principle of comparative advantage was developed by Ohlin (1935). It states that a product will be produced where its ratio of advantage compared with alternative products is greatest, in exchange for products from other areas. In this case, farmers in each region will specialize in producing that product in which the region has the greatest edge over its competitors and will exchange the surplus commodities for others from the other regions.

In its basic form, the principle of comparative advantage disregards transportation costs (Buse and Bromley 1975). However, produce

must be moved from a surplus area to a deficit area for trade to occur. Since specialization is advocated when exchange and competition occurs in the market place, the final decision as what to produce should take into consideration the transportation costs.

The principles of specialization and comparative advantage may be clarified with an example. Beef and potato production is possible in most parts of Central Province and Masailand in Kenya. However, it can be demonstrated that when the regions are isolated, less of the two commodities will be produced; while if the principle of comparative advantage was utilized, the two regions would produce more beef and potatoes. In isolation, a hectar of land in Masailand would probably produce 1000 kg. of potatoes or 250 kg. of beef per year. The same size of land in the high potential Central Province would produce 4500 kg. of potatoes or 500 kg. of beef. Under these assumptions, Central Province has an absolute advantage, while Masailand has an absolute disadvantage. This disadvantage is least in beef, while Central Province has the greatest advantage in potatoes. Before trade, 9 kg. of potatoes are exhcnaged for 1 kg. of beef in Central Province, while 4 kg. of potatoes are exchanged for 1 kg. of beef in Masailand. Under these conditions, specialization and trade would benefit these two regions.

Trade negotiations would allow Central Province to exchange 9 kg. of potatoes for more than 1 kg. of beef, while Masailand would be able to get more than 4 kg. of potatoes for 1 kg. of beef. If an exchange rate of 6 kg. of potatoes for 1 kg. of beef is agreed upon between the two regions, Masailand might exchange 100 kg. of beef for 600 kg. of potatoes. The region will, therefore, end up with 150 kg. of beef and

600 kg. of potatoes. Central Province will end up with 100 kg. of beef and 3900 kg. of potatoes. Before trade, Central Province could only produce a combination of 67 kg. of beef and 3900 kg. of potatoes, while Masailand could only produce 150 kg. of beef and 400 kg. of potatoes.

Thus, by specializing in the production of those products where each region has the greatest (least) comparative advantage (disadvantage), both regions end up better off.

Location and General Equilibrium Theory

Regional specialization calls for an exchange in the market place, thus, requiring goods to be transported between or within regions. Therefore, an essential part of this study involves transportation of livestock products from several surplus regions to the deficit regions.

A general model of spatial equilibrium examined in this study is the one introduced by Lefeber (Nef 1979). Lefeber's model allows evaluation of plans aimed at the optimal resources reallocation and their utilization connected with production among industries and transportation of resources between regions over a period of time (Bailey 1980).

The conditions associated with the optimal solution as defined by Lefeber are:

1. If two different regions export a similar product to the same market, the difference between the shadow prices of the good at the two regions must exactly equal the differences between the respective marginal costs of transporting a unit of that product from the two production regions to that market.

2. If two surplus regions ship to the same deficit region, the difference between prices in the surplus regions will be equal to the

difference between their transport costs to the deficit region (Judge and Wallace 1958).

3. If a factor such as capital is employed in both industries, locally and in transportation, its rent has to be uniform in all three employments. This rent, in turn, has to equal the value of the factor's marginal product in each occupation, evaluated in terms of the shadow prices of the respective goods.

4. If a factor is exported to another location for use in either one or both industries, its rent must equal rent obtained by identical factors employed in the second location. This, in turn, must be equal to the values of the marginal products evaluated in terms of the shadow prices of the goods in that location. Finally, this same rent paid in the second location must equal the sum of the factors rent in the first location plus mobilization cost. From this, it follows that identical factors originating from one region and employed in the production of the same good at two different locations must have different values of marginal products. The difference between the respective values of marginal product of the same factor employed in the same industry in both locations will equal the marginal cost of transporting a unit of the factor from the first to the second location.

5. Factors originating in a location which imports identical factors from abroad must not be employed in the production of transportation services.

The theory can be summarized as:

$$\text{Minimize} \quad Z = \sum\sum^{nm} C_{ij} X_{ij} \qquad i = 1 \text{ and } j = 1$$

subject to:

$$\text{all } X_{ij} \geqslant 0$$

$$\text{and } \sum^{n} X_{ij} = a_i \qquad j = 1$$

$$\sum^{m} X_{ij} = b_j \qquad i = 1$$

hence

$$\sum^{m} a_i = \sum^{m} a_i = \sum^{n} b_j \qquad i = 1 \text{ and } j = 1$$

with (i = 1, 2, 3, . . . , m) and (j = 1, 2, 3, . . . , n) for all cases, and where,

X_{ij} = number of units shipped

C_{ij} = costs of shipping from origin i to destination j

m = number of origins

n = number of destinations

a_i = quantity available at origin i

b_j = quantity required at destination j.

A linear program model transforms this problem as:

Minimize $Z = \sum^{n} C_j X_j$ (j = 1, 2, 3, . . . , n)

subject to:

$$\sum^{n} a_{ij} X_j \leqslant b_i \quad (i = 1, 2, 3, \ldots, m)$$

where

X_j = variable to be determined, n are being considered

C_j = per unit contribution of the j^{th} variable to the objective function

Z = objective to be minimized

a_{ij} = exchange coefficient of the j^{th} variable in the i^{th} constraint

b_i = requirement to be met.

The use of the above formulation will help determine the direction of livestock products' transfers between regions as well as the optimal reallocation of these products.

An interregional study must, therefore, consider both the physical limits to production as well as the economic factors and consequent changes in them in order to determine the direction of change in an economy.

Linear Programming

Linear programming has its origin during World War II, where it was extensively used for minimization of travel distances as well as allocation of such scarce resources as labor, equipment, and tools (Heady and Candler 1958). Since the 1950s, its application has had wide use in analyzing regional and interregional competitive advantages of United States agricultural and livestock sectors. Full coverage of the linear programming methodology will not be presented here. Several applications in the past will be cited in the literature review. However, a brief explanation of the logic behind its usage in this study, as well as most of the assumptions taken, will be done. For a more complete coverage of

its application to agriculture and interregional analysis, one is advised to read Heady and Candler (1958) and Dorfman (1953).

Linear programming (LP) as a tool is used in maximizing or minimizing a given objective subject to given constraints. In agriculture, the tool is used to specify such objectives as: (a) the optimum organization of resources and enterprises on farms; (b) the profit maximizing mixes of commodities produced in the market areas; (c) the cost minimizing methods of processing products such as fertilizers or mixed feeds; and (d) to specify spatial equilibrium patterns of the flow of agricultural products. The LP tool can also be used either to indicate the optimum interregional patterns of resource use and product specialization in agriculture or suggest desired farm adjustments (Heady and Candler 1958).

Programming models can be as simple as possible or very complex. They all have an objective function subject to some constraints. For this study, the objective function is to minimize the cost of producing and transporting red meat given the available livestock population and forage produced with the several regions delineated in Kenya. The use of a computer is essential for a large model, as the one developed in this study.

Assumptions of linear programming

Several important assumptions are implicit in order to use the LP approach (Heady and Candler 1958, Takayama and Judge 1971, Judge and Wallace 1958, and Egbert and Heady 1961). Some of these assumptions are:

1. Markets are competitive. This dictates the requirements for the regional pattern of prices and flow of the commodity unhampered by trade barriers.

2. Resources and products are homogenous, so consumers are indifferent as to the supply source.

3. Within a region, the technical coefficients of production are known and that these coefficients are constant within the delineated regions (Heady and Egbert 1959). This implies constant returns to scale.

4. Resource supplies and final demands for each region are known and that total demand equals total supply.

5. The factor and output markets are represented by a fixed point for each region.

6. Regional prices are known for certainty.

7. The number of alternative activities is limited with each activity being capable of being undertaken at any positive level.

8. Transportation costs are known, they occur at positive levels and are independent of quantity shipped.

9. The system is static in that consumption must be met from current production, the production period is the calendar year.

10. The level of activity in other sectors of the economy is assumed known.

Limitations of linear programming

Several of the above limitations reduce the effectiveness of the model as related to the real world. The assumptions of competitive markets, homogenous outputs, and similar production functions for each

farm in a region are not really realistic. The quality of beef produced in region seven, though dominating in the transactions, is not of the same quality as beef coming out of region eleven. Competitive marketing in Kenya is marred by the disease ordinances that determine the nature of regional flows of livestock. However, frequently it is useful to compute programs ignoring various types of subjective, legal, or institutional restrictions needed by farmers or marketing firms. These restrictions may be due to lack of knowledge, undesirable institutions, etc. (Heady and Candler 1958). The concern is the removal of obstacles to more efficient use of resources rather than modify the programs to fit restricted operating patterns.

Major limitations arise in specifying accurately the technical coefficients, demand, and prices (Stovall 1966). Getting the accurate figures is difficult, particularly in developing countries where even the secondary data is hard to come by. Even in the developed countries, it is really time-consuming to derive all the needed coefficients for such work (Hall and Heady 1971). In this model, apart from relying on several livestock project papers, my experience as a project plans evaluator is relied on heavily. The regions delineated are also small enclosing uniform operations, thus, reducing variations in most of the coefficients used on a per region basis.

Review of Literature

Several past applications of linear programs in agriculture, particularly the livestock sector, in the last 30 years are presented below.

Fox (1953), after concluding that the use of trial and error methods for an equilibrium solution in a 10-region area was very laborious, used a spartial equilibrium LP to determine a solution for regional beef prices and feed utilization by livestock. Variations in freight rates, extreme droughts, and forecasting were used in the model to analyze the U. S. livestock sector.

Judge and Wallace (1958) used spartial price equilibrium models to estimate the equilibrium prices and quantities of beef for 21 regions of the United States. One of the observations was that from an economic point of view, the interdependent nature of the livestock sector necessitates an analytical model depicting the joint determination of sector variables if the consequences and repercussions of certain policy actions are to be isolated.

Schrader and King (1962) broke United States into 20 regions and, using the 1957-58 livestock conditions--regional cattle feeding organization factor and product shipments and beef demand, applied an LP model to determine optimum beef production regions.

Since 1959, several applications of LP models have been used under Professor Heady to analyze the U. S. agriculture and livestock sectors. Heady and Egbert (1959) used an LP model to assess the regional adjustments in grain production in order to eliminate surpluses. Using an interregional programming model, Brokken and Heady (1968) combined crop-producing and livestock-producing models to determine the geographical allocation of crop and livestock production and interregional commodity flows. This particular model, consisting of 20 livestock and 157 crop-producing areas, has been updated and serves as the present U. S. national agricultural linear programming model.

Dietrich (1971) delineated the U. S. into 27 livestock-producing and consuming areas and used an LP model to identify the optimum locations and sizes of feedlots and cattle slaughter facilities in these regions. The model was also used to determine the least-cost shipment routes for cattle, feed grains, and dressed beef. In this study, the conclusion was that readily available supplies of feeder cattle, feed grains, and economies of size in feedlot operations were of major importance in determining the optimum location and levels of cattle feedlots. Economies of size in cattle feeding by themselves were generally not sufficient to offset severe locational disadvantages relative to input and output markets.

Grimshaw (1972) used an LP model to analyze the possibilities of expanding livestock production in the Pacific Northwest. The model showed that the local supply of feeds within all regions was important in determining the optimum production of livestock products within each region.

Grimshaw's model has been modified in several studies at Utah State University to determine the optimal allocation of resources in producing agricultural outputs. Using the modified model, Gray (1972) found that Utah had a comparative advantage over other U. S. regions in producing broilers, eggs, and milk. Sorensen (1978) modified Grimshaw's model and found that milk, eggs, and pork could be expanded profitably in Utah. In both of these studies, Utah was shown to have a comparative advantage in producing livestock products for domestic consumption.

Nef (1979) simulated drought magnitudes to show what effect these droughts had on reallocation of optimum production of livestock products in the whole of the United States.

Several literature listings of past usage of linear programming in analyzing interregional and regional adjustments in optimal production or reallocation of resources is included in the bibliography. The review of other literature is judged to be irrelevant to the present work.

All the above studies have demonstrated how useful an LP model can be in determining the most efficient pattern of production to meet a certain objective. Several assumptions, however, have to be kept in mind before drawing any conclusions.

Studies of importance to livestock production location in Kenya

Livestock development in Kenya has aroused interest ever since the Synnerton plan (Synnerton 1954), which was drawn during the colonial era. This plan drew the attention to the need of developing the areas outside the "scheduled areas."

Most of the studies have either been oriented towards ecological or forage production potential of East Africa. These studies have been done by both Kenya government personnel, international organizations, and private institutions. Lampkin and Howard (1962) were among the first to do studies on the production of beef from zebu cattle in East Africa. Kidner (1964) was more specific in giving a paper on beef production in Kenya during the 1964 conference held at Kitale on animal production and management in rangeland areas of Kenya. A team of FAO/UNDP (1967) carried out a lengthy livestock survey and concluded that both the small stock (goats and sheep) should be given a serious thought in any livestock development program in the whole of East Africa. The most

recent livestock studies include: *The Outlook for Meat Production and Trade in the Near East and East Africa* (FAO/World Bank 1977) and *The Livestock and Meat Industry Development in Kenya* (Chemonics 1977). Several review and appraisal papers have been written by the World Bank since the 1968 inception of the Kenya Livestock Development Project. The project has resulted in the concentration of different development proposals in different parts of the country as indicated in Chapter I of this paper.

Several research papers on livestock production potential have been given since 1965. The East African Classification Committee was set in 1965 to classify the whole of East Africa into ecological zones. The outcome was the present six ecological zones indicating the livestock carrying capacity of the different parts of the country.

FAO/UNDP have also carried several livestock production studies covering different districts (Marsabit, Tana River, Kajiado, etc.). Since the 1960s, Spinks (1965) and Aldington and Wilson (1968) have both written papers on livestock and meat marketing in Kenya.

All of these studies, though relevant to the present study, have either been related to one area of the present study or they covered only a single region without reference to the other regions. Those studies have tried to offer guidelines to the proper use of various regions studied. The Range Management Division is presently planning most of livestock-producing areas based on those past studies.

The present study is hoped to help bridge the gap present in most of the studies mentioned above by incorporating carrying capacity

restrictions, production and transportation costs to indicate the optimum red meat production and producing locations to meet the demand for Kenya.

CHAPTER III

METHODOLOGY

Model Development

This study is probably the first for Kenya as far as the entire livestock sector is concerned. For this analysis, Kenya was divided into eleven separate and autonomous livestock-producing regions (Figure 1).

The regions

The country was divided into eleven livestock production and consumption regions as shown in Figure 2. Three of these regions (5, 6, and 11) fall within the high potential areas. The major differences in these regions are mainly culture, human population concentrations, red meat demand, and production patterns. Region eleven is important since its red meat production potential is presently being affected by settlement resulting from land subdivision schemes.

The other nine regions fall either within the semiarid or arid lands. The major differences are the ethnic compositions, annual grazing radius, and herd compositions. Region two is composed of only one district (Marsabit) due to the unique influence Marsabit mountain ranges have on the region. Region seven comprises the whole of the southern range. This makes it unique since it comprises one single tribe (Maasai) and lies alongside the southern side of the high potential area. Region

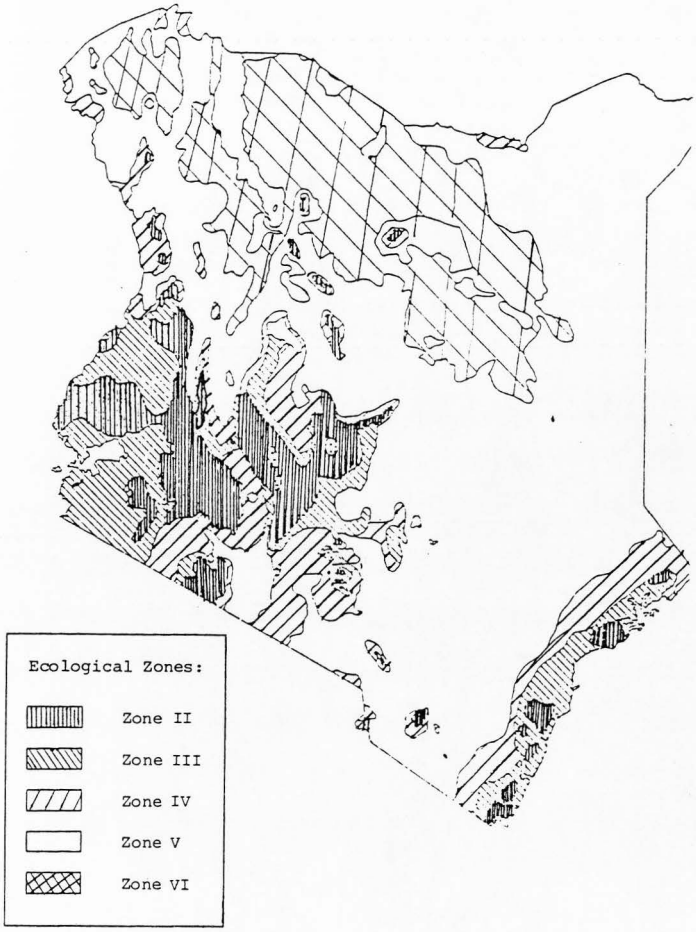

Fig. 1. Kenya's ecological zones.

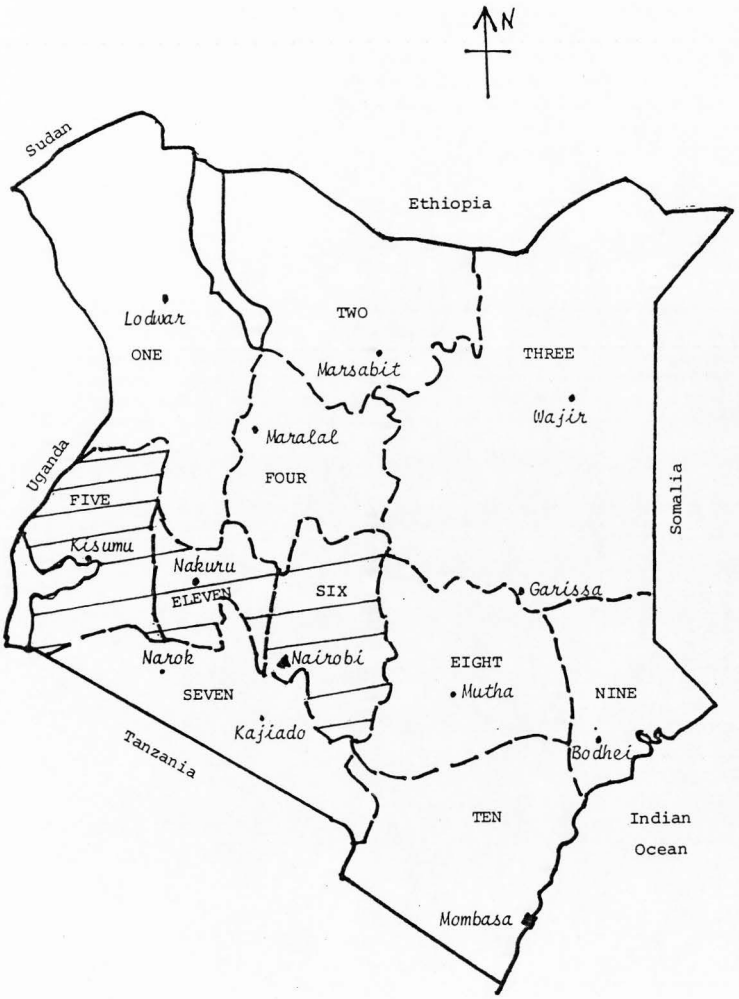

Fig. 2. Livestock-producing and consuming regions (Kenya).

four is similar to region seven, except it lies on the northern side of the high potential zone. While region seven has the potential to attract encroachment by wheat and barley growers, part of region four has similar problems with region eleven.

Region eight is the most drought-prone region within the country (Ominde 1975). Regions nine and ten are similar in vegetation, culture, and the nature of livestock development proposed so far. These two regions could easily follow under company ranch development schemes. Most of this area is uninhabited state land. The regions, however, are different in relation to major markets, disease problems, and tribal representation.

Eight different categories of grazing animals were included in the model. These include both culled bulls and cows; steers over three years, two years, and one year; culled male and female small stock; as well as young small stock (Table 1). Small stock refers to both goats and sheep. The contribution of red meat from camels is ignored since the activity is very localized both in production and consumption. The per capita consumption of camel meat is also thought to be very low, even in regions where camels are produced (Pratt and Gwynne 1976).

Transportation is mainly between the major consuming centers. Due to the location of region seven in relation to the major consuming areas, two shipping centers were selected. All regions and regional centers are shown in Table 2.

Transportation costs between regions are based on distances between the major market centers. Intraregion transportation costs are assumed to be zero as most consumption is done on the farms.

TABLE 1

LIVESTOCK CLASSES AND GRAZING SEASONS

Livestock Classes	Grazing Seasons
1. Culled bulls	1. Dry season (December - February)
2. Culled cows	
3. Steers over 3 years	2. Wet season (March - May)
4. 2-3 year old steers	
5. 1-2 year old steers	3. Dry season (June - August)
6. Culled rams/billies	
7. Culled ewes/nannies	4. Wet season (September-November)
8. Young small stock	

TABLE 2

REGIONS AND REGIONAL CENTERS USED IN THE STUDY

Region	Regional Center	Districts/Divisions
One	Lodwar	Turkana, W/Pokot, E/Marakwet, Baringo
Two	Marsabit Town	Marsabit
Three	Wajir	Wajir, Mandera, Isiolo, N/Garissa, N/Tana, Tharaka
Four	Maralal	Samburu, N/Laikipia
Five	Kisumu	Nyanza, W/Province, Nandi, Vasin Gishu, Tranzoia
Six	Nairobi	C/Province, Embu, Meru, Machakosi
Seven	Narok, Kajiado	Narok, Kajiado
Eight	Mutha	E/T. River, Kitui
Nine	Bodhei	S/Garissa, Lamu
Ten	Mombasa	Coast Province
Eleven	Hakuru	Hakuru, S/Laikipia, Kericho, Lower Kijabe-Mai Mahiu

Four grazing seasons are included in the model (Table 1). These are the dry-wet-dry-wet seasons. Since this pattern is more pronounced east of the Rift Valley (Pratt and Gwynne 1976), deviations in forage production is large in these regions. Feed requirement for each class of livestock is based on respective livestock weights. A cow-calf is taken as the base and expressed as one livestock unit (LU). "A L.U. is a standardized animal unit to which different ages, types of species of livestock can be related for purposes of matching forage availability to animal needs" (Pratt and Gwynne 1976). Table 3 shows the coefficients used. These coefficients vary over regions mainly to reflect the difference in weights of animals in these areas. For this reason, animals in such regions as eleven and six have higher coefficients than those in regions two and three.

The model reallocates red meat production between regions and transports these products from surplus areas to deficit areas.

The objective function

The problem is:

$$\text{Minimize} \quad \sum_{ikg} A_{ikg} + \sum_{ijkg} C_{ijk} + \sum_{jkg} E_{jkg} + \sum_{jkm} Y_{jkm} Z_{jkm} \qquad (1)$$

Subject to:

$$V_{ikg} = A_{ikg} \qquad (2)$$

$$T_{jkg} = E_{jk} + \sum_{gk} Y_{jgk} - \sum_{kg} Y_{jkg} \qquad \text{for all } j \text{ and } i \qquad (3)$$

$$A_{ik}, C_{ijk}, E_{jk}, Y_{jkg} \geq 0 \qquad (4)$$

TABLE 3

LIVESTOCK UNIT COEFFICIENTS APPLIED*

Regions	Cattle			Small Stock		
	> 3 Yrs.	2 - 3 Yrs.	1 - 2 Yrs.	Rams**	Females	Young Stock
One, two & three	0.7	0.5	0.4	0.113	0.093	0.072
Four	0.7	0.5	0.4	0.113	0.093	0.072
Five	0.7	0.5	0.4	0.079	0.068	0.057
Six	0.8	0.6	0.5	0.079	0.063	0.058
Seven	0.7	0.5	0.4	0.074	0.068	0.057
Eight	0.7	0.5	0.4	0.074	0.063	0.053
Nine	1.0	0.8	0.6	0.103	1.090	0.068
Ten	1.0	0.8	0.6	0.079	0.068	0.066
Eleven	1.0	0.8	0.6	0.117	0.090	0.074

* Cow/calf and bulls are 1.0 LU for all regions.

** Culled rams and billies.

where

A_{ikg} = the quantity of i^{th} feed (livestock units) produced in region k during season g

C_{ijkg} = the quantity of i^{th} feed (livestock units) fed to j^{th} class of livestock in region k during season g

E_{jkg} = the quantity of j^{th} livestock product produced in region k during season g

F_{jkg} = the nonfeed costs of producing one unit of the j^{th} class of livestock in region k during season g

Y_{jkm} = the quantity of the j^{th} livestock produced and shipped from region k to region m

Z_{jkm} = the per unit cost of transporting the j^{th} livestock unit from region k to region m.

V_{ikg} = the quantity of the i^{th} feed (forage) available for feeding in region k during season g

T_{jkg} = the quantity of j^{th} livestock consumed in region k during season g.

The subscripts i, j, g, and k represent the following:

i = 1, livestock units (forage)

j = 1, 2, . . . , 8

where

1. culled bulls
2. culled cows
3. steers over 3 years old
4. 2 - 3 year old steers
5. 1 - 2 year old steers
6. culled rams/billies
7. culled ewes/nannies
8. young small stock

$k = 1, 2, \ldots, 11$

where

1. region one
2. region two
3. region three
4. region four, etc.

$g = 1, 2, 3, \text{and } 4$

where

1. dry season (December - February)
2. wet season (March - May)
3. dry season (June - August)
4. wet season (September - November)

The objective function can be expressed as a minimization of livestock production costs (nonfeed) and transportation costs. This should be done without violating any of the constraints (2 through 4). The first constraint (2) requires the quantity of forage available for feeding in a region to be more than or equal to local requirement. There is no feed transfer involved. Equation (3) requires demand for red meat to be equal to local production plus net imports. Excess production is exported while deficits are met through interregional imports. Equation (4) implies zero or positive activities in production and transportation.

An illustration of the linear programming matrix for one region is presented in Figure 3.

Constraints	Feed Production	Forage Conversion	Livestock Production	Livestock Transfer	Consumption of Red Meat
Objective function	+c		+c	+c	
Feed production account	+1		-1		
Feed available account	-1		+1		
Livestock unit		+d	-d		
Red meat production account			+1	-1	
Red meat available account				+1	-1
	b		b		b

c -- cost of activity.

d -- livestock unit coefficient.

b -- bounds.

Fig. 3. Linear programming for one region.

Assumptions

Apart from the general assumptions held in Chapter II, the following assumptions are held for the present study:

1. Grazing forage is the only feed considered in the present study. Total production varies with seasons.

2. Forage consumption is based on animal weights.

3. The year 1979 is the base year.

4. Only the livestock forage economy is considered.

5. A subsistence herd must be maintained in all the regions to meet the milk requirement of the pastoral communities. Red meat production is secondary to milk production, therefore, it will utilize the net available forage.

6. There is no substitution between beef and mutton. Consumption rates are as indicated in Table 4.

7. The forage requirement is based on livestock unit coefficients indicated in Table 3.

8. Production of livestock products is bounded in each region so as to fall between given regional offtakes. Therefore, this approximates realities based on the size of the subsistent herd.

9. Since such animals as donkeys and camels were not included in the model, their regional forage requirements were subtracted in arriving at the net available forage per season.

10. Red meat consumption is assumed to spread evenly over the four seasons. The abundance of milk supply or "Sukuma Week" during the wet season is assumed to have negligible effect on the demand for meat during the wet season.

TABLE 4

PER CAPITA RED MEAT CONSUMPTION, 1979 (Kg./Person)

	Beef		Small Stock	
Region	Rural	Urban	Rural	Urban
One, two	3.7	--	13.1	--
Three	3.7	13.1★	13.1	10.2
Four	6.8	23.1	10.2	10.2
Five	10.1	17.6	3.6	5.8
Six	7.3	28.6	2.4	5.8
Seven	8.0	28.6	10.2	5.8
Eight	4.7	28.6	5.3	5.8
Nine	3.6	3.6	9.8	9.8
Ten	3.4	17.6	3.5	5.8
Eleven	9.9	17.6	7.1	5.8

SOURCE: Chemonics International, *Livestock and Meat Industry Development Study*, Prepared for the Ministry of Agriculture (Washington, D.C. in association with Hawkins and Associates, Nairobi, 1977).

★Most urban consumption figures are derived averages.

Data Collection

Data for this study were collected mainly from secondary sources. The human population was based on the September, 1979 census (*Weekly Review* 1979). These figures are then contrasted with the comprehensive 1962 census coverage (Morgan and Shaffer 1966) so as to fit the delineated regions. The 1979 population figures are represented in Appendix 1.

The supply of red meat was assumed to come from the different categories of livestock produced. For the model, the demand and supply of red meat is expressed in terms of live animals slaughtered or transferred from one region to another for slaughter. The regional demand is as shown in Table 5.

The total supply of red meat was based on the total herd surveyed by the Kenya Rangeland Evaluation and Monitoring Unit in the 1978-79 season. The livestock census for region seven appeared low (Review Mission 1977) and had to be adjusted to fit the most recent estimates (Wamukota 1979, and Appendix 1). Livestock distribution projected for all livestock categories are shown in Table 6.

Most of the livestock kept in East Africa are kept to furnish the owners with subsistent requirements in the form of milk, meat, and blood on some occasions. This ration, 3/4 milk and 1/4 meat, was tried first in estimating the subsistent level of herd requirement. In the past, several studies have estimated the number of cows required to sustain a family of 6.5 adults equivalent at 2300 calories per day. These are all varied; L. Brown arrived at 30 - 35 cows (Pratt and Gwynne 1976), 20 - 25 cows (Review Mission 1977), 20 milking cows (Windstrand 1975), Dahl and Hjort (1976) recommend 9 milking cows or a total of 60 head of cattle

TABLE 5

TOTAL LIVESTOCK HEAD DEMANDED, 1979

Live-stock	Region										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
Bulls	248	45	133	197	5,125	4,831	275	158	22	1,290	1,239
Cows	1,660	236	934	1,381	88,527	137,300	2,263	1,584	256	8,621	12,530
> 3 yr. steers	8,537	1,271	7,196	3,290	137,277	100,756	6,904	4,657	533	34,415	53,092
2-3 yr. steers	9,664	1,398	9,100	8,054	167,509	146,608	18,100	13,248	1,166	6,539	2,433
1-2 yr. steers	--	--	--	--	--	120,574	--	--	--	--	--
Rams/ billies	7,965	1,170	5,002	1,434	26,623	21,521	5,121	350	947	6,929	8,063
Females	144,580	21,255	90,881	25,981	460,776	403,576	84,194	6,228	15,911	119,931	149,409
Young stock	427,715	62,880	268,855	76,860	1,234,324	1,097,560	225,537	16,938	47,161	282,717	411,230

TABLE 6

LIVESTOCK DISTRIBUTION, 1979 (1,000 Head)

Live-stock	Region										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
Culled bulls	48.15	4.20	21.15	26.24	61.7	26.0	48.9	14.7	13.6	5.8	15.6
Culled cows	385.20	33.60	109.20	262.40	1,173.1	1,093.7	489.4	146.8	168.0	86.4	389.0
> 3 yr. steers	86.67	7.56	38.07	39.40	216.0	--	82.4	22.0	36.3	51.8	357.0
2-3 yr. steers	115.56	10.08	50.76	91.80	463.0	260.4	173.4	51.4	68.1	40.3	233.4
1-2 yr. steers	134.84	11.76	59.22	98.40	493.9	520.8	192.7	56.1	77.1	46.1	264.5
Calves	192.60	16.80	84.60	137.80	679.3	703.1	256.2	76.0	90.9	57.6	297.0
Total	963.00	84.00	423.00	656.00	3,087.0	2,604.0	1,243.0	367.0	454.0	288.0	1,556.0
Camels	95.00	113.00	350.00	17.00	--	--	--	--	6.0	--	--
Mature male stock	60.20	10.30	28.60	17.80	52.0	41.0	23.8	7.6	3.7	4.3	20.1
Females	925.90	159.40	440.00	274.10	802.0	1,147.3	665.4	227.3	57.0	128.3	602.6
Young stock	1,418.90	244.30	674.40	420.20	1,229.0	1,679.7	1,211.8	371.1	87.3	209.4	984.3
Total	2,405.00	414.00	1,143.00	712.00	2,083.0	2,868.0	1,901.0	606.0	148.0	342.0	1,607.0

SOURCE: Projected from figures stated in Z. J. Mwangi, "Rangeland Production," Letter Grass/I/VI of April 12, 1979 sent to the Head of Animal Production Branch, Nairobi.

for a family of 6, Jacobs (Dahl and Hjort 1976) puts 10 - 15 cows as being sufficient for the Maasai. This criteria, though widely quoted in literature, fails its test in all the regions except region four. Therefore, either the pastoralists are not entirely dependent on "3/4 milk and 1/4 meat" diets or the 1973-76 drought had very heavy livestock mortality rates. The first suggestion appears more plausible as the total 1979 livestock population was not much lower than expected. Studies carried out among the Maasai, a major pastoral tribe, have indicated a major shift in their dietary habits. A survey carried out in 1974 (Metson 1974) found that 93 percent of the households in Kajiado bought maizemeal weekly. Traditionally, maizemeal was eaten only under stress and not by choice. The weekly consumption of maizemeal, particularly among the women and children, was confirmed by Meadows and White (1979) in their 1977 survey.

The minimum regional subsistent herd was, therefore, arrived at after deducting the offtake rates required to meet the indicated national demand for meat (Table 4). An allowance of 10.3 million kg. for export was allowed for in the bounds section. This is the average quantity of beef exported between 1967 and 1974 (Heyer, Maitha, and Senga 1976).

The production bounds were fixed through the expected offtake rates. The lower bounds are based on the minimum offtake required to sustain the population in the region. The upper bound is the estimated maximum offtake that a given region could be expected to sell through the livestock trade centers. These offtakes vary from region to region (Dahl and Hjort 1976, Review Mission 1977, Chemonics Int. 1977, and Ayuko 1976). In the past, the offtake rates for the small stock in most

pastoral areas have been about 30 percent. The present small stock project expects to raise this rate to over 60 percent through the marketing of excess mature males in the country (FAO/UNDP 1978).

The transportation costs were based either on the Shs. 70 charged by the Livestock Marketing Division (LMD) for moving cattle from North-east Province to either Taita or Laikipia ranches (Review Mission 1977--Annex 5), the 1978-79 Kenya railways charge of Shs. 150 to transport cattle from Nakuru to Coast Province, or an estimated Shs. 1.25/ton/km. charge for trucking animals from region one to region eleven by LMD. Most stock routes are assumed to use various means (droving, trucking, railing, sea routes) to get livestock to the markets shipping charges from Lanu to Mombasa were assumed to be equivalent to rail charges.

The forage available was based on the ecological potential (Pratt and Gwynne 1976) and on the estimated hectares of grazing land available for livestock use in every region (Chemonics Int. 1977). Table 7 indicates the carrying capacity of various ecological zones (see Figure 1 for ecological classification).

TABLE 7

RELATIONSHIP BETWEEN ECOLOGICAL ZONE AND CARRYING CAPACITY

	Ecological Zones				
	II	III	IV	V	VI
Hectares required per LU	0.8	1.6	4.0	12.0	42.0
LUs required per head of population	2.5	3.0	3.5	4.0	4.5

SOURCE: D. J. Pratt, and M. D. Gwynne, eds., *Rangeland Management and Ecology in East Africa* (New York: Robert E. Krieger Publishing Col, 1976).

Total forage available is dictated by ecological potential as well as the rainfall pattern. Appendix 3 contains total hectares available for grazing. These are further divided by the carrying capacity[1] as given in Table 7 to arrive at the total LUs available. Table 8 lists the estimated forage available on a seasonal basis. The estimate was based on water availability and distribution, presence of tse tse flies, plant growing season, availability of wild game and other grazing animals, etc.

Table 8 is adjusted further to account for the requirement of the subsistent herd. This net balance in forage (Table 9) gives the basis for red meat production for both cattle and small stock.

In the model a cow calf, mature bull, or animal weighing 190 kg. CDW (cold dressed weight) was taken as one LU. This latter measure is taken as the basis for converting livestock to red meat. Livestock unit coefficients vary from region to region as reflected by the different weights in these regions. Thus, while steers in region ten are expressed as 1.0 LU, those in region three are expressed as 0.7 LU.

The livestock coefficients used to define stocking rates are those used by the Range Management Division for planning purposes. Coefficients for the small stock were formulated so as to compare their regional weights to 190 kg. of red meat. They compare favorably, however, with those reported from various sources (Chemonics, Int. 1977, and FAO/World Bank 1977).

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[1] Livestock carrying capacity: the maximum animal numbers that can graze each year on a given area of range for a specific number of days without inducing a downward trend in forage production, forage quality, or soil (Stoddart, Smith, and Box 1975).

TABLE 8

SEASONAL FORAGE AVAILABLE, 1979 (1,000 LU)

Region	Dec-Feb	Mar-May	Jun-Aug	Sept-Nov
One	665.0	912.6	665.6	849.6
Two	71.0	133.1	84.0	117.7
Three	310.0	512.4	305.0	420.0
Four	379.6	464.0	364.9	464.0
Five	1,729.0	2,000.0	2,000.0	1,864.8
Six	956.7	1,063.0	956.7	1,063.0
Seven	980.0	1,569.3	980.0	1,471.2
Eight	316.0	383.5	316.0	383.5
Nine	538.0	577.1	538.3	577.1
Ten	896.1	1,024.1	896.1	1,024.1
Eleven	805.1	876.6	805.1	876.6

TABLE 9

NET FORAGE AVAILABLE, 1979 (LU)

Region	Season			
	Dec-Feb	Mar-May	Jun-Aug	Sept-Nov
One	10,898	258,498	10,898	195,498
Two	21,279	83,379	34,279	67,979
Three	16,172	218,572	16,172	126,172
Four	20,628	105,028	20,628	105,028
Five	119,600	290,000	290,000	154,800
Six	11,543	117,843	11,543	117,843
Seven	211,926	801,226	211,926	703,126
Eight	91,635	159,135	91,635	159,135
Nine	279,456	318,256	279,456	318,256
Ten	728,216	856,216	728,216	856,216
Eleven	69,110	140,600	69,110	140,600

East African cattle, generally, are not very heavy animals. An average improved animal weighs 190 kg. CDW (Ayuko 1976). This also represents the average mature weight of N.E. Boran or the Maasai Zebu (Pratt and Gwynne 1976, and Meyn 1970). However, most of the immatures leaving these areas fall between 210 kg. to 260 kg. (Review Mission 1977), thus, falling between 0.6 and 0.7 LU at 50 percent killing weight. Steers from organized ranches will often weigh about 300 kg. before slaughter.

The operating expenses were estimated from the Review Mission's (1977) figures for 1977 as well as International Livestock Center for Africa (ILCA 1978) monitoring costs reported in June, 1978. These costs fall into three main categories:

1. The main pastoral areas of the North--regions one, two, and three--had very low operating expenses since none of them had any interest charges to meet, and disease control and prevention measures were heavily subsidized.

2. The established ranches or "program districts" where operating costs were well documented (ILCA 1978, and Review Mission 1977).

3. The traditional areas of regions five, eight, and nine, whose livestock management were yet to be organized. Region nine, however, showed a high operating expense due to heavy infestations of tse tse flies (*Glossina spp.*).

The operating expenses considered included labor, drugs, dipping charges, salt, water charges, interest payments, and maintenance of machinery where available. These costs are lower than ILCA's (1978) and Review Mission's (1977). Their figures were calculated based on total

ranch operating costs at a period when the sampled ranches had very low stocking rates as a result of the 1974-76 drought. This had forced the per head average operating expenses to shoot up (ILCA 1978). There is, however, room to improve these figures (Table 10) with comprehensive regional cost surveys.

The price of livestock was based on the regional controlled price of red meat for the standard grade. These prices were, however, adjusted slightly down to cover the slaughter houses' operating expenses. The adjustments ranged from Sh. 1.00 per kg. of cattle meat (Chemonics, Int. 1977) to Shs. 0.50 per kg. of slaughtered small stock. Controlled prices are customarily higher in the urban centers than in the rural areas.

TABLE 10

COST OF PRODUCING LIVESTOCK, 1979 (Shs./Head)

Livestock	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
Cattle:											
Bulls	110.00	110.00	110.00	186.05	146.40	232.35	122.10	163.10	315.00	310.00	250.00
Cows	137.00	137.00	137.00	194.95	174.20	231.80	149.90	174.10	315.00	298.00	240.00
< 3 yrs. steers	104.75	104.75	104.75	155.80	140.86	189.70	116.56	141.00	265.70	253.05	195.00
2-3 yrs. steers	96.50	96.50	96.50	142.80	129.86	169.20	105.56	130.00	252.00	230.00	180.00
1-2 yrs. steers	89.00	89.00	89.00	124.76	113.86	151.20	89.56	115.60	212.00	180.00	160.00
> 1 yr. steers	51.50	51.50	51.50	114.50	113.30	150.00	79.00	98.10	175.00	150.00	150.00
Small Stock:											
Males	11.50	11.50	11.50	14.00	12.50	20.40	12.00	12.00	22.50	23.30	23.30
Females	12.10	12.10	12.10	15.50	13.00	21.50	13.40	13.40	25.40	25.40	23.50
0-3 yrs.	8.85	8.85	8.85	11.35	10.35	15.35	10.90	11.50	19.35	19.85	17.70

CHAPTER IV

RESULTS AND ANALYSIS

This chapter presents optimal solutions to the linear programming model developed as described in the previous chapter. Emphasis is mainly on the base year solutions. However, these "optimal" solutions may not represent what actually happened in 1979, particularly because of the restricted veterinary regulations in the movement of livestock. It also should be remembered that the results and their interpretation are based on the assumptions made previously. The program's objective was to minimize costs throughout all the regions based on the national production and demand for red meat. These results probably would be different if either fewer or more regions were delineated or if the regions were analyzed individually.

Base Year Solutions

This study used 1979 as the base year. For that year, total cost of producing and marketing red meat was K£2.15 million. The livestock owners earned a net profit of K£52.27 million. This net profit may appear overstated, but then one must remember that it included the value of home-consumed beef, which never reached the markets. Also, apart from its low production costs, it never faced any transportation costs. However, its opportunity cost was real.

Seasonal Forage Utilization

Actual forage consumption for the base year is given in Table 11. Optimal forage utilization varied from season to season and from region to region. These consumption levels should be compared with the actual net forage available as indicated in Table 8.

TABLE 11

FORAGE UTILIZATION, 1979 (Stock Units)

Region	Seasons			
	Dec - Feb	Mar - May	Jun - Aug	Sep - Nov
One--optimal	10,898★	37,466	10,898★	35,674
Two--optimal	2,747	4,366	5,297	3,297
Three--optimal	14,589	15,255	16,172★	15,255
Four--optimal	5,737	9,848	9,848	9,848
Five--optimal	40,310	66,984	78,310	67,637
Six--optimal	11,543★	69,369	11,543	71,113
Seven--optimal	31,806	37,248	57,991	45,078
Eight--optimal	9,860	7,370	4,426	4,811
Nine--optimal	2,766	2,766	6,534	2,741
Ten--optimal	12,623	12,623	20,399	8,956
Eleven--optimal	67,175	82,550	69,110★	39,548

★All available forage was fully utilized during that particular season.

The production levels indicate that regions one, three, six, and eleven had their forage fully utilized mainly during the dry seasons. The potential for expansion of livestock production in these regions is

minimal during the two dry periods unless livestock numbers can be increased by import into those regions during each wet season. The limiting factors seemed to be the dry months, since large forage balances occurred during the wet seasons.

Large forage balances were available in regions eight, seven, nine, and ten. Region one had also large balances in forage during the wet seasons. The rest of the regions seemed to have a well-balanced forage supply.

Red Meat Production

The regional livestock production to meet the national demand for red meat in the base year is presented for regions one through eleven. Seasonal forage supply was the major determinant in the level of production. The regional location, with reference to the major markets, determined what was shipped out of each region and, therefore, the total livestock produced in each region.

Tables 12 through 15 indicate the seasonal shadow prices of producing different categories of livestock at any particular season that were generated by the model. The "shadow" prices indicate the amount by which total costs would change if one more unit of a particular activity were added.

Region one

The optimal livestock offtake numbers in region one are given in Table 16. Production of the different categories of livestock varied over the seasons. Bulls were produced at the lower bound at all seasons except during the short rains (September - October). Most of these bulls

TABLE 12

SEASONAL SHADOW PRICES, 1979 (Dec - Feb Season--Shs./Stock Unit)

	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
Bulls											
Actual	665	665	1,425	1,140	1,482	1,767	1,482	1,482	1,140	1,577	1,577
Shadow	385	690	1,425	1,128	1,507	623	1,573	1,482	1,003	1,501	1,538
Cows											
Actual	665	665	1,425	1,140	1,482	1,767	1,482	1,482	1,140	1,577	1,577
Shadow	385	678	1,425	1,123	1,465	638	1,560	1,482	1,030	1,540	1,549
< 3 yr steers											
Actual	665	665	1,140	1,140	1,767	2,080	1,482	1,482	1,140	1,862	1,577
Shadow	556	704	1,140	1,127	1,712	1,140	1,482	1,482	1,140	1,947	1,611
2-3 yr steers											
Actual	636	636	1,111	1,111	1,453	1,738	1,453	1,453	1,111	1,538	1,538
Shadow	636	809	1,250	1,245	1,711	1,338	1,728	1,607	1,342	1,899	2,019
Small Stock:											
Males											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,067	1,045	1,624	1,599	1,740	2,191	1,576	1,520	1,671	1,897	1,834
Females											
Actual	1,045	1,045	1,520	1,520	1,615	1,615	1,520	1,520	1,520	1,710	1,720
Shadow	1,045	1,052	1,599	1,568	1,725	2,185	1,520	1,669	1,697	1,774	1,736

TABLE 12--Continued

	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
0-3 yr olds											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,045	1,045	1,540	1,520	1,703	2,185	1,548	1,520	1,648	1,939	1,875

TABLE 13

SEASONAL SHADOW PRICES, 1979 (Mar - May Season--Shs./Stock Unit)

	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
Bulls											
Actual	665	665	1,425	1,140	1,482	1,767	1,482	1,482	1,140	1,577	1,577
Shadow	665	690	1,425	1,128	1,509	1,767	1,573	1,482	1,345	1,501	1,538
Cows											
Actual	665	665	1,425	1,140	1,482	1,767	1,482	1,482	1,140	1,577	1,577
Shadow	665	678	1,425	1,123	1,482	1,783	1,560	1,482	1,030	1,540	1,549
> 3 yr steers											
Actual	665	665	1,140	1,140	1,767	2,090	1,482	1,480	1,140	1,862	1,577
Shadow	752	704	1,140	1,123	1,753	2,028	1,482	1,482	1,140	1,947	1,611
2-3 yr steers											
Actual	636	636	1,111	1,111	1,453	1,738	1,453	1,453	1,111	1,538	1,538
Shadow	775	839	1,250	1,245	1,711	2,024	1,728	1,607	1,342	1,899	2,019
Small Stock:											
Males											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,098	1,045	1,624	1,599	1,740	2,281	1,576	1,520	1,671	1,887	1,834
Females											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,071	1,052	1,599	1,568	1,725	2,257	1,583	1,520	1,696	1,774	1,710

TABLE 13--Continued

	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
0-3 yr olds											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,065	1,045	1,560	1,520	1,703	2,251	1,548	1,520	1,648	1,774	1,765

TABLE 14

SEASONAL SHADOW PRICES, 1979 (Sep - Nov Season--Shs./Stock Unit)

	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
Bulls											
Actual	665	665	1,425	1,140	1,482	1,762	1,482	1,482	1,140	1,577	1,577
Shadow	665	690	1,425	1,128	1,509	1,762	1,503	1,482	1,003	1,501	1,538
Cows											
Actual	665	665	1,425	1,140	1,482	1,767	1,482	1,482	1,140	1,577	1,577
Shadow	665	678	1,425	1,123	1,482	1,783	1,560	1,482	1,030	1,540	1,549
> 3 yr steers											
Actual	665	665	1,140	1,140	1,767	2,082	1,482	1,140	1,140	1,862	1,577
Shadow	752	704	1,140	1,127	1,753	2,057	1,482	1,140	1,140	1,947	1,577
2-3 yr steers											
Actual	636	636	1,111	1,111	1,453	1,738	1,453	1,453	1,111	1,538	1,538
Shadow	776	809	1,250	1,245	1,711	2,024	1,729	1,607	1,342	1,809	2,019
Small Stock:											
Males											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,099	1,045	1,624	1,599	1,740	2,282	1,576	1,520	1,671	1,897	1,834
Females											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,071	1,052	1,599	1,568	1,725	2,257	1,582	1,520	1,669	1,887	1,773

TABLE 14--Continued

	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
0-3 yr olds											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,065	1,045	1,560	1,520	1,703	2,251	1,548	1,520	1,648	1,939	1,765

TABLE 15

SEASONAL SHADOW PRICES, 1979 (Jun - Aug Season--Shs./Stock Unit)

	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
Bulls											
Actual	665	665	1,425	1,140	1,482	1,762	1,482	1,482	1,140	1,577	1,577
Shadow	385	690	1,425	1,128	1,509	623	1,573	1,482	1,003	1,501	1,504
Cows											
Actual	665	665	1,425	1,140	1,482	1,767	1,482	1,482	1,140	1,577	1,577
Shadow	385	678	1,425	1,123	1,482	623	1,560	1,482	1,030	1,540	1,514
> 3 yr steers											
Actual	665	665	1,140	1,140	1,767	2,080	1,482	1,482	1,140	1,862	1,577
Shadow	556	704	1,140	1,123	1,753	1,140	1,482	1,482	1,140	1,947	1,577
2-3 yr steers											
Actual	636	636	1,111	1,111	1,453	1,738	1,453	1,453	1,111	1,538	1,538
Shadow	636	839	1,250	1,245	1,711	1,338	1,799	1,507	1,342	1,899	1,992
Small Stock:											
Males											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,067	1,045	1,634	1,579	1,740	2,191	1,576	1,520	1,670	1,897	1,830
Females											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,045	1,052	1,599	1,568	1,725	2,185	1,589	1,520	1,669	1,887	1,770

TABLE 15--Continued

	Regions										
	One	Two	Three	Four	Five	Six	Seven	Eight	Nine	Ten	Eleven
0-3 yr olds											
Actual	1,045	1,045	1,520	1,520	1,615	2,185	1,520	1,520	1,520	1,710	1,710
Shadow	1,045	1,045	1,560	1,520	1,703	2,185	1,568	1,520	1,648	1,939	1,763

TABLE 16

REGION ONE--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Live-stock	Season				Total Production	Transfers Out		Transfers In	
	Dry	Wet	Dry	Wet					
Bulls	13	13	12	461	499	197(four)★	54(eleven)		
Cows	100	2,341	100	100	2,641	981(four)			
> 3 yr steers	500	2,750	500	2,750	6,500	--	--	729(two)	1,308(three)
2-3 yr steers	12,041	34,680	1,586	34,680	82,987	1,398(two) 3,892(eleven)	59,979(five) 8,054(four)		
1 yr steer	--	--	--	--	--				
				Total	92,628				
			Consumption Offtake		10%				
Small Stock:									
Males	2,254	2,255	2,254	2,255	9,018	1,053(five)			
Females	29,249	57,818	5,000	57,818	149,895	5,306(five)			
0-3 yr	20,000	141,895	123,925	141,895	427,715				
				Total	587,578				
			Consumption Offtake		32%				

★Numbers written out in parentheses refer to either destination or origin of transfer.

were shipped out of the area to regions four and eleven. An optimal solution in the production of culled cows was obtained only during the long rains. Production in all other seasons was at its lower bounds. Sixty percent of the culled cows produced were consumed within the region.

The production of steers was at its upper bound during the long and short rains. This was not sufficient for the regional demand, and extra steers were imported from regions two and three. Base solutions were obtained in the production of 2 - 3 year steers while production was at the upper bound during the rainy periods. Most of these steers were shipped to regions two, four, five, and eleven. A total of 92,628 head of cattle were produced.

Production of the male small stock (rams and billies) was at the upper bound for all seasons. A base solution was obtained in the off-takes of the female small stock during the December - February dry period and the upper bounds reached during the two wet seasons. Upper bounds in the production of the young stock were reached during the wet seasons and an optimal solution given during the second dry period (June - August). The exports of the small stock were mainly to region five. A total of 587,578 head of small stock were produced.

Marginal costs in the production of red meat per livestock unit during the December - February dry season are: bulls--Shs. 279, cows--Shs. 279, steers--Shs. 108, and male small stock--Shs. -22. This indicates that region one has a disadvantage in producing cattle and an advantage in producing small stock during the dry seasns. Production for all classes of stock is favorable, with more cost savings during the wet seasons.

Region two

Region two has a more even production of cattle throughout the seasons than any other region. Most of the culled bulls and culled cows are exported to region six. As observed earlier, 3 year old steers are shipped to region one in an apparent exchange for 2 - 3 year old steers. Some of the 2 - 3 year old steers are also transferred to region six. This is shown in Table 17.

Production of the male small stock is lowest during the dry periods, rising to peak production during the last two seasons. Exports occurred to regions five, six, and eleven. Female small stock production is spread over the seasons with most of their consumption occurring within the region and the rest shipped to region three. Production of the young stock occurred at optimal levels and consumed within the region. A total of 9,260 head of cattle and 106,080 head of small stock are produced in this region.

The "shadow" prices indicate that increasing production activities by one livestock unit will add to costs: bulls--Shs. -25, cows--Shs. -13.45, steers--Shs. -39.2, 2 - 3 year old steers--Shs. -203, and female small stock--Shs. -7.

This further indicates that region two, while holding an advantage in the production of all livestock classes, has an advantage in the production of two classes of steers.

Region three

Livestock production activities for region three are presented in Table 18. Production of the bulls occurs at the upper bounds during the wet seasons. Most of the bulls are exported to region ten. Production

TABLE 17

REGION TWO--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Livestock	Season				Total Production	Transfer Out	Transfers In
	Dry	Wet	Dry	Wet			
Bulls	105	105	105	105	420	375(six)★	
Cows	840	840	840	840	3,360	3,124(six)	
> 3 yr steers	500	500	500	500	2,000	729(one)	
2-3 yr steers	870	870	870	870	3,480	3,480(six)	1,398(one)
1 yr steers	--	--	--	--	--		
				Total	9,260		
			Consumption Offtake		11%		
Small Stock:							
Males	33	1,375	4,896	4,896	11,200	7,496(five) 1,535(eleven) 999(six)	
Females	8,000	8,000	8,000	8,000	32,000	10,745(three)	
0-3 year olds	3,750	24,130	31,250	3,750	62,880		
				Total	106,080		
			Consumption Offtake		28%		

★Numbers written out in parentheses refer to either destination or origin of transfer.

TABLE 18

REGION THREE--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Livestock	Season				Total Production	Transfers Out		Transfers In
	Dry	Wet	Dry	Wet				
Bulls	75	529	8	528	1,140	17(nine)★	990(ten)	
Cows	2,115	2,115	3,776	2,115	10,121	460(nine)	6,621(ten)	
> 3 yr steers	1,554	2,000	1,680	2,000	7,234	1,308(one)	2,490(four)	
2-3 yr steers	2,538	2,538	2,538	2,538	10,152	1,052(six)		
1 yr steers	248	--	--	--	248	248(six)		
				Total	28,894			
			Consumption Offtake		7%			
Small Stock:								
Males	1,375	1,375	1,375	1,375	5,500	498(ten)		
Females	37,503	37,503	37,503	37,503	150,012	4,692(nine)	65,186(ten)	10,745(two)
0-3 year olds	87,500	87,500	87,500	87,500	350,000	1,417(nine)	79,727(ten)	
				Total	505,512			
			Consumption Offtake		40%			

★Numbers written out in parentheses refer to either destination or origin of transfer.

of culled cows is more evenly spread out through the four seasons. The major markets are in the coastal regions nine and ten. Base solutions in the production of steers occurs during the dry seasons, while production reaches the upper bounds during the wet seasons. The steers are exported to regions one and four. The 2 - 3 year old steers are produced at the upper bound mainly for the home market. Only a total of 248 1 year old cattle are produced during the December - February dry season and shipped to region six. A total of 28,894 head of cattle are produced.

Production of small stock is at its upper bounds for all classes and during all seasons. All exports of small stock are destined to the Coast Province--regions nine and ten. Some female small stock are imported from region two to region three. Region three produces a total of 505,512 head of small stock, which is used for exports to aforementioned coastal markets and home consumption.

Most of the cattle are produced at optimal level during all seasons. Increasing the other activities adds to costs: 2 - 3 year old steers--Shs. 139, female small stock--Shs. -78.63, young stock--Shs. -39.57, and male small stock--Shs. -104.01. The advantage in this region is in production of 2 - 3 year old steers and small stock.

Region four

Table 19 contains region four's livestock production and marketing activities. Production of bulls, cows, and mature steers are at their lowest level for the four seasons. All bulls produced in the region are exported to region eleven, with internal consumption requirements met by exports from region one. Culled cows are imported from

TABLE 19

REGION FOUR--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Livestock	Season				Total Production	Transfers Out	Transfers In
	Dry	Wet	Dry	Wet			
Bulls	10	10	10	10	40	40(eleven)★	197(one)
Cows	100	100	100	100	400		981(one)
> 3 yr steers	200	200	200	200	800		2,490(three)
2-3 yr steers	4,540	4,540	4,540	4,540	18,160	18,160(six)	8,054(one)
1 yr steers	2,460	2,460	2,460	2,460	9,840	9,840(six)	
				Total	29,200		
			Consumption Offtake		5%		
Small Stock:							
Males	1,248	1,248	1,248	1,248	4,992	3,560(six)	
Females	18,750	18,750	18,750	18,750	75,000	17,234(five) 31,784(six)	
0-3 yr olds	5,407	62,500	62,500	62,500	192,907	116,047(six)	
				Total	271,467		
			Consumption Offtake		48%		

★Numbers written out in parentheses refer to either destination or origin of transfer.

region one to the low regional production. The region also imports steers from region three. Production of 2 - 3 year old steers is at its upper bound throughout the four seasons. All these steers are exported to region six, with regional internal requirements met from imports from region one.

All mature small stock are produced at their upper bounds throughout the four seasons. Exports of males occurs to region six. Female stock are exported to regions five and six. Production of young small stock is at the lower bound throughout the December - February dry season but remains at the upper bound for the following three seasons. Most of these stock are exported to region six. This region produces a total of 271,467 head of small stock.

Analysis of the cost effects shows that per livestock unit increases production costs by: bulls-Shs. 12, cows--Shs. 17.15, steers--Shs. 13, 2 - 3 year old steers--Shs. 134.19, 1 year old steers--Shs. -29.1, male small stock--Shs. -78, and female small stock--Shs. -47.75. This region has advantage in producing mature small stock and young steers.

Region five

Production of beef is at the upper bound throughout all seasons except for culled cows (see Table 20). Very few culled cows reached the markets during the first dry season. Mature steers are produced at the lower bound, indicating a slight disadvantage in producing this category of stock. This results in steers being imported from region eleven and bulls and culled cows being exported from region five to region eleven. Production of 2 - 3 year old steers is at the upper bound. The deficit

TABLE 20

REGION FIVE--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Live-stock	Season				Total Production	Transfers Out	Transfers In	
	Dry	Wet	Dry	Wet				
Bulls	1,543	1,543	1,543	1,543	6,172	1,045(eleven)★		
Cows	2,000	28,673	40,000	29,326	99,999	11,472(eleven)		
> 3 yr steers	8,500	8,500	8,500	8,500	34,000		72,293(eleven)	
2-3 yr steers	23,150	23,150	23,150	23,150	92,600		59,979(one)	9,330(eleven)
				Total	232,771			
			Consumption Offtake		8%			
Small Stock:								
Males	3,905	3,905	3,905	3,905	15,620		7,053(one) 879(seven)	7,496(two)
Females	100,244	100,245	100,245	100,244	400,976		22,540(four)	5,306(one)
0-3 yr olds	212,595	212,595	212,595	212,595	850,380		179,342(eleven)	
				Total	1,266,976			
			Consumption Offtake		38%			

★Numbers written out in parentheses refer to either destination or origin of transfer.

in meeting regional demand for this class of beef is met by importing steers from regions one and eleven.

Small stock production remains at upper bound. There is also extra importation of male small stock from regions one, two, and seven; female small stock from regions one and four; and young small stock from region eleven.

The region produces a total of 232,771 head of cattle and 1,266,976 head of small stock. Marginal costs on red meat production throughout the first season are: bulls--Shs. -27.52, steers--Shs. 14.57, young steers--Shs. -258.17, female small stock--Shs. -109.75, male small stock--Shs. -124.66, and young small stock--Shs. -88.96. This indicates that, with the exception of mature steers, the region could economically expand production of all other classes of livestock. Economic advantage is in expanding production of young steers and mature small stock.

Region six

As can be seen in Table 21, this region records the highest economic activity due to the heavy rural population concentrations together with the large Nairobi Metropolitan Center. Bull production is at the lowest bounds throughout the dry seasons and only attained optimal level during the short rains. Production of culled cows falls into the same pattern with the disadvantage falling during the dry months. Production of cows has a large shadow price throughout the dry periods (Shs. 1,128.74), while a small shadow price (Shs. -15.77) occurs throughout the wet seasons. This indicates that cow production is more favorable through the wet seasons. Production of young steers shows the same pattern as those shown by the other classes of cattle.

TABLE 21

REGION SIX--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Live-stock	Season				Total Production	Transfers In		
	Dry	Wet	Dry	Wet				
Bulls	25	243	25	1,987	2,280	375(two)★	2,175(seven)	
Cows	1,000	21,124	1,000	21,124	44,248	3,124(two) 324(eleven)	59,448(seven)	7,618(eight)
> 3 yr steers	--	--	--	--	--		31,717(seven)	25,798(eleven)
2-3 yr steers	312	22,785	313	22,785	46,195	3,480(two) 16,589(seven)	1,052(three) 6,132(eight)	18,160(four) 46,926(eleven)
1 yr steers	625	32,550	625	32,550	66,350	248(three)	35,000(seven)	11,456(ten)
				Total	159,073			
			Consumption Offtake		10%			
Small Stock:								
Males	3,750	3,750	3,750	3,750	15,000	999(two)	3,560(four)	
Females	86,047	86,047	53,609	86,047	311,750	31,784(four)	28,970(seven)	31,391(eleven)
0-3 yr olds	74,150	212,743	109,385	212,743	609,021	116,047(four)	344,477(seven)	
				Total	935,771			
			Consumption Offtake		34%			

★Numbers written out in parentheses refer to either destination or origin of transfer.

There is a large importation of cattle from several regions: bulls are imported from regions two and seven; culled cows from regions two, seven, eight, and eleven; and steers from regions seven and eleven. Regions two, three, four, seven, eight, and eleven supply young steers while regions three, seven, and ten supply 1 year old cattle. The region produces 159,073 head of stock internally.

Production of small stock is optimal for mature small stock and marginally optimal for young stock. Production is at the upper bound throughout the two wet seasons. The model indicates that increased production of small stock during the wet seasons will reduce the overall cost of meeting national demand of red meat. A total of 935,771 head of small stock is produced within the region. The rest of the supply is obtained from: males from regions two and four; females from regions four, seven, and eleven; and young stock from regions four and seven.

Costs are reduced by producing fewer beef bulls (Shs. 1,144.51) and beef cows (Shs. 1,128.74) during the dry seasons. The model indicates positive savings by not producing mature steers in this region. Production of young steers has a disadvantage throughout the dry seasons. However, the production of young steers throughout the wet seasons has a cost of Shs. -285.8. Expansion of small stock production throughout the wet seasons results in marginal cost reduction: females--Shs. 72.1, young stock--Shs. 66.38, and males--Shs. -6.24, per LU increased.

Thus, total savings due to change in production varies from season to season. The region has a disadvantage in producing mature cattle throughout the dry periods.

Region seven

Table 22 presents region seven emerging as a strong supplier of beef to region six. This is explained by the fact that Masailand lies parallel to region six. Production of mature cattle is at the upper bounds throughout the four seasons. Mature steers are produced at optimal levels. Production of other steers is at the highest allowable level. This implies that cost savings are made by producing many more steers of this category from region seven. All surplus cattle offtake is shipped to region six.

Production of all categories of small stock is at its highest allowable level. The excess males are exported to region five, females to region six, and young stock are shipped to both region five and region six.

A total of 170,113 head of cattle and 852,938 head of small stock are produced in the model. Increased livestock production results in cost reductions of: bulls--Shs. 91.05, cows--Shs. 78.47, young steers--Shs. 275.64, 1 year steers--Shs. 164.35, female small stock--Shs. 62.51, male small stock--Shs. 55.84, and young small stock--Shs. 28.32. Thus, region seven has an absolute advantage in producing all types of red meat. The greatest advantage, however, lays in expanding steer production for markets.

Region eight

Table 23 presents an optimal production of bulls, cows, and mature steers in this region. All of this production, except for 7,618 head of cows exported to region six, were consumed within the region. The other classes of beef are produced at the upper bounds. Most of these are

TABLE 22

REGION SEVEN--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Livestock	Season				Total Production	Transfers Out	
	Dry	Wet	Dry	Wet			
Bulls	612	612	612	612	2,448	2,175(six)★	
Cows	12,237	12,237	25,000	12,237	61,711	59,448(six)	
> 3 yr steers	375	5,290	16,477	16,477	38,619	31,717(six)	
2-3 yr steers	8,672	8,672	8,672	8,672	34,688	16,589(six)	
1 yr steers	5,000	10,000	10,000	10,000	35,000	35,000(six)	
				Total	170,113		
			Consumption Offtake		17%		
Small Stock:							
Males	1,500	1,500	1,500	1,500	6,000	879(five)	
Females	29,942	29,942	29,942	29,942	119,768	28,970(six)	
0-3 yr olds	181,792	181,793	181,792	181,793	729,170	344,477(six)	148,506(five)
				Total	852,938		
			Consumption Offtake		31%		

★Numbers written out in parentheses refer to either destination or origin of transfer.

TABLE 23

REGION EIGHT--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Livestock	Season				Total Production	Transfers Out		Transfers In
	Dry	Wet	Dry	Wet				
Bulls	8	8	7	136	158			
Cows	2,300	2,301	2,300	2,301	9,017	7,618(six)★		
> 3 yr steers	3,832	275	275	275	4,657			
2-3 yr steers	1,927	1,927	1,927	1,927	7,708	6,132(six)		7,295(nine)
1 year steers	1,377	1,377	1,377	10,000	5,508	5,508(six)		
				Total	27,048			
		Consumption Offtake			8%			
Small Stock:								
Males	7	7	2,307	3,408	5,729	1,318(nine)	4,061(ten)	
Females	375	375	375	4,040	5,165	1,151(nine)		
0-3 yr olds	62,676	62,676	3,910	1,000	130,262	105,372(ten)		
				Total	141,156			
		Consumption Offtake			30%			

★Numbers written out in parentheses refer to either destination or origin of transfer.

exported to region six, while region eight supplements its 2 - 3 year old steers by importing some 7,295 head from region nine.

Mature small stock production is at its lowest level throughout the first half of the year. Optimum production is obtained during the short rainy season. Production of young stock shows the opposite trend, with optimum production occurring early in the year while lowest production falls during the short rains. Mature small stock are shipped to the coastal regions. Over 80 percent of young stock produced in this region are exported to region ten.

Generally, this region has optimal regional production in all categories of red meats. Young steers, however, have a slight advantage over the rest of the livestock.

Region nine

Region nine shows an advantage in producing immature steers (2 - 3 year olds) throughout the year (see Table 24). Increased production of this class of stock reduces cost by Shs. 231.34. Optimal production of mature steers occurs during the last half of the year. The disadvantage in producing mature cattle is offset by importing this class of stock from region three. The steers produced are exported to both regions eight and ten.

The advantage in this region lays in the production of small stock. Increased production results in cost savings of: male small stock--Shs. 150.84, female small stock--Shs. 149.24, and young small stock--Shs. 128.38. Production of small stock is at the upper bound, with a total of 56,616 head produced within the region. There is an importation of males from region eight (possibly from the Tana River

TABLE 24

REGION NINE--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Livestock	Season				Total Production	Transfers Out		Transfers In	
	Dry	Wet	Dry	Wet					
Bulls	--	--	--	--				17(three)★	
Cows	15	15	15	15	60			460(three)	
> 3 yr steers	25	25	1,793	2,000	3,843	3,311(ten)			
2-3 yr steers	2,125	2,125	2,125	2,125	8,500	7,295(eight)	39(ten)		
1 yr steers	--	--	--	--	--				
				Total	12,403				
			Consumption Offtake		3%				
Small Stock:									
Males	175	175	175	175	700	700(ten)		1,318(eight)	
Females	2,564	2,564	2,564	2,564	10,256			4,692(three)	1,151(eight)
0-3 yr olds	11,415	11,415	11,415	11,415	45,660			1,417(three)	
				Total	56,616				
			Consumption Offtake		47%				

★Numbers written out in parentheses refer to either destination or origin of transfer.

District) of females from both regions three and eight and an importation of young stock from region three. The model also shows region eight exporting a few male small stock to region ten.

Region ten

The large metropolitan centers of Mombasa and Malindi turn this region into a heavy importer of all categories of livestock (see Table 25). Bull production, as well as culled cow production, are the lowest allowable levels. These two classes of livestock have marginal production costs of Shs. 75.6 for bulls and Shs. 36.6 for cows. The other classes of cattle are produced at their respectful upper bounds. Increased production results in reduced costs of: mature steers--Shs. 85.45, young steers--Shs. 361.25, and 1 year old steers--Shs. 149.83. This means that the region has a big comparative advantage in producing steers. The advantage lies in the production of 2 - 3 year old steers. This region relies on regions three and nine for supplies of imported beef. It also exports young steers to region six.

All categories of small stock are produced at their upper bounds. The model indicates that further cost savings are available by producing more small stock within the region. The national cost of producing red meat is reduced by as much as Shs. 229.43, and/or Shs. 176.84 by increasing the production of one livestock unit in the form of young stock and mature females, respectively. Most of the small stock imports to the region are from regions three and eight.

Region eleven

Table 26 presents the livestock activities as generated by the

TABLE 25

REGION TEN--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Livestock	Season				Total Production	Transfers Out	Transfers In	
	Dry	Wet	Dry	Wet				
Bulls	75	75	75	75	300			
Cows	500	500	500	500	2,000		6,621(three)★	
> 3 yr steers	7,776	7,776	7,776	7,776	31,104		3,311(nine)	
2-3 yr steers	1,625	1,625	1,625	1,625	6,500		39(nine)	
1 yr steers	1,152	1,152	1,152	8,000	11,456	11,456(six)		
				Total	51,360			
			Consumption		Offtake 19%			
Small Stock:								
Males	375	375	375	375	1,500		498(three) 700(nine)	4,061(eight)
Females	7,695	7,695	7,695	7,695	30,780		65,186(three)	
0-3 year olds	26,184	26,184	26,184	26,184	104,736		79,727(three)	105,372(eight)
				Total	137,016			
			Consumption		Offtake 28%			

★Numbers written out in parentheses refer to either destination or origin of transfer.

TABLE 26

REGION ELEVEN--LIVESTOCK PRODUCTION (OFFTAKES) AND TRANSFERS (1979 Base Year--Animal Head)

Live-stock	Season				Total Produc-tion	Transfers Out		Transfers In
	Dry	Wet	Dry	Wet				
Bulls	25	25	25	25	100			40(four)★ 1,045(five) 54(one)
Cows	350	350	350	350	1,050		342(six)	11,472(five)
> 3 yr steers	44,625	60,000	250	46,309	151,184	72,293(five)	25,798(six)	
2-3 yr steers	8,752	8,752	8,752	30,000	56,256	9,330(five)	46,926(six)	3,892(one)
1 yr steers	--	--	--	--	--			
				Total	360,932			
			Consumption Offtake		24%			
Small Stock:								
Males	1,625	1,625	1,625	1,625	6,500			1,535(two)
Females	45,200	45,200	45,200	45,200	180,800		31,391(six)	
0-3 yr olds	147,643	147,643	147,643	147,643	590,572	179,342(five)		
				Total	777,872			
			Consumption Offtake		33%			

★Numbers written out in parentheses refer to either destination or origin of transfer.

model. Mature cows are produced at the upper bound in the region with extra supplies imported from regions one, four, and five.

Production of steers varies with seasons. This region produces more steers during the first dry season than any other region. Production during the second dry season is very minimal. More savings are made (Shs. 481.83) by increasing production of young steers by one LU. This region imports a few immature steers from region one and exports two classes of steers to regions five and six.

This region has an advantage in producing small stock. Small stock are produced at the maximum allowable levels. Some of these are exported to regions five and six, while mature male small stock are imported from region two.

The model indicates that substantial cost savings are available by increasing the production of several classes of livestock. These savings are: bulls--Shs. 38.59, cows--Shs. 28.31, mature steers--Shs. 34.4 (during first half of year), young steers--Shs. 481.83, female small stock--Shs. 63.52, young stock--Shs. 55.22, and male small stock--Shs. 123.72. Thus, it is more economical to increase production of steers, particularly those between 2 and 3 years; this also is true for small stock

Simulated Reduction in Available Forage in Region Eleven

Region eleven and parts of region four cover areas that have been developed as commercial ranches over many years. These regions have supplied the urban areas with good quality beef for several decades,

but this source is now threatened by settlement schemes and consequent land subdivision.

Increased resettlement is expected to have an adverse effect on the capability of these regions to produce beef, particularly during the dry seasons. This is mainly because settlements tend to spread from ecologically-favorable producing areas (Zone III) to the marginal producing areas that are heavily relied on for grazing during wet periods.

Two simulations were incorporated into the base model. The first one involved a 43 percent (30,000 LU) reduction of the surplus forage available during the dry months. The results are shown in Table 27. The second simulation involved a 90 percent (60,000 LU) reduction of the excess forage available in region eleven as calculated earlier in Table 9. These calculation results are shown in tabular form later in this section.

43 percent forage cut in region eleven

The results presented in Table 27 indicate that this reduction has very little affect on the overall trend in red meat production. The changes in production affects the supply of mature steers involving regions five, six, seven, and eleven. Other livestock sectors are unaffected. Production of mature steers in region eleven falls by more than 60 percent during the December - February season. This results in a market reduction in animals exported to regions five and six from region eleven.

The reduction in exportation from region eleven is met by increasing production in region five to meet internal needs and by increasing

TABLE 27

LIVESTOCK PRODUCTION CHANGES, 43% FORAGE CUT IN REGION ELEVEN (Mature Steers)

Region	Seasonal Production				Total Production	Transfers Out	Transfers In
	Dry	Wet	Dry	Wet			
Five	18,511	18,511	18,511	129	55,662	--	-38,963(eleven)★
Six	--	--	--	--			27,289(seven) -19,103(eleven)
Seven	16,102	11,187	--	--	27,289	27,289(seven)	
Eleven	-28,066	--	--	-30,000	-58,066	-38,963(five) -79,103(six)	

★Numbers written out in parentheses refer to either destination or origin of transfers.

production and exports from region seven to replace losses in mature steer exports from region eleven to region six.

One observation in Table 27 is that replacement figures representing head of stock are not equal. A reduction of 19,103 head of steers from region eleven is replaced by 27,289 head of steers from region seven. The difference is due to the fact that steers from region eleven weigh 190 kg. CDW while those from region seven weigh 133 kg. CDW. Demand in red meat is expressed in terms of kg. of CDW, and both categories of steers add up to the same weight of beef exported to region six (3.6 million kg.) from either region seven or region eleven.

90 percent forage reduction in region eleven

This large reduction involves eliminating most of the present estimated excess (above subsistent requirement), 60,000 LU. Such a large cut, which is highly likely in the future, means a subsistent tillage of most of Zone III in Nakuru, Laikipia, and Kericho districts. It is the policy of the Kenyan government to settle people "on former large scale farms, so that more people will be employed and the land will be used more intensively" (*Development Plan*, 1974, p. 199). Further cooperative or total settlement allocation of most of the large ranching farms which are later subdivided into small individual plots would have such drastic effects. This is already going on in several parts of Nakuru district (ILCA, 1978).

The model solution indicates that such large reduction in forage available in region eleven has a drastic affect on the pattern of red meat production and intraregional shipments in all livestock-producing areas of Kenya. Changes that were observed are following.

Cattle--culled cows. The changes in the production and supply of culled cows is indicated in Table 28. The offtake of culled cows is affected in three regions. Both regions one and five increased their seasonal production while region three reduced the dry seasons' output by 52 percent. The model indicates large savings in costs by not producing beef cows in region eleven while optimal production is reached in region five. Culled cows offtake shows better returns in most of the regions during the wet seasons.

There is a marked shift in market flows of culled cows. Shipments from region three to ten are halted and replaced by exports from region eight. Region eleven transfers to region five are rerouted to region six. Region four produces for region six, importing its entire requirements from region one. The model also indicates region five becoming an important supplier of this class of stock to region six.

Cattle--mature steers. Steer production is heavily affected by the reduction of grazing availability in region eleven. Except for regions two, six, and ten, all regions increased their total output as shown in Table 29. The model shows that large cost reductions are made by producing more steers starting with region ten (Shs. 2,111.50), region nine (Shs. 2,026.05), region seven (Shs. 1,548.81), and region five (Shs. 1,537.21). Similar magnitudes in cost savings are made by expanding production in region six during the rainy periods. Increased production in all other regions except region two have similar marginal costs.

Reduced steer production in region eleven means a reduction in exports from this region to regions five and six. The largest reduction

TABLE 28

ADJUSTMENTS IN CULLED COW PRODUCTION (Animal Head)

Region	Seasonal Production			Transfers Out		Transfers In	
	Dry	Wet	Dry				
One		400		400(four)★			
Three	-731		-2,324	-3,055(ten)			
Four				400(six)		400(one)	
Five	2,001	653		1,596(six)		-1,058(eleven)	
Six						-3,055(eight) 1,596(five)	1,058(eleven) 400(six)
Eight				-3,055(six)	3,055(ten)		
Ten						-3,055(three)	3,055(eight)
Eleven				-1,058(five)	1,058(six)		

★Numbers written out in parentheses refer to either destination or origin of transfers.

TABLE 29

ADJUSTMENTS IN MATURE STEERS PRODUCTION (Animal Head)

Region	Seasonal Production				Transfers Out		Transfers In	
	Dry	Wet	Dry	Wet				
One	2,250		2,250		2,463(four)★		-729(two)	-1,308(three)
Two					-729(one)	729(six)		
Three	3,446		3,321		-1,308(one) 9,737(six)	-1,663(four)		
Four	1,925	1,925	1,925	1,925	8,500(eleven)		2,463(one)	-1,663(three)
Five	18,511	18,511	18,511	18,511			-26,726(eleven)	19,799(seven)
Six							9,737(three) 897(ten) -25,798(eleven)	17,616(eight) 7,491(seven)
Seven	16,102	11,187			7,491(six)	19,799(five)		
Eight	572	4,129	4,129	4,129	17,616(six)		3,260(nine)	
Nine	1,975	1,975	207		3,260(eight)	897(ten)		
Ten					897(six)		897(nine)	
Eleven	-44,375	-8,178		-44,886	-65,690(five)	-25,798(six)	8,500(four)	

★Numbers written out in parentheses refer to either destination or origin of transfers.

(90 percent) is on steers marketed to region six. This shortage is picked by increasing intraregional production supplemented by more supplies from region seven to six. Regions three, eight, and ten also play prominent parts in supplying steers to the large metropolitan population of region six. Region four supplements region eleven with the latter's falling production. Region nine boosts the supply of region eight, thus, making it possible for region eight to release its production to region six.

Cattle--young steers. Forage production in region eleven has very little effect on the production and marketing of the rest of the cattle classes. The offtake of 2 year old steers is affected only in regions one and eleven. The December - February production is reduced in both regions. Further reductions are observed in region eleven, thus, affecting the supply of this category of steers to region five. Production in region one is increased during the third season, with the surplus marketed to region five to offset the reduced supply from region eleven (see Table 30).

The supply of 1 year old steers are reduced from region four, apparently, to allow for increased offtake of mature steers. This reduction affects the supply of 1 year old steers to region six. However, this was offset by region three's increase in production and supply of this same class of steer to region six.

Small stock--culled males. A 1 percent change in culled males' output is observed in region eleven during the first three seasons of the year. Production also decreases in both regions one and six during

TABLE 30

ADJUSTMENTS IN THE PRODUCTION OF YOUNG STEERS (Animal Head)

Region	Seasonal Production				Transfers Out	Transfers In	
	Dry	Wet	Dry	Wet			
				2-3 Year Steers			
One	-1,710		6,248		4,538(five)★		
Five						4,538(one)	-2,836(eleven)
Eleven	-418		-2,418		-2,836(five)		
				1 Year Steers			
Three	-248	2,220		866	2,839(six)		
Four	-1,420		-1,420		-2,840(four)		
Six						2,839(three)	-2,840(four)

★Numbers written out in parentheses refer to either destination or origin of transfers.

the dry seasons but shows a marked increase in regions two and eight (see Table 31).

Region two plays an important role by meeting requirements of region five after the latter's reduced supply from region one. It also ships some animals to regions one, six, and eleven to meet these regions' reduced internal production. Region eight also becomes a major supplier by shipping its entire increase in production to region six.

Small stock--culled females. Production of female stock repeats the same pattern as that of male stock. Reduction in production is observed in regions one, six, and eleven. Region eleven records a more than 80 percent reduction in production during the first three seasons of the year. Similar large production deficits occur in region six during the two dry seasons.

Marginal costs indicate large savings are made by increasing production in region one--Shs. 107.57 during the dry months and Shs. 179.33 during the wet months. Regions two and four also offer large advantages in cost savings if production is increased.

Table 32 indicates a general trend for most of the regions trying to be self-sufficient and export very little to other areas. Region two stops its shipment to region three and transfers this export to region four. Region four ceases to be a major exporter of culled nannies as it increases its production of both mature steers and young small stock. Most of regions six and eleven requirements are met mainly from region seven. Region eight, however, dominates the interregion exports with shipments to regions six, seven, and nine.

TABLE 31

ADJUSTMENTS IN CULLED MALE PRODUCTION (Animal Head)

Region	Seasonal Production			Exports		Imports	
	Dry	Wet	Dry				
One	-2,004		-2,005	-1,053(five)★		2,956(two)	
Two	4,863	3,521		2,956(one) -243(six)	1,053(five) 4,132(eleven)		
Five						-1,053(one)	1,053(two)
Six	-3,625		-3,625			-243(two)	7,369(eight)
Eight	3,402	2,866	1,102	7,369(six)			
Eleven	-1,402	-1,402	-1,402			4,132(two)	

★Numbers written out in parentheses refer to either destination or origin of transfers.

TABLE 32

ADJUSTMENTS IN CULLED FEMALE STOCK PRODUCTION (Animal Head)

Region	Seasonal Production				Exports		Imports	
	Dry	Wet	Dry	Wet				
One	-5,306				-5,306(five)★			
Two					-10,745(three)	10,745(four)		
Three					-4,692(nine)	-6,053(ten)	-10,745(two)	
Four					-17,234(five)	-31,784(six)	10,745(two)	
Five							-5,306(one)	-17,234(four)
Six	-81,672		-49,234				-31,784(four) 130,912(eight)	30,828(seven) -31,391(eleven)
Seven					30,828(six)	31,553(eleven)	67,331(eight)	
Eight	105,645			108,460	130,912(six) 15,862(nine)	67,331(seven)		
Nine					6,254(ten)		-4,692(three)	17,013(eight)
Ten							-6,053(three)	6,254(nine)
Eleven	-36,587	-40,200	-40,200		-31,391(six)		31,553(seven)	59,764(four)

★Numbers written out in parentheses refer to either destination or origin of transfers.

Small stock--young stock. Region eleven shows large reductions in the production of young stock during the dry seasons. Production is at upper bounds during the short rains but expanded production is achieved economically during this season. Region two increases its production as region one decreases it, hence, region one decreases its exports to region two. Savings of Shs. 138.83 is achieved by increasing per livestock unit production of young stock in region one during wet seasons. Stepped-up production also is noticed in regions four, six, and eight.

Table 33 presents the adjustments that occur in young stock production. Region seven rechannels its exports from region six to region five. Region six requirements are met through increases in intraregional production and with some imports from region eight. A reduction in production in region eleven results in market imports from region four. Region four's exports replaces region eleven imports from region five.

TABLE 33

ADJUSTMENTS IN YOUNG STOCK PRODUCTION (Animal Head)

Region	Seasonal Production				Exports		Imports	
	Dry	Wet	Dry	Wet				
One			-62,120					
Two	27,500	7,120		2,750			-62,120(one)★	
Four	57,093				-26,833(six)	83,925(eleven)		
Five							-179,345(eleven)	228,816(seven)
Six	93,651		58,416				-228,816(seven)	120,442(eight)
Seven					-228,816(six)	228,816(five)		
Eight			58,766	61,676	120,442(six)			
Eleven	-133,893		-127,107		-179,345(five)		83,925(four)	

★Numbers written out in parentheses refer to either destination or origin of transfers.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Beef production will always remain a major production sector because most of Kenya is rangeland, suitable only for either livestock keeping or wildlife habitation. Livestock remains the major source of income and subsistent living for the majority of people living in the pastoral districts of Kenya. The purpose of this study was to develop a production and transportation model that yields optimal solutions to the production and supply of red meat to meet national requirements under: (1) 1979 forage supply conditions, and (2) region eleven's forage reductions due to resettlement schemes and land subdivision.

Conclusions

The base year (1979) yields the least-cost regional sources and distributional patterns for supplying red meat for that year. Forage availability and regional location in relation to major urban areas are major factors determining red meat production.

All regions show a very high cost of supplying red meat from culled bulls compared to other classes of livestock. Base year simulation shows that regions two, three, five, and seven have a comparative advantage in producing bulls. The greater disadvantage lays with region

six. Bulls are, therefore, an expensive means of supplying beef and less of the same should be produced.

Production of cows shows the same pattern as for bulls. The wet seasons favor increases in production of cows in more regions than they do for bulls.

Regions one and six have the disadvantage in producing both bulls and cows during the dry seasons. This conclusion is based on beef production since milk production is not included in the model. Large marginal costs in the production of "breeding herds" do not mean that production is uneconomical. In many areas, beef production from this class of livestock is secondary to dairy production.

It apparently is uneconomical to raise steers to mature levels in region six in any season. Savings, though on a smaller magnitude, are made by not producing steers to mature levels in regions four and five. Such steers are produced with good results during the dry seasons in region one. The country could optimally produce mature steers in all the other regions. The advantage is found in producing these steers in regions ten, nine, seven, and two. Region eleven has similar advantages in producing mature steers during the wet seasons. This indicates that mature steers can be raised or finished profitably in regions nine and ten and only during the wet seasons in region eleven. It should be remembered that level of management is very important in deciding where to produce.

Young steers (2 - 3 years) can be expanded economically in all regions. Regional advantage in their production is in the following order: eleven, ten, seven, five, nine, two, eight, one, three, four, and six.

While regions eleven and ten have overall comparative advantage throughout the year, region six has an advantage in having steers only during the wet seasons.

Regions eleven, seven, and three stand prominently, in that order, in the supply of beef to markets. This compares favorably with the normal pattern of interregional beef supply in the country. The advantage in beef production is in regions eleven, ten, nine, and seven.

The model indicates that all regions can profitably increase production of all classes of small stock. Considerable advantage can be achieved by increasing production of small stock in regions nine and ten. This, apparently, is due to the small "shoats" population in an area with a large urban center of Mombasa. Regions five and eleven are the next areas showing large advantages in expanding production of small stock.

The simulated forage reduction shows that increased cultivation in region eleven does not very much affect the supply of red meat. The supply still can be met at an added cost of K£262,056. Shifts in the pattern of production and exports are necessary in order to meet the demand for red meat.

The production of "breeding cattle" changes very little except for an increased output in region five to meet the reduction in supply from region eleven. It becomes necessary for this region to become self-sufficient in culled cows and export some to region six. Region three also has to change its pattern of production by increasing production of mature steers at the expense of culled cows.

The largest increase in costs due to region eleven's cut in forage availability occurs through a wide diversification in the production of steers. Diversification means increasing production of steers in some regions that have shown to have a disadvantage in the base model.

All regions show a large cost savings by producing steers. Regions ten, seven, and five have the advantage while regions one, three, and four have the disadvantage. This indicates that it is profitable to purchase young steers from regions one, three, and four and finish them in regions ten, seven, and five. Finishing of steers also is profitable in region eleven during the rainy seasons.

There is no change in the production of male small stock. Diversification in the production of steers in region one also reduces production of small stock. Regions two, seven, and eight become the most important suppliers of small stock. It is very profitable to increase production of young stock in region six during the wet seasons. This occurs despite the reduction of small stock breeding herds in the same region. Big cost reductions are made by increasing small stock production in regions nine and ten.

The base solution indicates that the major markets are:

1. Region six--mainly supplied by regions four, seven, eight, and ten in beef and by regions four, seven, and eleven in small stock.

2. Region five--mainly supplied by regions one and eleven in beef and by regions one, four, and eleven in small stock.

3. Region ten--mainly supplied by regions three and nine in beef and by regions three and eight in small stock.

In the simulated forage reduction model, region eight increased its livestock shipment to region six. Region seven had to divert most of its production to region five, importing 20 percent of its small stock requirement from region eight.

Diversification in regional livestock production is eminently visible with the reduction in region eleven's potential to produce livestock. In both models, region three does not play a prominent role despite its size. Region eight is more important in meeting market demands.

Recommendations

Solution of the present livestock production problems in Kenya calls for a larger research than this study offers. The author would recommend a larger scale of study incorporating the dairy sector as well as other sources of red meat (swine, poultry, etc.). A larger study involving all range resources beneficial to the country would indicate the full productivity of Kenyan rangelands.

The present study assumes unrestricted movement of livestock from surplus areas to deficit regions. This is assumed even though present veterinary regulations prohibit some interregional movements. A study on the cost of this prohibitation, particularly between regions one and five, is recommended. This study also should show whether it is economical to haul animals between regions by lorries for immediate slaughter.

Settlements in the Rift Valley do not seem to bring deficits in the red meat supply only if increased production is met particularly from regions two, five, seven, and eight. Region ten indicates a large advantage in production of steers, but the total offtake is restricted

by the number of steers in the region. The model recommends more investments in livestock facilities in regions five, seven, and eight. Extra forage available in regions six and eleven during the wet seasons could boost the supply of red meat. The model indicates that it is profitable to produce young stock for the market during the rainy periods in region six. This calls for either the importation of this category of stock to the region during the two seasons, or, if supplemental feeding can be found during the June - August dry months, then it is possible to bring intraregionally-born young small stock to market in nine months.

Since region ten shows an advantage in producing steers, present ranching activities are emphasized even more in view of the present likelihood of large reductions of livestock keeping potential of region eleven.

Thus, it appears that the country has the capacity to satisfy the demand for red meat if more widespread livestock production is emphasized. Diversification calls for added capital costs since most of the already developed areas are fully stocked. The model shows that the indicated diversification would raise the total operating costs by 12.3 percent. The increase in operating costs, extra capital costs, and the possible year-to-year inflationary trend would mean regular increases or government appraisal of red meat prices. The price incentive will be a necessary component of successful diversification in production.

Total salable output is based on the assumption that the livestock holders will always be willing to sell their stock. This is not always the case, and lack of supplies, as indicated, would affect the optimal solution. Fortunately, most pastoralists are becoming

commercially minded and are willing to sell their stock whenever they think the price given is right. Transformation of traditional subsistent livestock husbandry into systems increasingly oriented towards production for the market has been a Kenyan government objective.

The model indicates forage surpluses in most of the regions. Therefore, it appears that the limit in increased production seems to be the national herd size, degree of animal husbandry, extension work activities, and investment and distribution of livestock facilities. Increased investments in these inputs would help towards boosting livestock production in the country.

SELECTED BIBLIOGRAPHY

Aldington, T. J., and Wilson, F. A. *The Marketing of Beef in Kenya*. Nairobi, Kenya: Institute of Development Studies, University College, 1968.

Andersen, Douglas Lee. "An Interregional Competition Study of Utah Agriculture Using the Linear Programming Technique." M. S. thesis, Utah State University, Logan, Utah, 1975.

Ayuko, L. J. "The Potential of Ruminant Livestock to Produce Food and Other Products for Man." Paper presented to Wilcox International, 1976.

Bailey, DeeVon. "Economic Impacts of Public Grazing Reduction in the Livestock Industry with Emphasis on Utah." M. S. thesis, Utah State University, Logan, Utah, 1980.

Brokken, Ray F., and Heady, Earl O. *Interregional Adjustments in Crop and Livestock Production: A Linear Programming Analysis*. Technical Bulletin No. 1396. Washington, D.C.: U. S. Department of Agriculture, 1968.

Bunderson, N. L. "Livestock Production from Rangeland and Ranches." *Proceedings of the Seminar on Animal Husbandry and Marketing*. Nairobi, Kenya, 1968.

Buse, B. C., and Bromley, D. W. *Applied Economics*. Ames, Iowa: Iowa State University Press, 1975.

Chemonics, Int. *Livestock and Meat Industry Development Study*. Prepared for the Ministry of Agriculture by Chemonics International, Washington, D.C. in association with Hawkins and Associates. Nairobi, Kenya, 1977.

Dahl, G., and Hjort, A. *Having Herds and Pastoral Herd Growth and Household Economy*. Sweden: University of Stockholm, 1976.

Development Plan: Kenya 1974-1978. (Parts I and II). Nairobi, Kenya: Government Printer, 1974.

Dietrich, Raymond A. *Interregional Competition in the Cattle Feeding Economy*. Texas Agricultural Experiment Station Bulletin B-1115. College Station, Texas, 1971.

Dorfman, Robert. "Mathematical or 'Linear' Programming: A Nonmathematical Exposition." *American Economic Review* 43(December 1953): 797-825.

East African Range Classification Committee. "Report of the East African Range Classification Committee." Nairobi, Kenya: East African Agriculture, Forest, and Research Organization, 1965.

Egbert, Alvin C., and Heady, Earl O. *Interregional Competition of Spatial Equilibrium Models in Farm Supply Analysis in Agricultural Supply Functions*. (Edited by Earl O. Heady) Ames, Iowa: Iowa State University Press, 1961.

ESSO Oil Company. *East Africa Road Map*. Nairobi, Kenya, 1971.

Food and Agriculture Organization (FAO). "Report of the First FAO Africa." Regional meeting on animal production and health held at Addis, Adaba, Ethiopia, 1964.

FAO, and United Nations Development Project. *East African Livestock Survey: Regional--Kenya, Tanzania, and Uganda*. Nairobi, Kenya, 1967.

FAO, and United Nations Development Project/Kenya. *Sheep and Goat Development II*. Project of the Government of Kenya. Nairobi, Kenya, 1978.

FAO/World Bank. *The Outlook for Meat Production and Trade in the Near East and East Africa: Volume I--Market Situation, Problems and Prospects, and Volume II--Livestock Development Country Studies*. Nairobi, Kenya, 1977.

Fox, K. A. "A Spatial Equilibrium Model of the Livestock Feed Economy in the United States." *Econometrica* 21(1953):547-566.

Gray, Kenneth H. "An Evaluation of the Competitive Position of Utah Livestock Production to Other Livestock Production Areas." M. S. thesis, Utah State University, Logan, Utah, 1972.

Griffiths, H. F. "The Climate of East Africa." *The National Resources of East Africa* (1962):77-87. East African Literature Bureau.

Grimshaw, Paul R. "Economic Considerations for Expanded Feeding of Livestock in the Pacific Northwest." Ph.D. dissertation, Oregon State University, Corvallis, Oregon, 1972.

Gulliver, P. H. *The Family Herds. A Study of Two Pastoral Tribes in East Africa--The Jie and the Turkana*. London: Routledge & Kegan Paul Ltd., 1955.

Hall, Harry H., and Heady, Earl O. "Models of Interregional Competition, Production Allocation Land Use, and Spatial Equilibrium." In *Economic Models and Quantitative Methods for Decisions and Planning in Agriculture*. Edited by Earl O. Heady. Ames, Iowa: Iowa State University Press, 1971.

Heady, Earl O., and Candler, Wilfred. *Linear Programming Methods*. Ames, Iowa: Iowa State University Press, 1958.

Heady, Earl O., and Egbert, A. C. "Programming Regional Adjustments in Grain Production to Climinate Surpluses." *Journal of Farm Economics* 41(November 1959):718-733.

Heady, H. F. *Range Management in East Africa*. Nairobi, Kenya: Government Printer, 1960.

Heyer, J., Maitha, J. K., and Senga, W. M. *Agricultural Development in Kenya: An Economic Assessment*. Nairobi, Kenya: Oxford University Press, 1976.

Hornby, H. E., and Van Rensburg, H. J. "The Place of Goats in Semi-Arid Areas of East Africa." *East African Agricultural Journal* 14 (1948):94-98.

International Livestock Center for Africa (ILCA). "Preliminary Results of the Ranch Component Monitoring Programme." Nairobi, Kenya, 1978.

_____. *Economic Trends: The Nigerian Economy, Agriculture and the Livestock Sector*. Bulletin 6. Addis Ababa, Ethiopia, 1979.

_____. Working Document 13--district ranch development briefs. Nairobi, Kenya, 1979.

_____. *Economic Trends: The ILCA Research Programme on Small Ruminants*. Bulletin 7. Addis ababa, Ethiopia, 1980.

Judge, G. G., and Wallace, T. O. "Estimation of Spatial Price Equilibrium Models." *Journal of Farm Economics* 40(November 1958): 801-820.

Kenya Beef Industry Development Project. *Molasses Supplement for Livestock*. Bulletin 1. Nairobi, Kenya, 1969.

Kenya Government. *Proceedings of the Livestock Development Conference*. Nairobi, Kenya, 1967.

_____. *Atlas of Kenya*. Nairobi, Kenya, 1969.

Kidner, E. M. "A Note on Beef Production in Kenya." Paper presented at the Conference on Animal Production and Management in Range Areas, Kitale. 1964.

Kindleberger, Charles P. *Economic Growth in France and Britain, 1851-1950*. New York: Simon and Schuster, 1969.

Lampkin, K., and Howard, D. A. "Studies on the Production of Beef from Zebu Cattle in East Africa." *Journal of Agricultural Science* 59 (1962):245-249.

Ledger, H. P. "The Importance of Stock Selection for Increasing Productivity of Semi-Arid Areas." Nairobi, Kenya: East African Agriculture, Forest, and Research Organization, 1961.

_____. "Special Problems of African Meat Production." *Proceedings of the Seminar on Animal Husbandry and Marketing* (Vol. 1). Nairobi, Kenya, 1968.

Malory, G. M. O., and Heady, H. F. "Grazing Conditions in Kenya Maasailand." *Journal of Range Management* 18(March 1965):269-272.

Mares, R. G. *The African Nomad. East Africa: An Introduction to Animal Husbandry in the Tropics*. London: Longmans, 1959.

Mbithi, P., and Barnes, C. *Spontaneous Settlement Problems in Kenya*. Nairobi, Kenya: East African Literature Bureau, 1975.

Mbithi, P., and Wisner, B. "Drought and Famine in Kenya: Magnitude and Attempted Solutions." Nairobi, Kenya, University of Nairobi, 1975.

Meadows, S. J., and White, J. M. *Structure of the Herd and Determinants of Offtake Rates in Kajiado District in Kenya, 1952-1977*. Nairobi, Kenya: Overseas Development Institute, 1979.

Metson, J. E. *A Baseline Survey for the Evaluation of the FMD Control Programme in Narok and Kajiado Districts--IDS*. Nairobi, Kenya: University of Nairobi, 1974.

Meyn, Klaus. *Beef Production in East Africa*. Munich, Germany: Institut Fur Wirtschaftsforschung, 1970.

Mighell, Ronald, and Black, John D. *Interregional Competition in Agriculture*. Cambridge, Mass.: Harvard University Press, 1951.

Morgan, W. W., and Shaffer, N. M. *Population of Kenya: Density and Distribution*. Nairobi, Kenya: Oxford University Press, 1966.

Musangi, R. S. "The Digestibility of a Tropical Grass/Legume Herbage Mixture During the Dry Season." *African Soils* 10(1965):313-316.

Mwangi, Z. J. "Rangeland Production." Letter Grass/I/VI of April 12, 1979 sent to the Head of Animal Production Branch, Nairobi.

Nef, Dennis L. "A National Interregional Study of Agricultural Sector Adjustments to Drought with Emphasis on Utah." M. S. thesis, Utah State University, Logan, Utah, 1979.

Ohlin, Bertil G. *Interregional and International Trade*. Cambridge, Mass.: Harvard University Press, 1935.

Ominde, S. H. *Population of Kenya, Tanzania and Uganda*. Nairobi, Kenya: Heineman, 1975.

Pratt, D. J., Greenway, P. J., and Gwynne, M. D. "A Classification of East African Rangeland with an Appendix on Terminology." *Journal of Applied Ecology* 3(1966):369-382.

Pratt, D. J., and Gwynne, M. D., eds. *Rangeland Management and Ecology in East Africa*. New York: Robert E. Krieger Publishing Company, 1976.

Review Mission. *Kenya's Second Livestock Development Project--Credit 477-KE*. Nairobi, Kenya, 1977.

Schrader, Lee F., and King, Gordon A. "Regional Location of Beef Cattle Feeding." *Journal of Farm Economics* 44(February 1962):64-81.

Shell Oil Company. *Road Map of Kenya*. Nairobi, Kenya: Kenya Shell Company, 1972.

Skerman, P. J. "Report on the Improvement of the Beef, Mutton and Wool Industries of Kenya." Nairobi, 1961. (mimeo)

Smith, Adam. *An Inquiry into the Nature and Causes of the Wealth of Nations*. London: George Routledge & Sons, Ltd., 1776.

Sorensen, Terrell D. "Interregional Competition in Markets Facing Utah Livestock and Poultry Producers." M. S. thesis, Utah State University, Logan, Utah, 1978.

Spinks, G. R. "Marketing of Livestock and Meat in Kenya." 1965. (mimeo)

Stoddart, L. A., Smith, A. D., and Box, T. W. *Range Management*. New York: MacGraw-Hill Book Company, 1975.

Stovall, John G. "Sources of Error in Aggregate Supply Estimates." *Journal of Farm Economics* 48(May 1966):477-479.

Synnerton, R. J. M. *A Plan to Intensify the Development of African Agriculture in Kenya*. Plan compiled for the Colony and Protecturate of Kenya, Nairobi, 1954.

Takayama, Takasi, and Judge, George S. *Spatial and Temporal Price and Allocation Models*. Amsterdam, The Netherlands: North-Holland Publishing Company, 1971.

Thom, Derrick J. Personal conversations on his experience with the Arid and Semi-Arid Project in Kenya. Logan, Utah, Professor of History and Geography, Utah State University.

Wamukota, H. W. *Analysis of Livestock Auction Prices in Various Regional Markets*. Nairobi, Kenya: Ministry of Agriculture, 1979.

Weekly Review (November 30, 1979). (Kenya census figures out).

Windstrand, C. G. "The Rationale of Nomad Economy." *AMBIO* 4(1975): 28-34.

APPENDICES

Appendix 1: 1979 Population Figures[1] (1,000)

Nairobi: 835,000

Central Province

Kiambu:	686,000
Kirinyaga:	295,000
Muranga:	647,000
Nyandarua:	233,000
Nyeri:	487,000

Eastern Province

Embu:	262,000
Isiolo:	43,000
Kitui:	464,000
Machakos:	1,019,000
Marsabit:	96,000
Meru:	833,000

Nyanza Province

Kisii:	867,000
Kisumu:	480,000
Siaya:	472,000
S/Nyanza:	815,000

Western Province

Bungoma:	503,000
Busia:	300,000
Kakamega:	1,033,000

Coast Province

Kilifi:	428,000
Kwale:	287,000
Mombasa:	342,000
Taita/Taveta:	148,000
Tana River:	92,000

N. Eastern Province

Garissa:	129,000
Mandera:	105,000
Wajir:	139,000

Rift Valley Province

Baringo:	203,000
E/Marakwet:	149,000
Kajiado:	149,000
Kericho:	635,000
Laikipia:	134,000
Nakuru:	522,000
Nandi:	293,000
Narok:	213,000
T/Nzoia:	260,000
Samburu:	77,000
Turkana:	143,000
Uasin Gishu:	304,000
W/Pokot:	158,000

TOTAL: Kenya -- 15,322,000

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[1] *Weekly Review* (November 30, 1979). Kenya census figures.

Appendix 2: Total Meat Demand

TABLE 34

TOTAL MEAT DEMAND (1,000 Kg.)

Region	Rural Areas		Urban Centers	
	Beef	Small Stock	Beef	Small Stock
One	2,416.1	8,554.2	--	--
Two	355.2	1,257.6	--	--
Three	1,446.7	5,122.1	577.6	255.0
Four	829.6	1,244.4	669.9	295.8
Five	50,176.8	17,884.8	6,318.4	2,082.2
Six	31,258.6	10,276.8	28,914.6	5,863.8
Seven	2,816.0	3,590.4	286.0	58.0
Eight	2,209.0	2,491.0	--	--
Nine	288.0	784.0	43.2	117.6
Ten	2,992.0	3,080.0	6,424.0	2,117.0
Export			10,315.0★	

★Average for 1967-74 (Heyer, Maitha, and Senga 1976).

Appendix 3: Regional Forage (HA) Availability

TABLE 35

REGIONAL FORAGE AVAILABILITY (Livestock Units)

District	Zone II	III	IV	V	VI	Total LU's
			Region One			
Baringo	61,958	82,479	186,680	647,000	1,000	
Turkana	654,000	8,000	61,300	353,900	2,150,915	
W/Pokot	67,554	92,871	89,000	194,000		
E/Marakwet	80,254	13,352	--	107,700		(1,259,374)
			Region Two			
Marsabit	8,135		119,042	(1,712,813)	5,372,000	(310,656)
			Region Three			
Wajir				4,580,000	1,033,000	
Mandera				45,000	2,602,000	
Isiolo				1,177,000	1,344,000	
Garissa				3,595,000	244,000	
Tana				1,000,000	--	
Tharaka				446,301	--	(1,028,000)
			Region Four			
Samburu	74,047	53,000	161,619	1,338,010	125,517	
Laikipia	4,422	60,450	481,805	107,000	--	(495,799)

TABLE 35--Continued

District	Zone II	III	IV	V	VI	Total LU's
			Region Five			
Nyanza	200,586	970,698				
W/Province	427,483	263,328				
Nandi	106,739	125,800				
U/Gisho	116,399	--	20,560	10,000		
T/Nzoia	22,181	177,855				(2,198,040)
			Region Six			
C/Province	619,534	260,094	46,300	2,000		
Embu	5,494	38,396	26,000	157,796		
Meru	105,467	84,345	60,379	--		
Machakos	36,000	179,713	409,055	749,150		(1,520,890)
			Region Seven			
Narok	669,544	381,000	646,000	79,000		
Kajiado	19,759	21,000	744,000	1,270,794		(1,962,000)
			Region Eight			
Kitui		86,263	151,785	2,198,545		
Tana		50,000	139,000	1,980,000		(449,421)
			Region Nine			
Lamu	107,564	265,764	200,017	23,000		
Tana	150,000	--	--	--		
Garissa	16,500	3,000	53,400	--		(777,474)

TABLE 35--Continued

District	Zone II	III	IV	V	VI	Total LU's
			Region Ten			
Kiliji	117,236	548,933	242,000	271,000		
Kwale	97,740	198,893	370,000	113,000		
Taita	17,600	7,000	100,175	680,648		
Tana	180,000	54,000	--	--		(1,280,080)
			Region Eleven			
Nakuru	237,607	121,000	256,637			
Laikipia	187,100	60,443	--			
Kericho	141,115	189,000	--			(1,002,963)

Appendix 4: Minimum Livestock Requirements

TABLE 36

MINIMUM LIVESTOCK REQUIREMENTS (1,000 Head)

	Cattle						Small Stock		
Region	Bulls	Cows	> 3 Yrs. M/Steers	2 - 3 Yrs. M/Steers	Y/Steers	Calves	Males	Females	0 - 3 Yrs.
One	46.65	375.15	51.22	85.56	134.82	192.60	19.48	487.06	730.59
Two	4.0	32.54	3.56	6.96	11.76	16.80	4.12	127.84	141.75
Three	20.36	163.64	18.07	23.56	59.22	84.60	12.23	305.70	458.56
Four	23.76	244.18	10.64	41.84	98.40	137.76	3.90	117.07	175.61
Five	54.18	1,120.39	75.09	262.88	493.92	679.14	52.08	801.96	1,228.97
Six	14.05	562.00	--	150.48	334.40	393.40	24.49	734.82	11,022.20
Seven	46.49	450.29	16.48	138.76	183.54	262.20	3.80	103.60	188.70
Eight	14.08	140.8	9.67	26.28	55.08	73.40	4.50	112.51	168.78
Nine	12.62	155.98	16.32	24.38	77.18	90.80	1.60	40.00	60.00
Ten	4.26	76.38	11.84	32.24	46.08	57.60	4.28	128.25	209.47
Eleven	8.56	318.20	57.00	222.40	264.52	295.64	20.09	601.63	963.70