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INVESTMENTS IN NIGERIA'S NORTHERN CATTLE INDUSTRY: A SIMULATION ANALYSIS

Earl D. Kellogg

Michigan State University

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Experiments were conducted on these computer models to investigate the likely consequences through time of alternative investment programs that might be implemented in the northern Nigerian cattle sector. The time span considered is the 25 year period from 1971 through 1995. The focus of these models is the cattle industry located in the northern part of Nigeria. No analysis of the cattle industry in southern areas of Nigeria is contained in this paper.

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INVESTMENTS IN NIGERIA'S NORTHERN CATTLE INDUSTRY: A SIMULATION ANALYSIS

Introduction

This paper presents and discusses the analyses of policy experiments conducted with models of the Nigerian cattle production and distribution sectors. The production sector was modeled using systems simulation techniques, while the distribution sector is analyzed using linear and quadratic mathematical programming techniques.[1] This report is focused on the results of the experiments and does not contain detailed descriptions of the models utilized. These descriptions are available in references [1] and [2] in the bibliography.

Purpose and Focus

Experiments were conducted on these computer models to investigate the likely consequences through time of alternative investment programs that might be implemented in the northern Nigerian cattle sector. The time span considered is the 25 year period from 1971 through 1995. The focus of these models is the cattle industry located in the northern part of Nigeria. No analysis of the cattle industry in southern areas of Nigeria is contained in this paper. This deletion does *not* imply that cattle production in southern Nigeria is not or will not be important now or in the future.

Linkages with the Broader Model

The cattle production model is only a part of the broader agricultural sector model developed for Nigeria. Therefore, it utilizes information generated from other parts of the agricultural model and in turn sends information to other components. In reality this occurs since the cattle sector does have several interactions with other parts of the total Nigerian economy. The main inputs

[1]The models were developed at Michigan State University under USAID contracts AID/csd-1557 and AID/csd-2975.

received by the cattle sector from other components of the broader model are change in acres of cultivated land in grazing areas, quantity of nutrition available from crop residue grazing, and total human population in Nigeria. The cattle component transmits information to other components on the amount of imports or exports, quantity of beef and milk supplied, and various measures of income for constructing national accounts.

Organization of the Report

The first section of this report briefly discusses the general procedure of operating the model for sensitivity tests and policy runs, with some sensitivity test results presented. The second section contains the results of production policy analyses. Transportation policy analyses are included in a third section. Finally, a summary section draws together some of the major conclusions. Most of the results in the report are organized and presented in graphical form. These graphs are submitted in a separate unit so the reader can observe the graph at the same time he is reading the narrative.

General Model Operating Procedure

The model parameters are initialized to represent the situation in Nigeria in 1953 as accurately as possible. Then the model is run through simulated time from 1953 to 1995. One of the reasons for this procedure is to examine results achieved in some year for which information is available to see if they are reasonably close to the investigator's concept of reality in that year. Most of the policy and sensitivity analyses are initiated in 1971 and results printed out at every four year interval (1971, 1975, 1979, 1983, 1987, 1991 and 1995).

Sensitivity tests were preceded by a careful assignment of numerical values to the model parameters. These assignments were

based upon available secondary data and educated guesses of people with experience in the Nigerian cattle industry. Some of these individual parameters were then varied to determine the sensitivity of the model to errors in measuring these parameters. Such knowledge should improve allocation of research resources to further data acquisition and be helpful to policy makers who have to choose among alternative programs.

Table 1 presents the results of sensitivity analyses for five parameters in the traditional cattle sector. The base run indicates the values of certain endogenous variables in 1995 after 25 years of simulated time. The following sensitivity runs show the values of the same variables in 1995 given the change in the value of the parameters in question. The number in parentheses beneath each value is the percentage change from the base run value.

The first sensitivity run (run 2) indicates the values of some endogenous variables at the end of a 25 year period if the supply elasticity (percentage change in quantity sold for a one percent change in price) was 0.6 instead of 1.0 as in the base run. If (as is the case in this run) the northern cattle producers are less responsive to price than is assumed in the base run, the total population in 1995 would be about 4 percent higher than the estimated population in the base run. The sales of females and extraction ratio would be 6 to 7 percent lower while the total number of animals sold from the Nigerian herd would be less than 2 percent lower. The only other variable significantly affected is the difference between the tax revenues from the Jangali versus a sales tax which would be 17 percent higher than in the base run.

The second sensitivity run compares the differences in endogenous variables at the end of a 25 year period if female sales were 1/2 as responsive to shortages or excesses in nutrients available as is assumed in the base run. This parameter does not seem to affect the endogenous variables significantly. No variable would be changed from base run values by more than 1.86 percent.

Table 1. Sensitivity Analyses on Selected Parameters.

Run	Female Population PFT	Male Population PMT	Female Sales SFT	Male Sales SMT	Extraction Ratio sales/population AERT	Total Sales SUP	Price of Animals PA	Range Condition RCON	Difference Between Jangali and Sales Tax DBJS	Income from Animals YA	Income from Milk YM	Income from Animals and Milk FARMIA	Value of Capital VALCAP	Remarks
	(thousands)		(number)		(%)	(number)	(£/head)	(index)	(£)	(thousand £)		(thousand £)		
1	5,973	3,073	312,400	715,500	11.4	1,028,000	37.7	.84	567,800	40,760	29,490	1,364,000	1,442,000	Base Run[a]
2	6,253 (+4.7)[b]	3,157 (+2.7)	288,700 (-7.6)	719,000 (+.49)	10.7 (-6.1)	1,008,000 (-1.95)	37.8 (+.27)	.83 (-1.19)	663,100 (+17.0)	40,240 (-1.28)	29,870 (+1.43)	1,358,000 (-.22)	1,451,100 (+.66)	Supply Elasticity = .6 from 1.0
3	6,034 (+1.02)	3,096 (+.75)	318,200 (+1.86)	718,600 (+.43)	11.4 (0)	1,037,000 (+.88)	37.8 (+.27)	.83 (-1.19)	576,000 (+1.4)	41,240 (+1.18)	29,450 (-.14)	1,366,000 (+.37)	1,453,000 (+.76)	Sales Adjustment for TDN = .075 from .15
4	4,899 (-17.98)	2,728 (-11.23)	263,100 (-15.78)	586,900 (-17.97)	11.1 (-2.63)	849,900 (-17.32)	41.1 (+9.02)	.96 (+14.29)	453,200 (-20.2)	36,620 (-10.16)	24,540 (-16.79)	1,190,000 (-12.56)	1,269,000 (-12.0)	Proportions of Males & Females tended to be sold = .17 & .06 from .208 and .023
5	5,735 (-3.98)	2,993 (-2.6)	324,700 (+3.94)	708,300 (-1.01)	11.8 (+3.5)	1,033,000 (+.49)	54.7 (+45.1)	.85 (+1.19)	497,000 (-12.5)	58,140 (+42.64)	28,730 (-2.58)	1,551,000 (+13.96)	1,826,000 (+26.6)	Price Elasticity of Demand = -1.0 from -1.54

[a]All values computed at the end of 25 years simulated time.

[b]Values in parentheses are percentage change from base run value.

The third sensitivity run (run 4) was conducted on parameters exerting partial control on the proportions of males and females that tend to be sold in any one year. For the base run, the percentages of total female population sold and total male population sold are partially controlled around 2.3 and 20.8 respectively. In the sensitivity run, these parameters are gradually changed from 2.3 percent in 1953 to 6 percent from 1971 to 1995 for females and 20.8 in 1953 to 17 percent from 1971 to 1995 for males. Model results seem to be relatively sensitive to these changes in proportions of females and males sold. Total population, number of cattle sold, and farm income would be 12-17 percent lower than the base run projections. Prices would be higher by 9 percent as a result of the lower supply. This test indicates the need to look more carefully at the structure and parameters of the model that simulate the sales of males and females over time since misspecification and data errors may result in serious projection errors. If female sales are substantially higher than 2-3 percent of total female population, this test indicates that Nigeria may be facing a serious situation in which total population and sales will be falling through time instead of slightly increasing as is reported later in this paper. Rapid increases in percentage of females sold per year with no improvement in birth rates or time to maturity does have major implications for future supplies. Therefore, more analysis in this area is especially needed now that some recent information indicates that the proportions of males and females being sold annually may be changing substantially.

The last sensitivity test performed on the model as it is presently developed involves the price elasticity of demand for beef (percentage change in quantity demanded for a one percent change in price). In the base run, the parameter has a value of -1.54, which is changed in the sensitivity run to -1.0. The major impact of this change occurred in the equilibrium price of cattle in 1995 and, therefore, in the income from animals, farm income, and value of the capital stock. Projected price of cattle in the sensitivity run was ₦54.7 per animal in 1995, 45 percent higher than in the base run. However, this higher price

had little effect on the sales of animals which was only .49 percent higher than the base run quantity supplied. This test indicates that a relatively small change through time (or error in measurement) in the price elasticity of demand for beef would affect predicted equilibrium prices significantly.

Additional sensitivity tests were conducted on earlier versions of the beef model. The results of these tests indicated that total digestible nutrients (TDN) per acre of fly-free grazing, TDN per acre from food crop residues, and initial area of fly-free grazing land affected model behavior fairly significantly. Interestingly, changes in the initial cattle population did not strongly affect the behavior of model performance variables. Assumptions about grazing rate equilibrium, range deterioration rates, adjustments in sales relative to nutrition supply and price elasticities of supply do not seem to be as crucial as the assumptions regarding TDN yield of various nutrition sources, proportions of males and females sold, and price elasticity of demand.

Production Policy Experiments

This section reports the results of alternative courses of action that might be taken to alter the system of producing cattle within Nigeria. Table 2 gives the list of policies relevant to the cattle production model. Each run is explained in more detail at the beginning of the respective subsections.

An additional model experiment for feeding Nigerian produced groundnut and cottonseed cake was run. No analysis is reported for this alternative since the model structure is not properly developed to accurately measure the results of this program. If more detailed analysis is desired for alternative nutritional sources, the model specification for growth, birth, and death rates will have to be developed in more detail.

Table 2. Policy Run Definitions for Cattle Production Model

Run Designation		Remarks
I	Base Run	No new public investment programs
II	Fly Eradication	Clearing 50,000 square miles of tsetse fly
III	Price-Import	Importation of cattle to keep price increase to 1% per year
IV	Grazing Reserve (group Fulani ranches)	Development of about 2,000,000 acres of more productive grazing area
V	Fly Eradication and Grazing Reserve	Investing in II and IV together
I-V	Jangali versus Sales Tax	Differences in tax revenues yielded by these two taxing schemes

Base Run - No Public Investment Programs

The base run represents the likely consequences that would occur in the 25 year period from 1971 through 1995 if no efforts were made to improve the environment facing the northern cattle producer. It is assumed that no further fly eradication is achieved, no supplementary concentrates are fed, and no improved grazing is developed. However, additional crop land is allowed to encroach upon the grazing land and the cattle still have the benefit of utilizing the residues from these cropped acres.

Given these assumptions, the number of cattle increases from about 8,000,000 in 1971 to slightly over 9,000,000 in 1995, less than .5 percent per year (see Figure 1). However, this growth in population is spread unevenly over time. From 1971 through 1979, the total cattle population increases by about 1 percent per year, while from 1979 through 1995, the population increase is almost zero--only .15 percent per year. The probable reason for this uneven growth rate is the 26,667,000 acres of new grazing land that was opened by fly eradication

projects conducted from 1961 to 1971. (These projects actually cleared 32 million acres, but it was assumed only 26.667 million acres were grazing land.) The cattle population began to adjust upwards to utilize these new grazing lands opened for year around use. From 1971 on, no new land is assumed to be cleared of the tsetse fly, so the increase in cattle numbers begins to decline as the new tsetse-free areas become occupied. This indicates that the cattle population tends to adjust over a considerable time period to changing grazing land availability. This appears reasonable since increases in total herd size cannot be accomplished in just 2 or 3 years if no large numbers of breeding cattle are allowed to enter from other countries.

Figure 2 shows the time path of the extraction ratio (number of cattle sold as a percent of total herd) as it rises from 9.1 percent in 1971 to 11.4 percent in 1995. This increase is due to the tightening grazing condition through time (7.9 acres of grazing land per animal to 6.5 acres per animal--Figure 3) and a rising price. The extraction ratio increases more rapidly during the first 10 years partly because the grazing rate is falling below the equilibrium of 8 acres per animal more rapidly than in later years. This in turn occurs because cattle numbers are still adjusting upwards to increases in tsetse-free grazing land acreage that terminated in 1971. The total number of cattle sold from the herd within Nigeria (shown in Figure 4) changes from 719,000 in 1971 to 1,028,000 in 1995. The more rapid increases in earlier years are due to the higher increases in cattle population and extraction ratio previously mentioned.

The lean beef supplied per capita falls from 4.75 pounds in 1971 to 3.1 pounds in 1995--a decrease of about 35 percent as shown in Figure 5.[2] The protein derived from meat and milk declines from 2.1 grams per capita per day in 1971 to 1.27 grams per capita per day in

[2]For all runs except the import-price analysis, 270,000 cattle are assumed to be imported each year into Nigeria from bordering countries.

1995. The usual standard for protein provides for a minimum allowance of 60 grams of total protein per capita per day, of which 10 grams should be animal protein. Both trends of protein per capita and lean beef per capita indicate that for the base run, human population is likely to grow much faster than cattle population and productivity.

Figure 6 shows the average price of cattle received by producers increases over 50 percent from ₦24.9 to ₦37.7. The price rise increases over time since increases in the supply of cattle fall over time and demand at constant prices continues to increase at a constant percentage rate.[3] For example, price increases only 2 percent from 1971 to 1975, but increases 10 percent between 1991 and 1995. The price levels and increases are very sensitive to the price elasticity of demand parameter (see sensitivity analysis). If the actual price elasticity coefficient is very much lower than -1.54, prices will increase much more rapidly. If marketing margins continue to be a constant percentage of the producer price, average retail prices in southern urban areas of Nigeria could increase from ₦62.3 per animal in 1971 to about ₦95 per animal in 1995. These projections are an average over space and time, so that one would expect differences in prices among areas and years as well as among months within any year.

Figure 7 shows that grazing land available for use by the cattle would decrease over 7 percent from about 63,230,000 acres in 1971 to 58,700,000 in 1995 causing the grazing rate to fall from 7.9 acres per animal to 6.5 acres per animal. This decline in acres of grazing land is caused by encroachment of crop land (which increases by 43 percent for the period) into areas that were used for grazing. This change in land use is reflected in the changing proportions of nutrition derived from tsetse-free grazing land versus crop residues (see Figure 8). In 1971, the total digestible nutrients (TDN) derived from crop residues was 42 percent of the TDN supplied by the naturally tsetse-free grazing land. However, in 1995 the crop residues

[3]Demand increases over time are assumed to be a function of population growth, income per capita growth, income elasticity and beef prices. At constant prices demand is projected to increase at an average of 3.8 percent annually.

contribute 88 percent as much TDN as the fly-free grazing land. This increase in nutrition available from crop residues is one of the main factors supporting a slightly higher total cattle population in 1995. If for some reason these residues became less available to the cattle through time, serious nutrition problems would occur.

Since the grazing pressure rises on the naturally fly-free grasslands, the range condition deteriorates through time from a base of 100 percent in 1953 to 91 percent in 1971 and 84 percent in 1995 (see Figure 9). Therefore the model indicates that not only will the acres of grazing land decrease through time, but the productivity per acre may also decline if no efforts are made to alter the environment facing the northern cattle producers.

The income of the cattle producers derived from animal and milk sales increases from Ł46,640,000 in 1971 to Ł70,250,000 in 1995 as shown in Figure 10. By the end of the 25 year period, a total income to producers of over Ł1,400,000,000 would be generated, with the income from milk accounting for almost 1/2 of the total. The present value of that income stream in 1971 would be Ł746,927,000. The total value of the capital stock including the cattle and grazing land increased from Ł935,600,000 in 1971 to Ł1,442,000,000 in 1995.

If 270,000 cattle were imported each year, a total of Ł276,700,000 of foreign exchange would be expended over the 25 year period (slightly more than an average of Ł11,000,000 per year).

Investments in Clearing Tsetse Fly from Grazing Land

In this policy analysis, it is assumed that Ł845,000 is invested per year to clear land of the tsetse fly from 1971 through 1980. Each year 5,000 square miles are cleared making a total of 50,000 square miles added to fly-free land at the end of the 10 year period. The model calculates the new grazing land to be the same proportion of the total newly cleared land as the original fly-free grazing land is to the original total fly-free land. Following this assumption, an estimated 2,666,700 acres for grazing are cleared each year of the 10 year period.

For this run, the total cattle population increases at 1.3 percent per year from 8,000,000 in 1971 to 11,600,000 in 1995 as shown in Figure 11. However, the percentage increase is about 2 percent per year through 1983 but drops to almost zero between 1987 and 1995. This occurs because cattle numbers are still adjusting through 1983 to increases in grazing land availability that occurred prior to 1980. The difference in cattle numbers between the base run and the fly eradication program continues to increase through 1991 and subsequently levels off. By 1991, there would be about 2,500,000 more cattle in Nigeria if 26,667,000 more acres were cleared of the fly than if no more fly eradication programs were undertaken after 1971.

Figure 12 shows the extraction ratio for the fly eradication program to be much lower than the base run extraction rate especially until 1987. This occurs because total herd size would be growing more rapidly if fly eradication programs were implemented than if they were not. A smaller proportion of the total herd is marketed each year to generate the increases in population desired to take advantage of the expanded nutrition resources. If modernization is equated with higher extraction ratios, then in one sense fly eradication programs delay the transition. While clearing grazing land of the fly would appear to have a major impact on numbers of cattle that could be supported within Nigeria, it probably would lower the productivity of the total herd for several years, compared to the base run. As shown in Figure 13, the total number of cattle sold might be lower up to 1983 if the fly eradication program would be implemented versus the base run. After 1983 the extraction ratio increases, grazing rate falls, acres of grazing land declines, and TDN from the grazing lands begins to fall, all causing the number of cattle being sold to increase more rapidly. (These relationships are graphed in Figures 12, 14, 17, 18 and 13 respectively.) Therefore, after 1983 the gap between the number of cattle that would be sold if fly eradication had been accomplished compared to the number that would be sold

in the base run increases rapidly until the difference is 270,000 cattle in 1995.

The dynamic adjustment to increased fly-free grazing land is also reflected in the pounds of lean beef supplied per capita through time as shown in Figure 15. From 1971 to 1979, lean beef supplied per capita falls and would be below the base run. However, between 1979 and 1987, because of the increasing herd size and extraction ratio, the number of animals sold increases slightly faster than human population causing the pounds of lean beef supplied per capita to increase very slightly. After 1987, the herd size and extraction ratio increases level off and the supply of beef per capita begins to fall again.

This general sales pattern between these two alternatives is reflected in the price movements through time. Prices would tend to be slightly higher in the fly eradication run until 1983 when they fall below the predicted prices for the base run (see Figure 16). For the 25 year period prices would increase over 50 percent to Ł37.7 per animal for the base run and 34 percent to Ł33.3 per animal for the fly eradication policy.

In the fly eradication run, two opposing factors are affecting the area of tsetse-free grazing land. One factor is the crop land that is expanding onto the grazing areas; the other is the tsetse infested areas being opened up by the eradication program. Figure 17 shows the net result of these two forces. Up to 1981, more land is cleared of the fly than is subtracted by crop land encroachment. After 1981, the total area in fly-free grazing begins to decline since the eradication program has been stopped and the crop land continues to expand. In 1995, 28,000,000 more acres would be available for year around grazing if the tsetse eradication plans were implemented than if they were not. Since the grazing rate and range condition would also be more favorable, the higher total grazing land area would be more productive per acre and of course yield considerably more total TDN (62 percent more) relative to the base run, as shown in Figure 18.

As seen in Figure 19, the fly eradication program would generate more income from milk and animal sales than the base run, particularly after 1979. The additional net revenue to the cattle producers (additional income minus additional Jangali tax) would be ₤167,500,000 for the 25 year period. Given the assumptions about costs and timing of the fly eradication program, a benefit-cost ratio of 10.0 results, the benefits (private) being increased net revenue to the cattle producers and the cost (public) being the operating and capital costs of the program for 10 years.

In terms of the national economy, the Gross Domestic Product (GDP) per capita with the fly eradication program would grow from ₤30.066 in 1971 to ₤37.591 in 1995. For the base run, GDP per capita would increase from ₤30.066 to ₤37.486. Therefore investment in fly eradication programs would result in per capita GDP being ₤.105 higher than without the program.

Price-Import Policy

The question asked in this analysis is: How many cattle would need to be imported into Nigeria if base run policies are followed to keep price increases to only one percent per year? Prices in the base run increased an average of 2.11 percent annually over the whole 25 year period, but increased 3 percent annually over the last 15 years assuming annual imports of 270,000 cattle (see Figure 20).

Figure 21 shows the number of cattle that would have to be imported (assuming no public investments) if prices of cattle were to be kept to annual increases of one percent. Up to 1979 these imports would be slightly less than 270,000. However, after 1979 the required number of imports increases rapidly. To keep annual price increases down to one percent, 344,100 cattle would need to be imported in 1983 with 452,000, 578,600 and 709,300 required in 1987, 1991 and 1995 respectively. Even with these large imports, the total lean beef available per person in Nigeria would fall continually from 4.75 to 4.13 pounds (see Figure 22). It seems apparent that the possibilities of having a growing or even constant supply of beef per person in Nigeria are not very good.

The costs of buying these imports would also increase over time with £9,100,000 required in 1975 and £33,050,000 in 1995 (see Figure 23). This compares with foreign exchange expenditures for the base run of £10,000,000 in 1971 and £15,000,000 in 1995. For the price-import policy, approximately £400,000,000 would have to be spent over the 25 year period to import the required number of cattle.

Grazing Reserve - Fulani Group Ranches

This policy analysis investigates the likely consequences through time of developing grazing reserves or Fulani group ranches on 1,959,000 acres for use by cattle producers in the northern area of Nigeria. Preliminary plans call for establishing units of about 2,400 acres each with about 1/3 of the area planted to Townsville Stylo and the rest in native pasture. The assumptions of this analysis are that 800 units will eventually be established (about 1,959,000 acres) with 1/3 of the units being initiated in each year from 1973-74 through 1975-76. On the average each unit is assumed to be fully developed and ready for use in three years after the initial investment. Capital costs per unit are assumed to be £81,700 with operating cost per unit being £13,600 per year [3].

The model assumes cattle will be transferred from the traditional herd to these new grazing areas as they are developed. The land that is utilized for these new areas is subtracted from traditional grazing acreage so that by 1983 (when the new areas will be fully developed) 1,959,000 acres will have been taken from traditional herd grazing use.

Figure 24 shows the time profile for the development of these areas. Given that 267 units are to be established in each year from 1973-74 through 1975-76 and that the average development period is 3 years (with some taking more or less time), the total acreage should be available for use in 1983. Rapid expansion in developed areas would occur between 1975 and 1979 (1,271,000 acres added) with about 300,000 acres added between 1979 and 1983. This same profile can be seen in the acreage of grazing land available for the traditional

herd through time. As the new areas are being rapidly developed between 1975 and 1983, the acres of grazing land available for traditional herd use is falling more rapidly for the grazing reserve program than it would under the base run assumptions (see Figure 25).

The number of cattle using the new grazing areas follows the same time profile (see Figure 26). By 1975, 60,000 cattle would be on the new reserves with 268,000 and 308,000 in 1979 and 1983 respectively. These cattle are transferred from the traditional herd, so that in 1995 there would be 150,000 fewer cattle in the traditional herd if the grazing program were instituted than with no public investment programs (see Figure 27). Therefore, by developing these grazing areas, the total grazing land in Nigeria (equal for both cases) can support 160,000 more cattle per year from 1983 on. This is the result of being able to graze the developed areas more intensively. Besides supporting a higher total population, the percentage of the total herd sold would be higher for the grazing reserve program. Figure 28 shows the differences in the total herd extraction rate for the grazing reserve program and the base run. Since the modern herd would have a higher extraction rate than the traditional herd, the percent of the total herd sold increases faster for the grazing reserve program after 1979 than for the base run. Because of the higher total cattle population and higher extraction rate, the grazing reserve program would result in 1,000,000 more cattle being supplied for the 25 year period than the base run. Figure 29 shows the difference is about 69,000 cattle per year from 1987 through 1995. The higher overall total sales and extraction rates are the result of having a more productive modern herd for which extraction rates increase from 26 percent in 1979 to 33 percent in 1995 compared to 11 percent for the traditional herd. As shown in Figure 30, sales from this modern herd increase from 42,000 cattle in 1979 to 100,000 in 1995.

The increased number of cattle that would be produced if the grazing reserve policy were introduced still would not be sufficient

to keep the pounds of beef supplied per person from falling from 4.11 pounds in 1971 to 3.3 pounds in 1995. However, as Figure 31 shows, this decline would be smaller than in the base run. The price of cattle would also be lower for the grazing reserve policy versus the base run by about £1.7 per animal from 1983 to 1995 (see Figure 32).

The annual total producer's income from milk and cattle sales becomes significantly higher for the grazing reserve policy versus the base run between 1975 and 1979 (see Figure 33). This difference increases from £1,500,000 per year in 1979 to £2,700,000 in 1995 so that by 1995, £42,000,000 of additional producer income would be generated by the grazing reserve policy versus the base run.

The cost of establishing and operating these units seems to be very high relative to the additional income they would generate. If it would cost £81,700 to establish a 2,400 acre unit and £13,600 per year to operate it, the present value of all capital and operating costs through 1995 for 800 units would be £119,279,400. The present value of the additional income generated would be only £18,177,000. If the cost assumptions are at all close to the actual costs that would be incurred, the Fulani group ranches appear to cost substantially more than they would yield.

The GDP per capita for Nigeria in 1995 would be £37.507 for the grazing reserve development program compared to £37.486 in the base run.

Grazing Reserves and Fly Eradication Investments

This policy analysis compares the likely results of implementing a tsetse fly eradication program *and* an improved grazing area program (Fulani group ranches) with the base run. Both the fly eradication and grazing reserve programs are assumed to be implemented with the same time profiles and levels as they were individually described earlier (see pages 10 and 14).

Implementation of both programs would support a higher total cattle population (11,847,000 in 1995) than is projected for the base run (9,046,000 in 1995). As shown in Figure 35, this difference

expands from 244,000 cattle in 1975 to 2,800,000 in 1995. Cattle population would increase at 2.8 percent per year from 8,787,000 in 1975 to 10,741,000 in 1983. This would occur because the tsetse-free grazing area would be expanding and the carrying capacity of the grazing reserve land would be improved.

Figure 36 shows the number of cattle sold per year for both the base run and the fly eradication-improved grazing land policy. From 1971 through 1975, as the new grazing areas are being developed and the cattle numbers on the developed grazing areas are just beginning to become significant, the total number of cattle sold is less than the base run. This occurs because as grazing acreage is expanded cattle are being retained within the herds to increase total numbers. However, after 1983, with the larger total population and the modern herd becoming more numerous, the number of cattle sold increases much more rapidly for the fly eradication-grazing reserve program than the base run. This difference increases from 63,000 per year in 1983 to 340,000 per year in 1995, making a total of 2,600,000 more cattle being supplied for the 25 year period. This same pattern can be observed by looking at the extraction rate changes through time as shown in Figure 37. For the fly eradication-grazing reserve program, the extraction rate declines slightly until 1979 as the rapid increase in total numbers is occurring. After 1979, the extraction rate for these investments begins to increase, but stays below the base run until 1991. After that, the high extraction ratios in the modern herd pull the total extraction rate above the base run. If new grazing areas are cleared of tsetse fly, it appears that the extraction rate will not improve substantially, causing the total number of cattle being sold to increase slowly for several years.

As shown in Figure 38, the pounds of beef supplied per person falls from 1971 through 1979 as the numbers of cattle being sold increase slowly. However, from 1979 through 1987 the total number and extraction rate increase because of the increasing importance of the modern herd and the decline in acreage of tsetse-free grazing land.

Both of these trends cause the number of cattle sold to increase more rapidly than population. Consequently, the pounds of beef supplied per person increases slightly over this time period until 1987, when it begins to fall again. By 1995, 4 pounds of beef per person would be supplied if the fly eradication and grazing reserve programs were instituted versus 3.11 for the base run.

Prices would be slightly higher for this investment program relative to the base run through 1979 because fewer cattle would be sold. However, after 1979 cattle prices increase much more rapidly during the base run (2.6 percent per year) versus the fly eradication-grazing reserve program run (1 percent per year). In 1995, cattle prices would be 18 percent cheaper for the combined programs versus the base run--Ł32.0 compared to Ł37.7 (see Figure 39).

The annual producer income from milk and cattle sales would increase from Ł46,550,000 in 1971 to Ł86,150,000 in 1995--an increase of 3.5 percent per year (see Figure 40). The difference between the income produced under the fly eradication-grazing reserve program and the base run steadily increases through time until 1995 when Ł16,000,000 more income would be received. From 1971 through 1995, a total of Ł210,000,000 more income would be generated. The present value of that additional income in 1971 would be Ł85,675,000. However, the present value of the costs incurred in fly eradication and developing and operating the grazing reserves would be Ł125,500,000. The primary reason for this large amount is the high cost of establishing and operating the grazing reserves.

In terms of the national economy, these combined programs would cause the GDP per capita to be Ł0.124 higher than the base run in 1995 (Ł37.610 versus Ł37.486).

Comparison of Grazing Reserve (Fulani Group Ranch) and Fly Eradication Programs

This section compares the results through time of instituting a tsetse eradication program (II) versus a grazing reserve development

program (IV). The details of timing, level, and cost of each of these two alternatives is discussed elsewhere in this report.

Figure 41 shows that both programs would support growing numbers of cattle through time in Nigeria. The fly eradication program would allow total population of cattle to grow an average of 1.8 percent a year from about 8,000,000 in 1971 to 11,683,000 in 1995, while the grazing reserve program would result in an average growth of .6 percent per year from 8,000,000 in 1971 to 9,205,000 in 1995. Program II supports the higher population by eradicating the tsetse fly from 50,000 square miles from 1971 to 1980, while program IV would improve just 1,959,000 acres of grazing land for use. Figure 42 illustrates the difference in grazing land acreage available for continuous use through time. The fly eradication program would expand the area up to 90,000,000 acres in 1983 with encroaching crop land finally decreasing the total to 86,740,000 acres in 1995. Under program IV, the total grazing land would slowly fall from 63,230,000 acres in 1971 to 58,700,000 acres in 1995. Therefore, from 1983 on, program II would furnish about 28,000,000 more acres for year around grazing use.

The percent of total herd sold annually would be higher for the grazing reserve program through all years (see Figure 43). From 1975 to 1995, program IV would have 1 to 2 percent higher extraction rates annually than program II. This results because, first, the modern herd on the developed grazing areas would have higher extraction rates, and second, the traditional herd's growth would be limited by decreasing availability of grazing land. Conversely, the fly eradication campaign would tend to keep extraction rates lower as herd sizes increased to take advantage of the additional grazing land.

The grazing reserve development program would result in more cattle sold per year from 1971 to about 1984. After that year, more cattle would be sold annually under the fly eradication program--200,000 more in 1995 (see Figure 44). The price of cattle follows the inverse of this relationship as shown in Figure 45. For the

entire 25 year period, only 716,000 more cattle would be marketed if the fly eradication program were implemented versus the grazing reserve program.

Figure 46 shows the trends in annual producer income from milk and cattle sales for the two programs. There would be no major difference (less than 3 percent) from 1971 to 1979. However, the fly eradication program would result in significantly higher annual incomes from 1983 to 1995 (10 percent and 15 percent respectively). The total income for the 25 year period would be 9.3 percent higher at ₦1,533,000,000 for program II versus ₦1,403,000,000 for program IV. The total value of the stock of cattle and grazing land would be ₦1,545,000,000 in 1995 for the grazing reserve program versus ₦1,705,000,000 for the fly eradication program.

The gross domestic product per capita for all of Nigeria would be ₦37.591 in 1995 for the fly eradication program and ₦37.507 for the grazing reserve development program--0.2 percent difference.

Differences Between Jangali Tax Revenues and Sales Tax Revenues

This section presents the effects of various investment programs on tax revenues generated by the Jangali and proposed sales taxes. The assumptions made in this analysis are (1) Jangali tax of 7/6 is collected on 55 percent of all cattle in Nigeria; (2) all cattle sold in Nigeria are taxed ₦1; and (3) all trade cattle imported pay the sales tax, but not the Jangali. There are numerous other taxes levied on cattle in Nigeria, but they are not considered in this section.

Figure 47 shows the difference between Jangali tax revenues and sales tax revenues through time for the base run. In 1971 about ₦1,650,000 would be collected in Jangali tax revenues with ₦1,866,000 to be collected in 1995. A sales tax of ₦1 would yield ₦990,000 in 1971 and ₦1,298,000 in 1995. Through time the difference between the two alternative taxes would decrease from ₦658,000 in 1971 to ₦568,000 in 1995. A sales tax of ₦1.82 per animal sold would yield the same revenue as the Jangali in 1995. The sales tax becomes relatively more

attractive as the extraction ratio increases since it is the ratio of number sold to total population. This relationship is illustrated in Figure 48. With the fly eradication program, the total population of cattle increases faster than the number sold up to 1983. Therefore, the Jangali tax revenues would grow more rapidly than the sales tax revenues. After 1983, the difference would decline as the extraction rate increases. In 1995 a sales tax of £1.86 would be sufficient to equal Jangali tax revenues.

The difference between the two alternative taxing schemes is smallest for the grazing reserve development program (see Figure 49). By 1995, the Jangali tax yields only £532,000 more than the sales tax. A sales tax of £1.7 per animal sold would yield the same amount of revenue as the Jangali for this investment program.

The largest differences occur when comparing the fly eradication program with the grazing reserve development policy. In 1983, the Jangali would yield £923,000 more than the sales tax if only the fly eradication policy were implemented. During the same year, only £567,000 would be the difference if only the grazing reserve investment were implemented (see Figure 50).

If both the fly eradication and grazing reserve policy were implemented, Jangali returns would increase from £1,650,000 in 1971 to £2,445,000 in 1995. Sales tax revenues would rise from £990,000 in 1971 to £1,637,000 in 1995. As can be seen in Figure 51, the difference between the two taxes increases from £658,000 in 1971 to £905,000 in 1983 and then falls to £806,000 in 1995.

It seems apparent that the relative attractiveness of the two taxing schemes changes as alternative investment programs are implemented. Sales taxes of £1.7 to £1.8 per animal would almost match Jangali returns in every case. If a sales tax of £1 per animal is instituted, the loss in tax revenues might be relatively small compared to the increased cooperation and trust that might be fostered in the cattlemen for public institutions and programs.

Transportation of Market Cattle Within Nigeria

Nigeria was divided into 15 areas to study the transportation of market cattle within the country. The 15 areas chosen are shown in Figure 52. The 13 areas in the northern section of Nigeria correspond to the former provinces of the former northern region as follows: Areas 1, 2, 3, 6, 7, 8, 11 and 12 respectively have the same boundaries as the former provinces of Sokoto, Katsina, Kano, Niger, Zaria, Bauchi, Plateau and Benue. Areas 4 and 5 divide the former province of Bornu. Area 9 combines the former province of Adamawa and the lower sector of the former Sardauna province, while the upper part of the former Sardauna province is designated as area 13 for this study. Area 10 is the combination of the former provinces of Ilorin and Kabba. Area 14 is the Western state plus 1/2 of the Mid-Western state. Area 15 is made up of 1/2 of the Mid-Western state plus all of the former Eastern region. Central locations within these 15 areas were designated for purposes of measuring average distances and are shown in Figure 52.

Costs of Transportation

Tables 3 through 10 show the costs of transporting cattle from some major northern production locations to some important southern consuming areas by categories of costs and by method of shipment.

In general, truck shipment appears to be the most expensive method of transporting live cattle. The primary reason for this is the high freight charges levied by truck owners--over 2-1/2 times the freight charges of rail service. A major cause of high freight charges is the frequent occurrence of accidents due to heavy traffic on relatively poor roads, poor mechanical condition and overloading of trucks, and driver stress from driving too long without rest. A survey of truck transportation costs indicated that the hauling time

Table 3. Costs of Transporting Cattle from Gusau to Ibadan

Truck			Walk			Rail		
Category	Cost £/animal	% of Total	Category	Cost £/animal	% of Total	Category	Cost £/animal	% of Total
Mortality cost	1.02	6.2	Mortality cost	.82	7.4	Mortality cost	.29	2.4
			Salvage cost	1.66	15.0			
Shrinkage cost	7.80	47.4	Shrinkage cost	5.62	50.5	Shrinkage cost	7.52	62.6
Other expenses	.40	2.4	Other expenses	.40	3.6	Other expenses	.40	3.3
Freight cost	725	44.0	Drover's fee	1.01	9.1	Freight cost	3.20	26.6
			Food money	.13	1.2	Attendant cost	.61	5.1
			Interest cost	.52	4.7			
			Feeding cost	.94	8.5			
Total	£16.47	100.0	Total	£11.10	100.0	Total	£12.02	100.0

Table 4. Costs of Transporting Cattle from Kano to Ibadan

Truck			Walk			Rail		
Category	Cost £/animal	% of Total	Category	Cost £/animal	% of Total	Category	Cost £/animal	% of Total
Mortality cost	1.18	6.5	Mortality cost	1.06	8.0	Mortality cost	.16	1.5
			Salvage cost	2.16	16.2			
Shrinkage cost	8.15	45.0	Shrinkage cost	6.63	49.8	Shrinkage cost	6.57	59.9
Other expenses	.40	2.2	Other expenses	.40	3.0	Other expenses	.40	3.8
Freight cost	8.37	46.3	Drover's fee	1.19	8.9	Freight cost	3.05	29.1
			Food money	.15	1.1	Attendant cost	.59	5.7
			Interest cost	.60	4.5			
			Feeding cost	1.12	8.5			
Total	£18.10	100.0	Total	£13.31	100.0	Total	£10.77	100.0

Table 5. Costs of Transporting Cattle From Maiduguri to Ibadan

Truck			Walk			Rail		
Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total
Mortality cost	2.40	9.5	Mortality cost	1.41	6.7	Mortality cost	.47	2.9
			Salvage cost	2.86	13.6			
Shrinkage cost	9.40	37.3	Shrinkage cost	11.00	52.4	Shrinkage cost	9.28	57.3
Other expenses	.40	1.6	Other expenses	.40	1.9	Other expenses	.40	2.5
Freight cost	13.00	51.6	Drovers' fee	1.98	9.4	Freight cost	5.10	31.5
			Food money	.26	1.3	Attendant cost	.94	5.8
			Interest cost	.95	4.5			
			Feeding cost	2.14	10.2			
Total	₦25.20	100.0	Total	₦21.00	100.0	Total	₦16.19	100.0

Table 6. Costs of Transporting Cattle from Maiduguri to Umuahia

Truck			Walk			Rail		
	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total
Mortality cost	1.44	6.9	Mortality cost	1.27	8.0	Mortality cost	.36	2.6
			Salvage cost	2.57	16.2			
Shrinkage cost	8.66	41.8	Shrinkage cost	7.75	48.9	Shrinkage cost	8.62	61.7
Other expenses	.40	1.9	Other expenses	.40	2.5	Other expenses	.40	2.9
Freight cost	10.25	49.4	Drovers' fee	1.40	8.8	Freight cost	3.83	27.5
			Food money	.18	1.1	Attendant cost	.74	5.3
			Interest cost	.69	4.4			
			Feeding cost	1.60	10.1			
Total	₦20.75	100.0	Total	₦15.86	100.0	Total	₦13.95	100.0

Table 7. Rail Costs Resulting from Increased Rail Speed

Gusau to Ibadan			Kano to Ibadan			Maiduguri to Umuahia		
Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total
Mortality cost	.21	2.0	Mortality cost	.13	1.4	Mortality cost	.29	2.3
Shrinkage cost	6.27	58.7	Shrinkage cost	5.49	56.8	Shrinkage cost	7.52	58.8
Other expenses	.40	3.7	Other expenses	.40	4.1	Other expenses	.40	3.1
Freight cost	3.20	29.9	Freight cost	3.05	31.6	Freight cost	3.83	30.0
Attendant cost	.61	5.7	Attendant	.59	6.1	Attendant cost	.74	5.8
Total	₦10.69	100.0	Total	₦9.66	100.0	Total	₦12.78	100.0

Table 8. Rail Costs Resulting from Regular Rail Speed

Gusau to Ibadan			Kano to Ibadan			Maiduguri to Umuahia		
Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total
Mortality cost	.29	2.4	Mortality cost	.16	1.5	Mortality cost	.36	2.6
Shrinkage cost	7.52	62.6	Shrinkage cost	6.57	59.9	Shrinkage cost	8.62	61.7
Other expenses	.40	3.3	Other expenses	.40	3.8	Other expenses	.40	2.9
Freight cost	3.20	26.6	Freight cost	3.05	29.1	Freight cost	3.83	27.5
Attendant cost	.61	5.1	Attendant cost	.59	5.7	Attendant cost	.74	5.3
Total	₦12.02	100.0	Total	₦10.77	100.0	Total	₦13.95	100.0

Table 9. Trek Costs Resulting from Trypanosomiasis Control Program

Sokoto to Ibadan			Kano to Ibadan			Maiduguri to Umuahia		
Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total
Mortality cost	.41	6.3	Mortality cost	.53	7.8	Mortality cost	.64	7.4
Salvage cost	.83	12.8	Salvage cost	1.08	15.9	Salvage cost	1.29	15.0
Shrinkage cost	2.25	34.7	Shrinkage cost	1.73	25.4	Shrinkage cost	2.41	28.0
Other expenses	.40	6.2	Other expenses	.40	5.9	Other expenses	.40	4.6
Drovers' fee	1.01	15.5	Drovers' fee	1.19	17.5	Drovers' fee	1.40	16.3
Food money	.13	2.0	Food money	.15	2.2	Food money	.18	2.1
Interest cost	.52	8.0	Interest cost	.60	8.8	Interest cost	.69	8.0
Feeding cost	.94	14.5	Feeding cost	1.12	16.5	Feeding cost	1.60	18.6
Total	₦6.49	100.0	Total	₦6.80	100.0	Total	₦8.61	100.0

Table 10. Trek Costs with no Trypanosomiasis Control Program

Sokoto to Ibadan			Kano to Ibadan			Maiduguri to Umuahia		
Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total	Category	Cost ₦/animal	% of Total
Mortality cost	.82	7.4	Mortality cost	1.06	8.0	Mortality cost	1.27	8.0
Salvage cost	1.66	15.0	Salvage cost	2.16	16.2	Salvage cost	2.57	16.2
Shrinkage cost	3.62	50.5	Shrinkage cost	6.63	49.8	Shrinkage cost	7.75	48.9
Other expenses	.40	3.6	Other expenses	.40	3.0	Other expenses	.40	2.5
Drovers' fee	1.01	9.1	Drovers' fee	1.19	8.9	Drovers' fee	1.40	8.8
Food money	.13	1.2	Food money	.15	1.1	Food money	.18	1.1
Interest cost	.52	4.7	Interest cost	.60	4.5	Interest cost	.69	4.4
Feeding cost	.94	8.5	Feeding cost	1.12	8.5	Feeding cost	1.60	10.1
Total	₦11.10	100.0	Total	₦13.31	100.0	Total	₦15.86	100.0

for lorries was about the same as for rail hauling. Over 1/2 of the drivers surveyed indicated that the cattle they were hauling showed severe road stress on trips between Kano and Katsina to Ibadan and Lagos. Truck shipment does give cattle dealers an opportunity to react quickly to favorable price conditions in the southern markets. Higher quality cattle that can not withstand the rigors of trekking and for some reason can not get rail permits are often moved by truck. The drivers surveyed indicated that no stops were made and no feed or water given on the 3 to 4 day trips to the south. Although truck shipment is the most expensive method considered in this study, future investments in improving the road structure in Nigeria might reduce these costs substantially. Present Nigerian development plans call for substantial investments in highway construction and improvement. If these investments are successfully completed, road conditions, turnaround time, and accident rates might be improved substantially. These improved conditions would probably be reflected in lower freight charges being levied by lorry owners. If adequate feed and water provision could be combined with these improved conditions, lorry transport of cattle may become very competitive with rail and trek methods, especially for higher quality cattle.

The major cost categories for rail shipment are shrinkage costs (60 percent) and freight charges (30 percent). The large shrinkage losses occur because of the long time cattle are on the rail cars (3 days to go 700 miles) and inadequate provision of feed and water for the cattle during that period. In general, rail shipment provides the least cost method of moving cattle from northern producing regions to southern consuming regions. The results show that for distances of 350 miles or greater, rail shipment is cheaper than trekking, especially if cattle are to be moved through tsetse infested areas. However, the distances between some important locations are much longer for rail travel than trekking. This is true for movement between many areas in the north since the rail lines are oriented to north-south

travel. In addition, the cost of rail shipment between areas 1 and 14 is higher than trekking costs because of the shorter trek distance as compared to rail mileage. No rail service is available for areas 9 and 13 (see Figure 52). Other than these exceptions, rail transport from northern excess supply regions to southern excess demand areas is less expensive than trekking.

If shrinkage losses could be reduced during rail shipment, this method of transportation would be especially attractive to dealers moving higher quality cattle. Reducing shrinkage on rail trips would entail provision of feed and water along the way and/or increasing the speed of rail service. Results of this study show that increasing the speed of rail service by 1/5 caused the costs of rail shipments to decrease by only 6.5 percent (see Tables 7 and 8). It seems that feed and water must be provided with increased rail speed if significant reductions are to be realized in rail transportation costs. If these factors can be successfully implemented and adequate rail car numbers can be provided at the proper place and time, rail service could be of increasing importance in beef distribution in the future as the quantity and quality of cattle to be marketed increases.

The major cost categories for trekking are salvage losses (15 percent), shrinkage costs (50 percent), drovers' fees (9 percent) and feed and water costs (9 percent). The shrinkage and salvage losses are mainly attributable to diseases and injuries contracted along the trek routes with trypanosomiasis being the major cause of these losses.

In general, trekking cattle is the most efficient method of moving cattle among areas in the northern tsetse free regions. It is also the most efficient method of transporting cattle from areas 1 to 14 and from areas 9 and 13 to 15, which are important routes for cattle moving south. Therefore, even with no trypanosomiasis control program and an unlimited number of rail cars, trekking will continue to be an important method for moving range cattle to the southern consuming regions.

Figure 53 illustrates the relative costs of transporting cattle over varying distances by truck, trek and rail. One must be careful in interpreting the results shown in this figure because distances between the same two locations may be different by trek route, road and rail. For example, the distance between Gusua and Ibadan is much shorter on the trek routes than on the road or rail system. As previously stated, trek costs are generally less for distances up to 350 miles. For farther distances, rail costs become increasingly more attractive. Therefore it appears that rail service should be organized to haul the cattle on the long trips from locations such as Maiduguri, Kano, Nguru and Gusua to southern markets.

Data from limited research trials indicate that losses from trypanosomiasis might be substantially curtailed. The results from these trials were mixed, but a conservative estimate is that salvage, shrinkage and mortality losses could be reduced by 1/2 by controlling trypanosomiasis on the trek routes. If this occurred, trek costs could be reduced by 40 percent (see Tables 9 and 10). These preliminary estimates indicate that investments in a trypanosomiasis control program should be investigated thoroughly. However, even with a program to control trypanosomiasis, the losses from trekking higher quality cattle for several weeks will be very high. Therefore if the quality of market cattle in Nigeria is to be broadly improved, alternatives to trekking must be developed.

Using estimates gathered for this model component, shrinkage and death losses were calculated for cattle moving to areas 14 and 15 over the 1954-1963 decade. It was estimated that 144,835 tons of live weight was lost from shrinkage and death in the railing and trekking of cattle over this decade (see Table 11). While the proportion of cattle trekked to the south over these years was slightly less than 50 percent, trekking accounted for 57 percent of the total pounds lost. Assuming an animal weighs 700 pounds, the total pounds lost over the 10 years is equivalent to 423,138 cattle which is over

Table 11. Live Weight Pounds Lost From Mortality and Shrinkage from Transportation of Cattle in Nigeria, 1954-1963

Fiscal Year	Cattle Hauled by Rail	Rail Losses	Cattle Trekked	Trek Losses	Total Rail and Trek Loss
	(number)	(tons)	(number)	(tons)	(tons)
1954-55	116,000	4,355	172,000	8,763	13,107
1955-56	120,000	4,494	156,000	7,948	12,422
1956-57	139,000	5,205	157,000	7,999	13,204
1957-58	156,000	5,842	138,000	7,031	12,873
1958-59	158,000	5,917	142,000	7,234	13,151
1959-60	167,000	6,259	155,000	7,898	14,157
1960-61	197,000	7,377	165,000	8,413	15,790
1961-62	204,000	7,634	164,000	8,362	15,996
1962-63	200,000	7,490	179,000	9,113	16,603
1963-64	201,000	7,527	196,000	9,985	17,512
TOTAL	1,658,000	62,089	1,624,000	82,746	144,835

42,000 cattle equivalents per year. The total pounds lost due to shrinkage and death was about 13 percent of the total pounds marketed. Each of the three methods discussed entail large losses due to shrinkage, death and salvage of the animals as they are moved over long distances. Adequate feed and water provision must be made if these losses are to be reduced and the transportation system is to contribute to increasing the quality and quantity of cattle to be marketed in Nigeria.

Organization of Transport Facilities Through Time

This section contains the results of the model component that estimates (1) the demand and supply of cattle through time in each of the 15 areas and (2) the least cost transportation configuration to service the required interarea flows for three transportation investment programs. The first program (option I) entails providing fewer rail cars than can be effectively utilized through time. The number of rail cars available in this option is 236 in 1971, 272 in

1979, 319 in 1987 and 355 in 1995--an increase of about 1.8 percent per year. No investments are made in option I for controlling trypanosomiasis along the trek routes. Option II consists of furnishing as many rail cars as are demanded for cattle shipment, but no investment is made for controlling trypanosomiasis on trek routes. The third investment program (option III) entails instituting a trypanosomiasis control program along with increasing the speed of rail service by 1/5 and furnishing as many rail cars as are demanded.

The number of market cattle generated by the fly eradication investment program is used in this analysis. Therefore 989,200 cattle are to be marketed in 1971, 1,118,000 in 1979, 1,431,000 in 1987 and 1,569,000 in 1995. Results in this section are reported at these eight-year intervals. No attempt was made to conduct this transportation analysis for all sets of cattle marketed for all possible production investment programs. The general conclusions should not change, but specific numbers in the results certainly would.

The major interarea flows are given in Table 12. It shows the major exporting areas to be 1, 2, 3, 4, 5, 8, 9, 11 and 13 with areas 12, 14 and 15 being large importers. Areas 6, 7 and 10 are neither large exporters nor importers in any case (see Figure 52). Sokoto, Katsina, Bornu and Nguru (1, 2, 4 and 5) are the major export locations for cattle moving into area 14. Through all the years and for all options, cattle are sent from these four areas to area 14. The pattern of exports from the large supply area 4 varies with investment options. Under option I approximately 2/5 of the total export of area 4 goes to the eastern area. As the number of rail cars is increased (option II) area 4 exports almost exclusively to the western area. This occurs because rail transportation tends to be more economic than trekking over longer distances. Therefore area 4 captures some of the western market from area 1 from which cattle are trekked to the south. The slack in demand left in area 15 is made up by increased shipments from areas 8 and 9. As trekking

Table 12. Major Interarea Flows of Cattle from 1971 through 1995 for All Three Options

Export \ Import	1971			1979			1987			1995		
	12	14	15	12	14	15	12	14	15	12	14	15
Option I												
1	--	155,762	--	--	186,069	--	--	250,200	--	--	277,722	--
2	--	26,778	--	--	34,758	--	--	59,274	--	--	65,794	--
3	--	7,475	--	--	19,727	--	--	59,956	--	--	66,551	--
4	--	35,574	48,651	--	64,985	43,456	--	87,121	62,354	--	96,704	69,213
5	--	111,711	--	--	128,329	--	--	167,051	--	--	185,427	--
8	--	--	12,901	--	--	23,360	--	--	43,370	--	--	48,141
9	43,040	--	20,898	42,451	--	36,807	42,375	--	65,070	47,036	--	72,228
11	--	--	18,259	--	--	26,113	--	--	41,732	--	--	46,323
13	--	--	18,202	--	--	25,550	--	--	39,659	--	--	44,021
Option II												
1	--	123,709	--	--	151,601	--	--	213,919	--	--	235,748	--
2	--	23,301	--	--	33,396	--	--	57,384	--	--	63,239	--
3	--	1,917	--	--	20,490	--	--	72,074	--	--	79,429	--
4	--	98,971	22,410	--	131,790	11,943	--	201,529	--	--	222,093	--
5	--	117,514	--	--	134,474	--	--	180,299	--	--	198,697	--
8	--	--	20,843	--	--	31,836	--	--	61,169	--	--	67,410
9	38,850	--	27,943	37,264	--	43,333	33,017	--	79,450	36,386	--	87,557
11	--	--	20,722	--	--	27,925	--	--	46,588	--	--	51,342
13	--	--	20,587	--	--	27,471	--	--	44,043	--	--	48,537
Option III												
1	--	140,953	--	--	171,449	--	--	238,688	--	--	261,278	--
2	--	27,705	--	--	35,741	--	--	66,530	--	--	72,833	--
3	--	2,183	--	--	23,303	--	--	85,275	--	--	93,354	--
4	--	102,851	24,244	--	133,994	16,325	--	202,782	10,043	--	221,993	10,995
5	--	116,557	--	--	134,467	--	--	180,859	--	--	197,993	--
8	--	--	23,569	--	--	35,162	--	--	64,956	--	--	71,110
9	17,072	--	52,021	9,573	--	73,912	--	--	117,090	--	--	128,183
11	--	--	21,973	--	--	29,833	--	--	50,236	--	--	54,995
13	24,082	--	--	30,846	--	--	38,228	--	12,384	41,850	--	13,557

becomes cheaper (option III) area 1 exports more to 14 than under option I or II. Since the cattle in much of area 1 are quite far from rail points, an increase in the number of rail cars available tends to decrease the number of cattle being exported from that area, because other areas can better utilize the additional rail cars (e.g. area 4 increased exports as rail car numbers increased).

It is interesting to note that area 3 rapidly becomes a major exporter to area 14 under all options. How these rapid increases in exports are generated in the northern areas will be discussed later in this section.

Area 15 received cattle from area 9 under all options in every run. As this eastern area recovered from the war, areas 8, 11 and 13 became additional major sources of supply for it. The traditional pre-war exports of areas 8, 9, 11 and 13 to area 15 were diverted to area 12 or kept within these areas. Fewer cattle tend to be exported to area 15 under option II (increased number of rail cars) than under options I or III. Since two of the major export areas to area 15 are not served by rail (9 and 13), improvement in trekking is important to consumers in this eastern area.

As the demand for beef rapidly increases in area 15 through the rehabilitation period, exports that went to area 12 are diverted to the eastern area. Area 12 is supplied by exports from either area 9 or 13. Again, neither of these areas is served by the rail system. Increasing the number of rail cars and improving trekking conditions both tend to decrease the number of cattle being exported to area 12. As trekking becomes cheaper, cattle tend to move from area 13 to area 15 rather than to area 12. As more rail cars are provided, area 11 exports to area 15 at the expense of area 12. Therefore, as a result of improving the transportation methods area 12 may pay higher prices for fewer cattle than if no improvements were made.

Table 13. Total Number of Cattle Produced and Exported to Areas 14 and 15 for 25 Years Under the Three Options

Year	Total Production of Cattle (b)	Increase of (b) in an 8 Year Period	Cattle Moving to 14 & 15 (c)	Increase of (c) in an 8 Year Period	Percent of (b) Moving to Areas 14 & 15
	(number)	(%)	(number)	(%)	(%)
Option I					
1971	989,200		463,595		47%
		13.0		28.4	
1979	1,118,000		595,354		53%
		28.0		50.6	
1987	1,431,000		896,591		63%
		10.0		11.0	
1995	1,569,000		995,216		64%
Option II					
1971	989,200		478,724		48%
		13.9		28.3	
1971	1,118,000		614,260		55%
		28.0		56.5	
1987	1,431,000		961,577		67%
		10.0		10.2	
1995	1,569,000		1,059,697		68%
Option III					
1971	989,200		511,275		51%
		13.0		27.6	
1979	1,118,000		652,285		58%
		28.0		57.5	
1987	1,431,000		1,028,824		71%
		10.0		9.5	
1995	1,569,000		1,126,292		72%

The importance of improvement in trek costs is emphasized by the fact that through time areas 1, 9 and 13 continue to be major exporting areas which are not served by the rail system.

Table 13 shows that the percentage increase of production in the northern areas is less than the percentage increase in their exports to the southern areas. The more rapid population growth and urbanization in these southern areas (14 and 15) cause demand for beef to increase faster than in the northern areas. Therefore the percentage of total marketed cattle going south increases quite

rapidly from 47-51 percent in 1971 to 64-72 percent by 1995 depending on which option is implemented. Since increased production can not fulfill the expanding demands in the southern areas, many northern areas may actually retain fewer cattle for consumption within the area. This phenomenon occurs in areas 1, 2, 3, 4, 5, 8, 9, 11 and 13. As transfer charges are lowered (especially option III) and demands increase rapidly in areas 14 and 15, more cattle are diverted from local markets and exported to the southern areas. This tends to increase local prices and hence decrease quantities demanded within these areas. This analysis shows that many areas within Nigeria may face declining numbers of cattle available for consumption purposes. It also indicates that an increasing percentage of this limited supply of market cattle will tend to be exported to the southern areas especially if transfer costs are lowered by investments in beef transportation.

Tables 14 through 17 give the least cost transportation configuration for investment option I from 1971 through 1995. In 1971, 50 percent of the total inshipments to areas 14 and 15 were hauled by rail. However, this decreases steadily through time until 1987, when less than 36 percent are hauled by rail to areas 14 and 15. The main reason for this is the decline in percentage of cattle transported to area 15 by rail from 41 percent in 1971 to zero by 1987 (see Table 18). This happens because the major supply areas for area 15 (9, 11 and 13) are not served by the rail system or are relatively closer to area 15 than the supply locations for area 14. The limited number of rail cars are more advantageously used to ship to area 14 versus area 15. Therefore if the number of rail cars becomes a serious limitation rail shipments to area 15 may decline substantially and investments in trek routes leading to area 15 should be considered.

Since the overall percentage of cattle hauled by rail is decreasing under option I, the number of cattle using trek routes increases. The trek routes connecting areas 1 and 2 with 14 and areas 4, 8, 9, 11 and 13 with 15 are heavily utilized. Of these routes,

Table 14. Optimum Transportation Pattern for 1971, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	--	155,762
"	4-6	--	8,224
"	4-7	--	11,941
"	8-15	--	12,901
"	9-12	--	43,040
"	9-15	--	20,898
"	10-14	--	7,384
"	11-15	--	18,259
"	13-15	--	18,202
Rail	2-14	24	26,778
"	3-14	6	7,475
"	4-14	50	35,574
"	4-15	56	48,651
"	5-14	100	111,711
Total Number of Rail Cars Per Year		236	

Percentage of Total Inshipments to Area 14 and 15 Hauled by Rail - 50%

Total Distribution Costs - £7,918,518

Table 15. Optimum Transportation Pattern for 1979, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	--	186,069
"	2-14	--	34,758
"	4-6	--	8,434
"	4-7	--	9,364
"	8-15	--	23,360
"	9-12	--	42,451
"	9-15	--	36,807
"	10-14	--	6,200
"	11-15	--	26,113
"	13-15	--	25,550
Rail	3-14	15	19,727
"	4-14	91	64,985
"	4-15	51	43,456
"	5-14	115	128,329
Total Number of Rail Cars Per Year		272	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 43%

Total Distribution Costs - £10,035,600

Table 16. Optimum Transportation Pattern for 1987, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	--	250,200
"	2-14	--	59,274
"	4-6	--	10,705
"	4-7	--	5,558
"	4-15	--	62,354
"	8-15	--	43,370
"	9-12	--	42,375
"	9-15	--	65,070
"	10-14	--	20,804
"	11-15	--	41,732
"	13-15	--	39,659
Rail	3-14	46	59,956
"	4-14	123	87,121
"	5-14	150	167,051
Total Number of Rail Cars Per Year		319	

Percentage of Total Inshipments in Areas 14 and 15 Hauled by Rail - 36%

Total Distribution Costs - £15,177,084

Table 17. Optimum Transportation Pattern for 1995, Option I

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	--	277,722
"	2-14	--	65,794
"	4-6	--	11,883
"	4-7	--	6,169
"	4-15	--	69,213
"	8-15	--	48,141
"	9-12	--	47,036
"	9-15	--	72,228
"	10-14	--	23,092
"	11-15	--	46,323
"	13-15	--	44,021
Rail	3-14	51	66,551
"	4-14	137	96,704
"	5-14	167	185,427
Total Number of Rail Cars Per Year		355	

Percentage of Total Inshipments in Areas 14 and 15 Hauled by Rail - 36%

Total Distribution Costs - £18,699,685

Table 18. Rail Car Requirements Through Time for Three Transportation Investment Options

Year	Option I			Option II			Option II		
	Rail Cars (No.)	Percentage of Imports to Area 14 Hauled by Rail (%)	Percentage of Imports to Area 15 Hauled by Rail (%)	Rail Cars (No.)	Percentage of Imports to Area 14 Hauled by Rail (%)	Percentage of Imports to Area 15 Hauled by Rail (%)	Rail Cars (No.)	Percentage of Imports to Area 14 Hauled by Rail (%)	Percentage of Imports to Area 15 Hauled by Rail (%)
1971	236	53	41	312	66	38	225	56	20
1979	272	48	28	390	68	31	266	54	11
1987	319	49	0	630	70	47	371	50	4
1995	355	49	0	694	70	47	405	50	4

only 1 to 14 and 9 and 13 to 15 are less expensive to travel by trek than by rail. Cattle trek over the remaining routes because the limited number of rail cars can be used more effectively on longer routes. Kano, Maiduguri and Nguru remain important rail loading points for shipment of cattle to areas 14 and 15. The number of cattle railed and rail cars per year required are given in Tables 14 through 17.

The second investment strategy consists of furnishing as many rail cars as are demanded for cattle shipment, but no investment is made for controlling the trypanosomiasis disease along the trek routes. Tables 19 through 22 show the results obtained from applying the transportation linear program to the interarea flows.

The demand for rail cars increases rapidly under option II. From 1971 to 1995, the number of rail cars utilized increases from 312 to 694. This represents an average increase of about 5 percent per year or about 2.5 times as much as rail car numbers were allowed to increase under option I.

The percentage of total inshipments to areas 14 and 15 hauled by rail is 60 percent in 1971 and increases to about 64 percent in 1995. It is interesting to note that over 1/3 of the total inshipments to areas 14 and 15 are trekked no matter how many rail cars are provided. This occurs because major excess supply areas (1, 9 and 13) are not close to rail lines. Rail shipments comprise about 38 percent of the total inshipments to area 15 in 1971 and about 1/2 in 1995. For area 14, about 2/3 of the total imports are carried by rail in each year.

Areas 2, 3, 4, 5, 8 and 11 are important rail loading locations in 1995. However area 11 does not rail cattle to area 15 until 1987. Previous to that, cattle were trekked along this route. This change in transportation method occurred because the price of beef increased in area 15 to the point that the large shrinkage and salvage losses from trekking raised the trek costs above the rail charges. This is an illustration of the phenomenon that trekking costs will

Table 19. Optimum Transportation Pattern for 1971, Option II

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-6	--	5,921
"	1-14	--	123,709
"	3-7	--	8,081
"	9-12	--	38,885
"	9-15	--	27,943
"	10-14	--	809
"	11-15	--	20,722
"	13-15	--	20,587
Rail	2-14	22	23,301
"	3-14	2	1,917
"	4-14	139	98,971
"	4-15	26	22,410
"	5-14	106	117,514
"	8-15	17	20,843
Total Number of Rail Cars Per Year		312	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 60%
Total Distribution Costs - £8,213,586

Table 20. Optimum Transportation Pattern for 1979, Option II

Method	Route	Number of Rail Cars/Year	Number Cattle/Year
Trek	1-6	--	6,267
"	1-14	--	151,601
"	3-7	--	5,691
"	9-12	--	37,264
"	9-15	--	43,333
"	11-15	--	27,925
"	13-15	--	27,471
Rail	2-14	30	33,396
"	3-14	16	20,490
"	4-14	186	131,790
"	4-15	14	11,943
"	5-14	120	134,474
"	8-15	24	31,836
Total Number of Rail Cars Per Year		390	

Percentage of Total Inshipments to Area 14 and 15 Hauled by Rail - 60%
Total Distribution Costs - £10,323,226

Table 21. Optimum Transportation Pattern for 1987, Option II

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-6	--	5,720
"	1-14	--	213,919
"	9-12	--	33,017
"	9-15	--	79,450
"	10-14	--	5,121
"	13-15	--	44,043
Rail	2-14	52	57,384
"	3-14	56	72,074
"	4-14	284	201,529
"	5-14	162	180,299
"	8-15	47	61,169
"	11-15	29	46,588
Total Number of Rail Cars Per Year		630	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 64%

Total Distribution Costs - £16,072,318

Table 22. Optimum Transportation Pattern for 1995, Option II

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-6	--	6,304
"	1-14	--	235,748
"	9-12	--	36,386
"	9-15	--	87,557
"	10-14	--	5,644
"	13-15	--	48,537
Rail	2-14	57	63,239
"	3-14	62	79,429
"	4-14	313	222,093
"	5-14	178	198,697
"	8-15	52	67,410
"	11-15	32	51,342
Total Number of Rail Cars Per Year		694	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 64%

Total Distribution Costs - £21,350,467

probably increase faster than railing costs as the price in the destination markets increases.

The major treks occur on the routes connecting areas 1 with 14, 9 with 12, and 9 and 13 with 15.

Option III consists of instituting a trypanosomiasis control program along with increasing the speed of rail service by 1/5. An unlimited number of rail cars are available for cattle shipment. The results of this analysis are shown in Tables 23 through 26.

The number of rail cars demanded increases from 225 in 1971 to 405 in 1995. This represents an increase of about 2.2 percent per year. The percentage of total imports to areas 14 and 15 hauled by rail decreases slightly through time from 48 percent in 1971 to 38 percent in 1995. The percentage of imports arriving by rail to area 14 declines from 56 percent in 1971 to 50 percent in 1995. This decline occurs because exports to area 14 from areas 2 and 3 are trekked and rapidly expand over time. With an effective trypanosomiasis control program, these routes can be utilized at lower costs by trekking rather than rail hauling. The long routes connecting areas 4 and 5 with area 14 utilize rail cars for cattle shipments. All cattle arriving in area 15 from areas 8, 9, 11 and 13 are trekked while the cattle originating from area 4 are railed. The percentage of total inshipments to area 15 carried by rail cars declines from 20 percent in 1971 to only 4 percent in 1995.

Under option III, the number of cattle using trek routes increases substantially through time. The routes connecting areas 1 with 14 and 9 and 13 with 15 will be required to accommodate a large number of cattle as was also the case for options I and II. However, because trek costs have been reduced, additional trek routes become important. The cattle produced in areas 2 and 3 to be exported to area 14 utilize trek routes as do the cattle moving from areas 8 and 11 to area 15.

It is apparent from these results that the number of cattle utilizing trek routes will increase if an effective program for

Table 23. Optimum Transportation Pattern for 1971, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	--	140,953
"	2-14	--	27,705
"	3-6	--	4,731
"	3-7	--	7,076
"	3-14	--	2,183
"	8-15	--	23,569
"	9-12	--	17,072
"	9-15	--	52,021
"	11-15	--	21,973
"	13-12	--	24,082
Rail	4-14	119	102,851
"	4-15	23	24,244
"	5-14	83	116,577
Total Number of Rail Cars Per Year		225	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 48%

Total Distribution Costs - £7,064,945

Table 24. Optimum Transportation Pattern for 1979, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	--	171,449
"	2-14	--	35,741
"	3-6	--	3,990
"	3-7	--	4,295
"	3-14	--	23,303
"	8-15	--	35,162
"	9-12	--	9,573
"	9-15	--	73,912
"	11-15	--	29,833
"	13-12	--	30,846
Rail	4-14	155	133,994
"	4-15	16	16,325
"	5-14	95	134,467
Total Number of Rail Cars Per Year		266	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 44%

Total Distribution Costs - £8,933,230

Table 25. Optimum Transportation Pattern for 1987, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	--	238,668
"	2-14	--	66,530
"	3-14	--	85,275
"	8-6	--	1,157
"	8-15	--	64,956
"	9-15	--	117,090
"	11-15	--	50,236
"	13-12	--	38,228
"	13-15	--	12,384
Rail	4-14	234	202,782
"	4-15	10	10,043
"	5-14	127	180,859
Total Number of Rail Cars Per Year		371	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 38%

Total Distribution Costs - £13,867,808

Table 26. Optimum Transportation Pattern for 1995, Option III

Method	Route	Number of Rail Cars/Year	Number of Cattle/Year
Trek	1-14	--	261,278
"	2-14	--	72,833
"	3-14	--	93,354
"	8-6	--	1,267
"	8-15	--	71,110
"	9-15	--	128,183
"	11-15	--	54,995
"	13-12	--	41,850
"	13-15	--	13,557
Rail	4-14	256	221,993
"	4-15	10	10,995
"	5-14	139	197,993
Total Number of Rail Cars Per Year		405	

Percentage of Total Inshipments to Areas 14 and 15 Hauled by Rail - 38%

Total Distribution Costs - £17,883,925

controlling trypanosomiasis is implemented. If this program is to be effective, substantial investments will need to be made to furnish adequate feed and water for the cattle being trekked so that the savings in reducing disease losses are not lost to shrinkage from inadequate nutrition provision along the routes.

The average cost of transporting an animal that enters inter-area trade is substantially lower for option III relative to options I and II. By implementing a trypanosomiasis control program and furnishing all the rail cars that can be effectively used, the average distribution cost per animal is £15.3 in 1995 compared to about £18.2 per cow for options I and II--a decrease of about 19 percent. This means that price spreads between production and consumption locations will tend to be smaller under option III versus options I or II.

Summary

This report contains analyses of policy experiments conducted with models of the Nigerian cattle production and distribution sectors. Sensitivity tests conducted on the production model indicate that errors in measurement (or changes through time) of the proportion of males and females sold, price elasticity of demand for beef, TDN yield of various nutrition sources, and initial area of fly-free grazing land would all affect model behavior significantly. Assumptions about grazing rate equilibrium, range deterioration rates, initial cattle population, adjustments in sales relative to nutrition supply and price elasticity of supply do not seem to be as crucial.

Production Model Results

Table 27 gives the values of several variables in 1995 for four policy runs conducted on the cattle production model. If no public investments were made in the northern cattle production sector, cattle population would increase about 0.5 percent a year from 8,000,000 in 1971 to 9,026,000 in 1995. Most of the growth would occur between 1971 and 1979 (one percent a year). After this,

Table 27. Values of Indicated Variables in 1995 for Four Policy Runs of the Cattle Production Model

Run Designation	Total Population	Total Sales	Total Extraction Ratio	Range Condition	Accumulated Income from Milk and Cattle Sales	Value of Capital	Present Value of Additional Income	Present Value of Additional Cost
	(thousands)		(percent)	(Index)	(Thousand L's)			
Base Run	9,046	1,028	11.4	.84	1,361,000	1,442,000	--	--
Fly Eradication	11,683	1,299	11.1	.93	1,533,000	1,705,000	62,924	6,219
Grazing Reserves	9,206	1,097	11.9	.84	1,403,000	1,545,000	18,177	119,279
Fly Eradication with Grazing Reserves	11,707	1,367	11.5	.93	1,570,000	1,804,000	85,675	125,500

grazing land would be available if the tsetse eradication plans were implemented than if they were not. After 1979 the fly eradication program would generate 12.6 percent more accumulated income for producers than the base run. The present value of the additional net income going to producers would be about 10 times the present value of cost of the program.

The grazing reserve program would support about 2 percent more cattle in 1995 than the base run (see Table 27). Because of the more productive modern herd on the developed grazing reserves, the extraction rate would also be higher. These two factors would result in 1,000,000 more cattle being supplied throughout the 25 year period for the grazing reserve program versus the base run. In 1975 60,000 cattle would be on the new reserves with 268,000 and 308,000 in 1979 and 1983 respectively. The extraction rates for these herds would be about 2.9 times the extraction rates in the traditional herds. The grazing reserve program would yield Ł42,000,000 more income for the 25 year period compared to the base run. However, the costs of establishing and operating these units are much higher than the additional income they yield (see Table 27).

By implementing a fly eradication and grazing reserve development program, a total cattle population of 11,707,000 could be supported in 1995, 29 percent more than the base run. Approximately 2,600,000 more cattle would be marketed during the 25 year period. As shown in Table 27, this investment program would have the least harmful effect on range condition through time. Compared to the base run, the fly eradication-grazing reserve program would generate Ł210,000,000 more income for the 25 year period. However, the present value of the costs incurred would be 1.4 times the present value of the additional income. This results from the high cost of establishing and operating the grazing reserve units.

cattle population would stay almost constant. The grazing rate on fly-free land would decrease from 7.9 acres per animal in 1971 to 6.5 acres per animal in 1995. By 1995 crop residues would be furnishing 88 percent as much TDN as the fly-free grazing areas. If these residues become less available to cattle through time, serious nutrition problems would occur since the acres of grazing land would be declining from 63,230,000 to 58,700,000. For the base run, the lean beef supplied per capita would fall 35 percent from 4.75 pounds in 1971 to 3.11 pounds in 1995. This indicates that human population growth will be faster than the increase in cattle supplied which grows from 719,000 in 1971 to 1,028,000 in 1995. Cattle prices would increase from £24.9 per animal in 1971 to £37.7 in 1995. However, the increase would occur slowly up to 1979 and then become much more rapid. If price increases were to be held to one percent per year by cattle imports, 344,100 cattle would need to be imported in 1983 with 452,000, 578,600 and 709,300 required in 1987, 1991 and 1995 respectively. Since the grazing pressure would rise on the tsetse-free grasslands, the range condition would deteriorate from a base of 100 in 1953 to 84 in 1995. Therefore not only will the acres of grazing land decrease, but the productivity per acre will also fall.

The fly eradication program would support a more rapid increase in the cattle population than the base run. By 1995 there would be about 2,600,000 more cattle with about 270,000 more sold in that year versus the base run. However the number sold each year for the fly eradication program would be less than the base run up to 1983. The extraction ratio would be lower than the base run for all years especially before 1987. This occurs because the herd size would be expanding to utilize the new tsetse-free grazing lands. Under this program the land available for grazing would increase until 1981. Thereafter cropland encroachment would cause the acreage to fall. In 1995 28,000,000 more acres of tsetse-free

A fly eradication investment program would result in a much larger total cattle population than the grazing reserve program. However, since the extraction rate would be lower for the fly eradication program, the total number of cattle sold annually would also be lower until 1984. From that year to 1995, fewer cattle would be sold annually under the grazing reserve program versus the fly eradication option. For the entire 25 year period, only 716,000 more cattle would be marketed if the fly eradication and not the grazing reserve program were implemented.

A sales tax of £1 per animal would yield less revenue than the Jangali for all investment options. The difference in 1995 ranges from £840,000 for the fly eradication policy to £532,000 for the grazing reserve program. Sales taxes of £1.7 to £1.8 per animal would almost match Jangali returns in all cases.

Transportation Model Results

Truck shipment appears to be the most expensive method of transporting live cattle. The primary reason for this is the high freight charges levied by truck owners--over 2-1/2 times the freight charges of rail service. In general, trekking is cheaper than rail transport for distances of 350 miles or less especially if the routes are through tsetse-free areas. Railing becomes more advantageous for distances over 350 miles and on routes that pass through tsetse infested areas (see Figure 53). Major cost categories for each method include freight charges, shrinkage cost and salvage or death losses. Two policies that might reduce shrinkage and death losses were investigated. Results showed that increasing the speed of rail service by 1/5 reduced railing costs by 6.5 percent. If an effective trypanosomiasis control program could be instituted (as achieved in some experiments), trekking costs could be reduced by 40 percent. These results indicate that investments in a trypanosomiasis control program should be investigated thoroughly. Supplementary feeding and watering must also be implemented with increased rail speed or trypanosomiasis control if either are to be successful in reducing transport costs.

The last model component discussed estimated the demand and supply of cattle through time in each of 15 areas and calculated the least cost transportation configuration to service the required interarea flows for three transportation investment options. Figure 52 shows the area divisions. The first option entails increasing rail car numbers by 1.8 percent per year. Option II consists of furnishing as many rail cars as can be effectively used. The third option involves investing in trypanosomiasis control, reducing rail car turnaround times, and furnishing as many cars as are demanded.

The major exporting areas are 1, 2, 3, 4, 5, 8, 9, 11 and 13, with areas 12, 14 and 15 being large importers. Areas 6, 7 and 10 are neither large exporters nor importers for any option. Sokoto, Katsina, Bornu and Nguru are major export locations for cattle moving into area 14. Area 15 receives cattle from area 9 for all options in every year. Areas 8, 11 and 13 also export to area 15 depending on the year and investment option. Since two of the major export areas to area 15 are not served by rail (9 and 13), improvement in trekking is important to consumers in this eastern area. The importance of improvement in trek costs is emphasized by the fact that through time areas 1, 9 and 13 continue to be major exporting areas which are not served by the rail system.

The percentage increase of production in the northern areas is smaller than the percentage increase in their exports to southern areas. This results in an increasing percentage of total marketed cattle going to the south from about 50 percent in 1971 to 67 percent in 1995. Since increased production can not fulfill the expanding demands in the southern areas, many northern areas may retain fewer cattle for consumption within the area through time.

The limited number of rail cars available in option I are more advantageously used to ship to area 14 versus 15. In 1971, 50 percent of the total inshipments to areas 14 and 15 were hauled by rail. However, in 1987 only 36 percent enter these areas by rail.

The main reason for this is the decline in percentage of cattle hauled by rail to area 15 from 41 percent in 1971 to zero by 1987. Therefore if the number of rail cars becomes a serious limitation, rail shipments to area 15 may decline substantially and investment in trek routes leading to area 15 should be considered.

The demand for rail cars increases rapidly under option II from 312 in 1971 to 694 in 1995. While the majority of total inshipments to the two southern areas are hauled by rail in all years, it is interesting to note that over 1/3 of the total are trekked no matter how many rail cars are provided. This occurs because major excess supply areas (1, 9 and 13) are not close to rail lines. Large numbers of cattle move along trek routes connecting areas 1 with 14, 9 with 12, and 9 and 13 with 15.

The number of rail cars demanded increases from 225 in 1971 to 405 in 1995 for option III. The percentage of total imports hauled by rail to the south decreases from 48 percent in 1971 to 38 percent in 1995. Results show that rail cars in this option can be more effectively used to haul cattle into area 14 versus 15. The percentage of total inshipments to area 15 carried by rail declines from 20 percent to only 4 percent from 1971 to 1995. The number of cattle utilizing trek routes increases substantially. Besides the trek routes coming from areas 1, 9 and 13, additional routes out of areas 2, 3, 8 and 11 become important. These results indicate that the number of cattle using trek routes will increase substantially if an effective program for controlling trypanosomiasis can be implemented. The average cost of transporting an animal that enters interarea trade is substantially lower for option III (£15.3 per animal) versus I and II (£18.2 per animal). This means that price spreads between consuming and producing locations would tend to be smaller for option III versus options I or II.

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2. Kellogg, E. D. *A Temporal and Spatial Model to Assist in Evaluating Investments in the Nigerian Beef Distribution System.* Unpublished Ph.D. Dissertation, Michigan State University, 1971.
3. *Federal Republic of Nigeria--Loan Application to the International Bank for Reconstruction and Development.* Federal Ministry of Agriculture and Natural Resources in association with Federal Livestock Department and the Nigerian Agricultural Bank, April 1972.

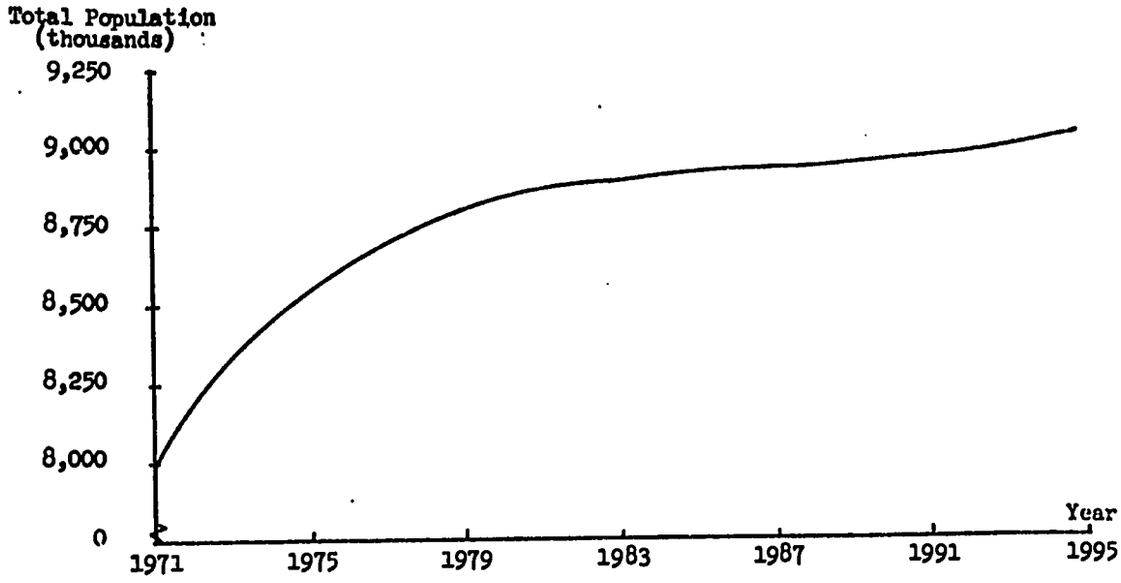

Figure 1 - Total number of cattle through time for Base Run.

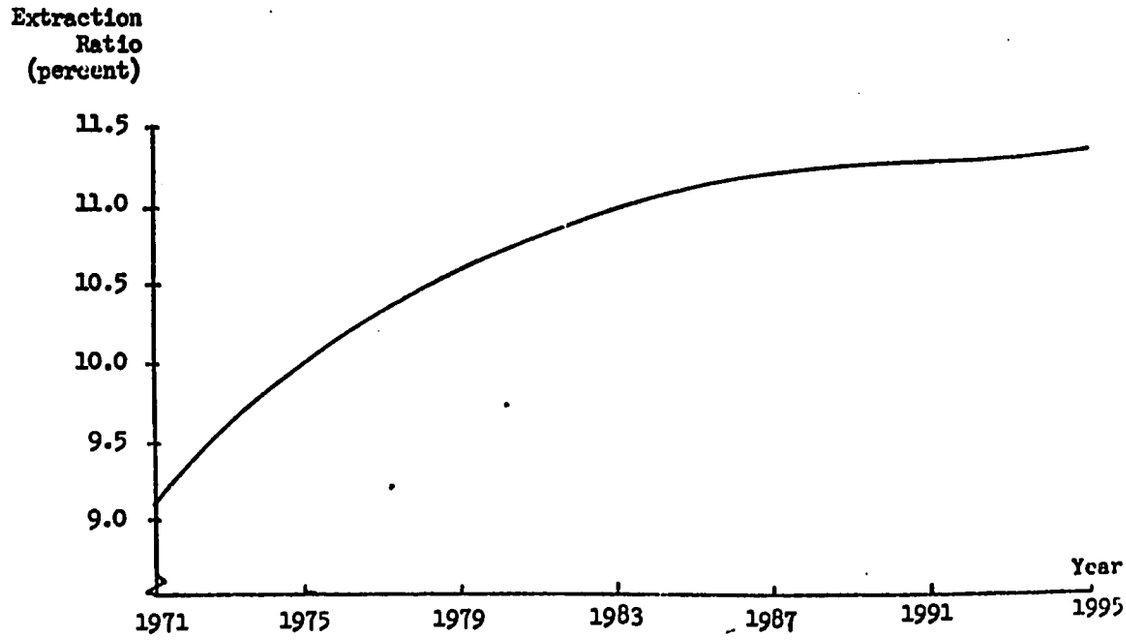

Figure 2 - Percent of total herd sold annually through time for Base Run.

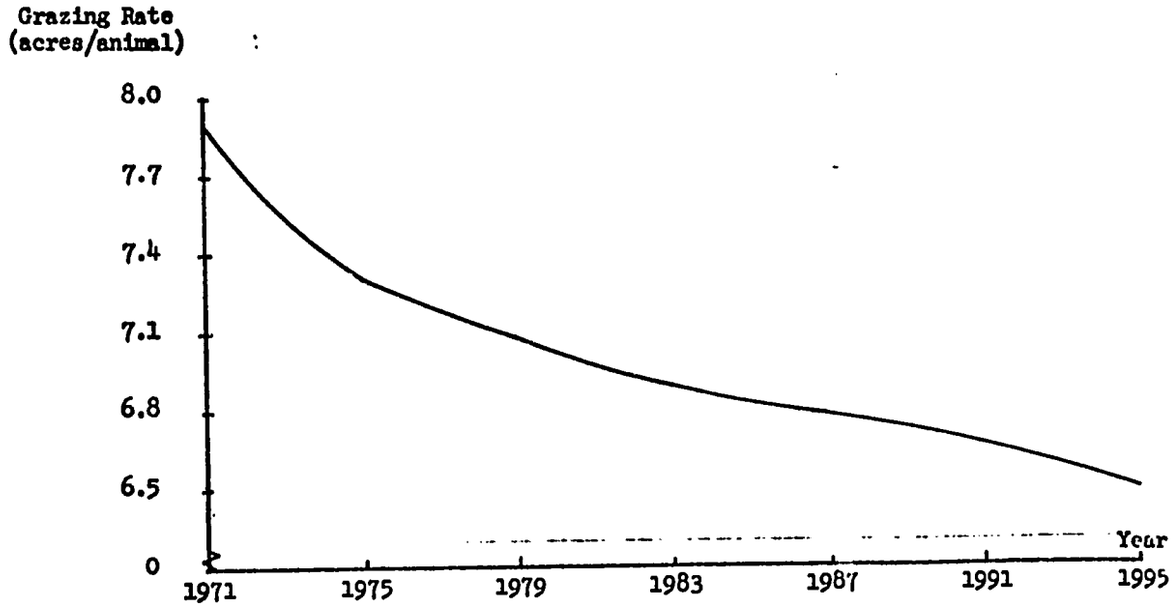

Figure 3 - Grazing rate through time for Base Run.

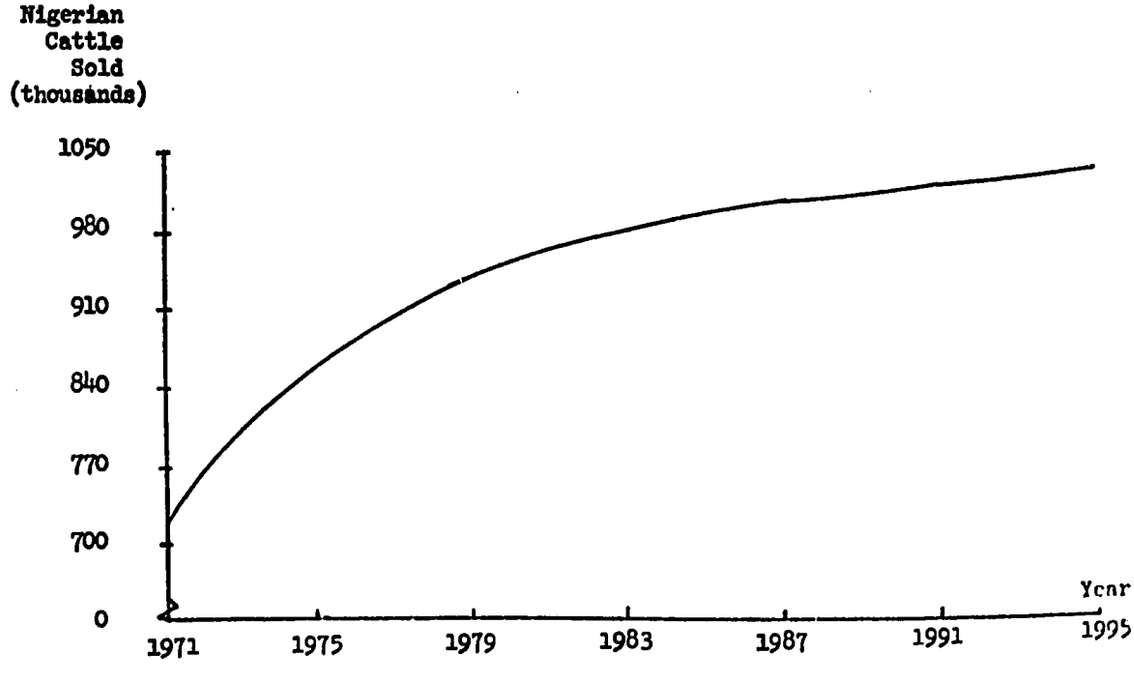

Figure 4 - Number of cattle supplied from Nigerian herd through time for Base Run.

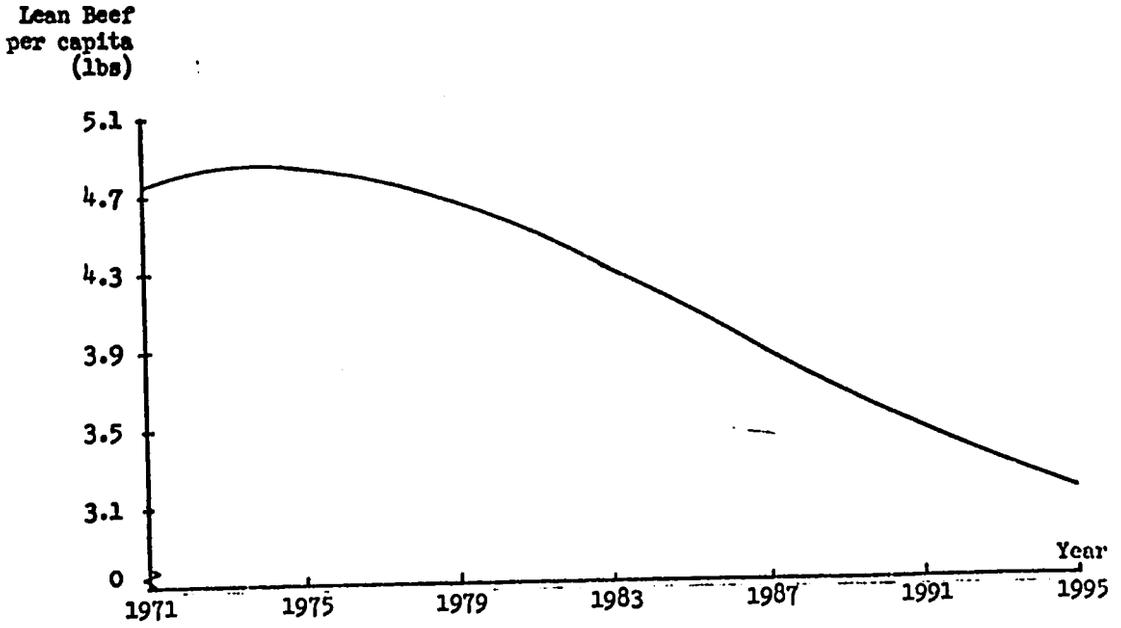

Figure 5 - Pounds of lean beef per capita supplied through time for Base Run.

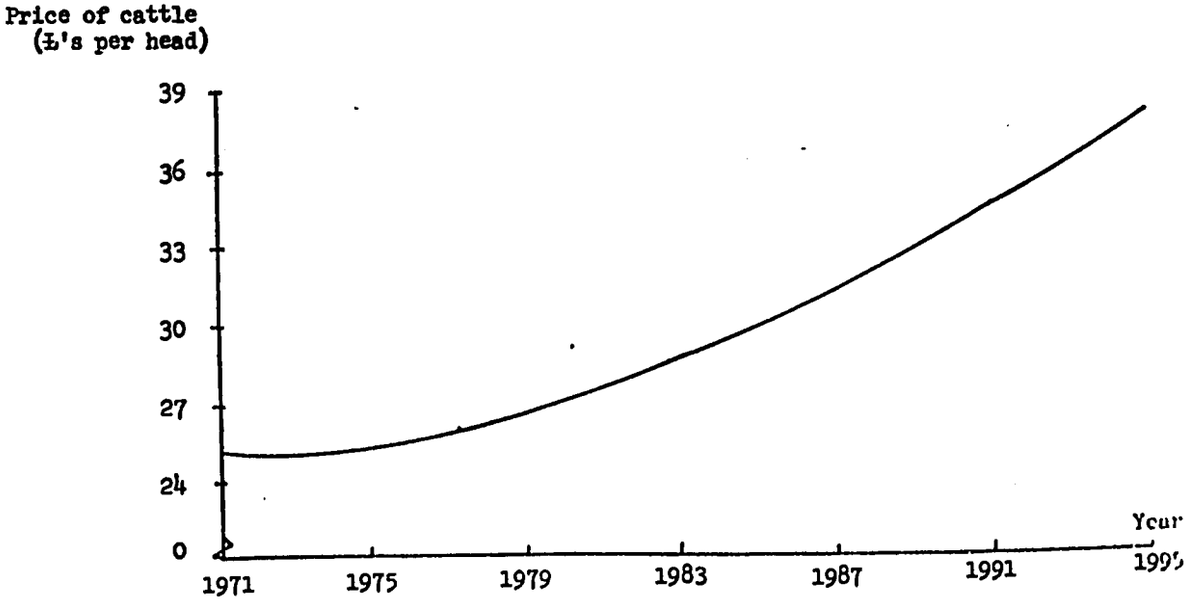

Figure 6 - Producer price of cattle through time for Base Run.

Figure 7 - Acres of year around grazing land available through time for Base Run.

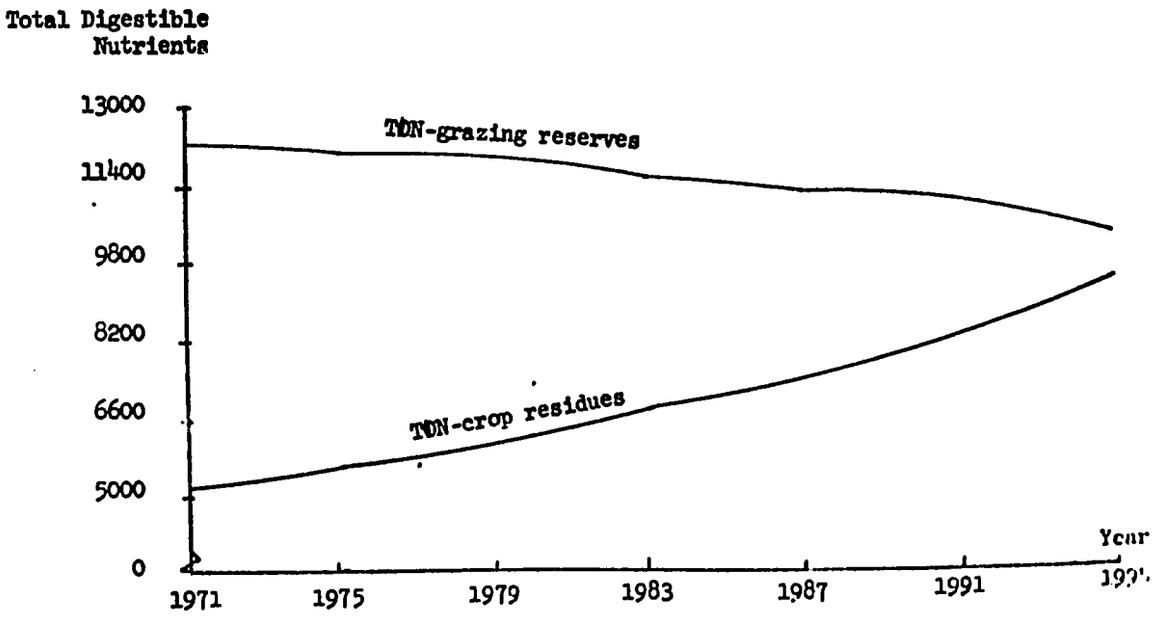

Figure 8 - Total disgestible nutrients from crop residues and grazing land through time for Base Run.

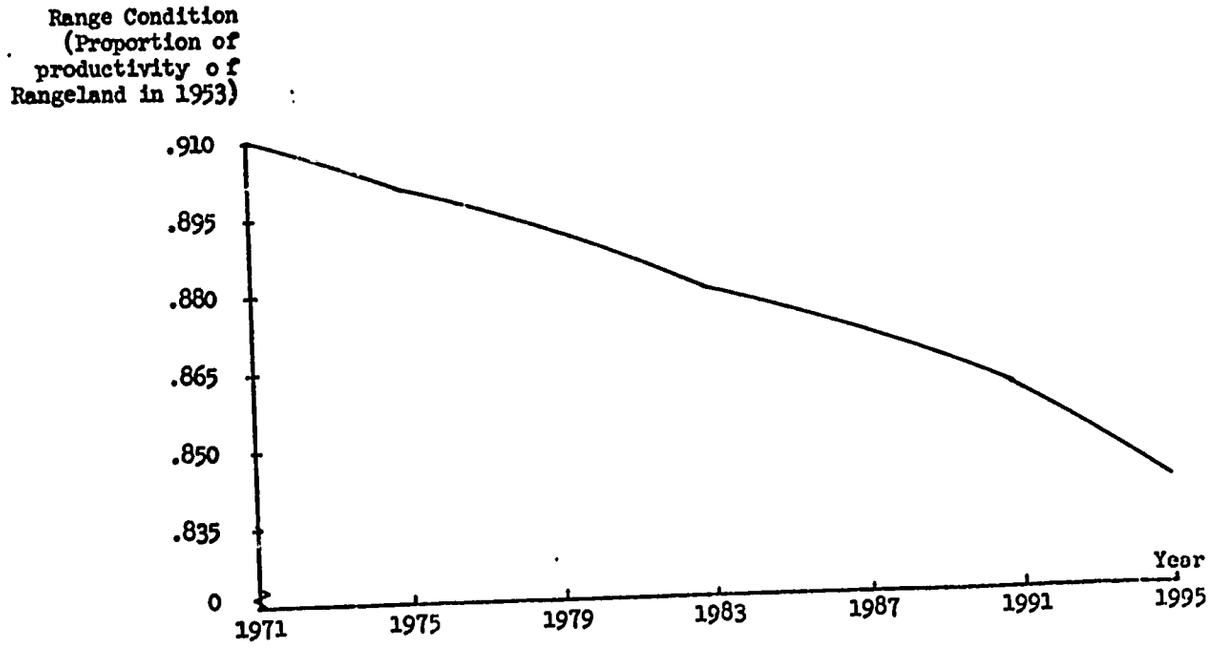

Figure 9 - Range condition through time for Base Run.

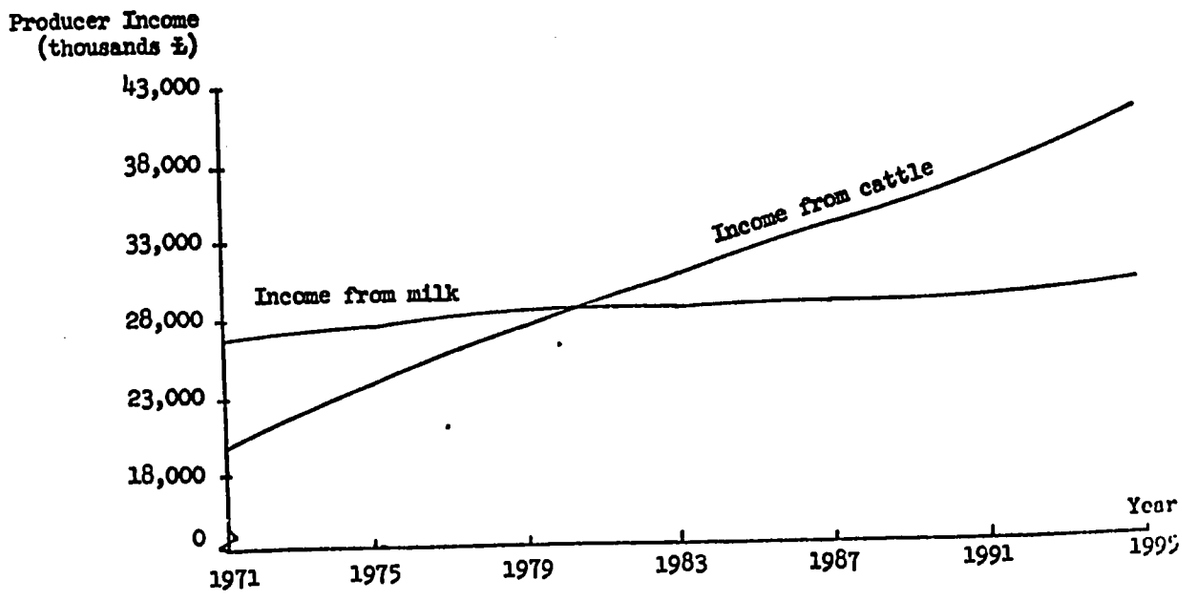

Figure 10 - Producers' income from cattle and milk sales through time for Base Run.

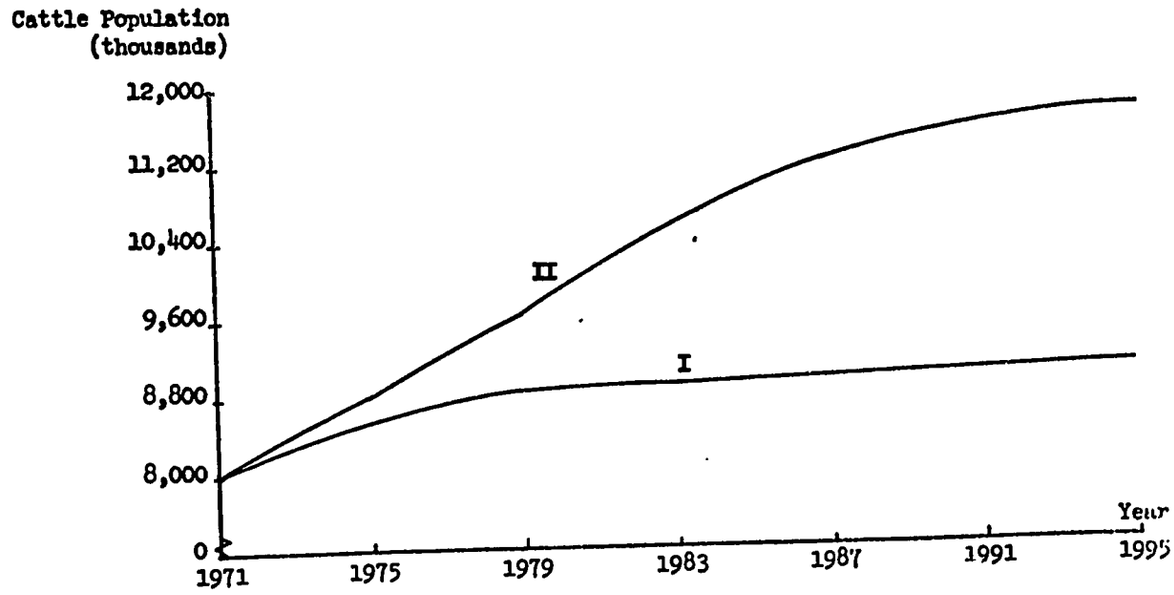

Figure 11 - Cattle population through time for Base Run (I) and Fly Eradication Program (II).

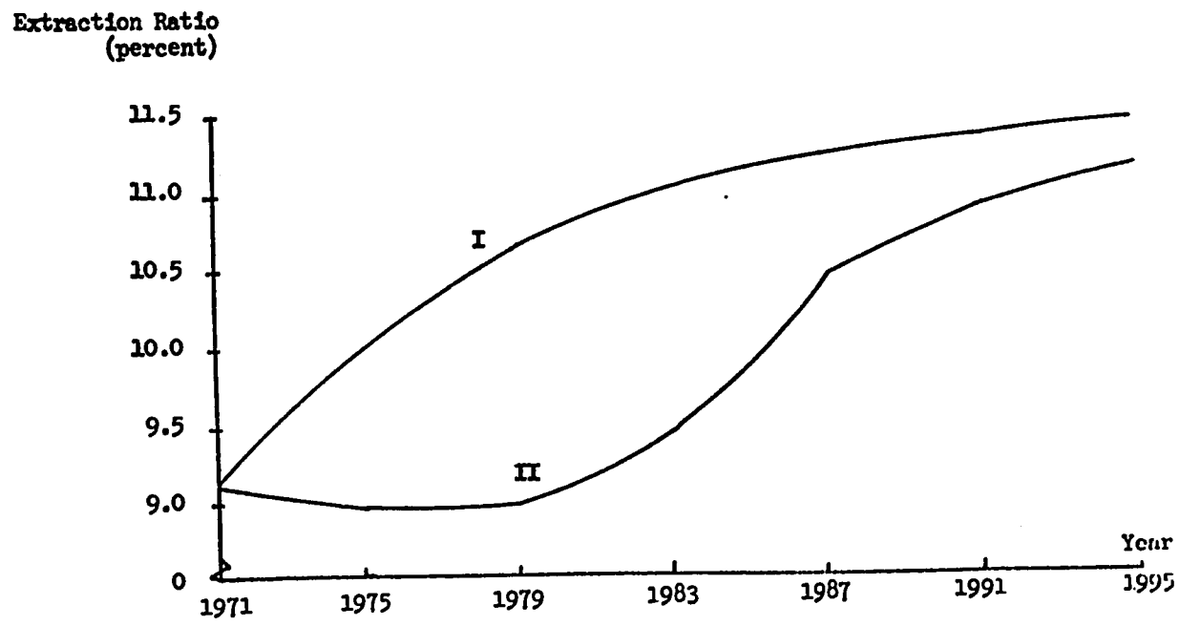

Figure 12 - Extraction ratio through time for Base Run (I) and Rly Eradication Program (II).

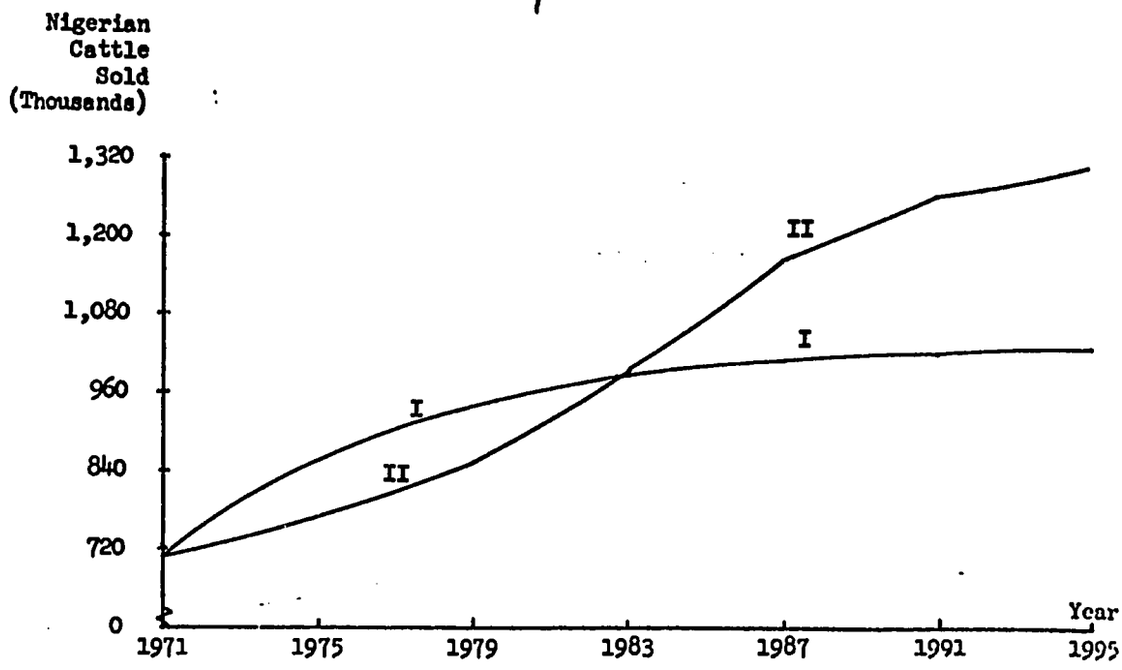

Figure 13 - Number of cattle supplied from Nigerian herd through time for Base Run (I) and Fly Eradication Program (II).

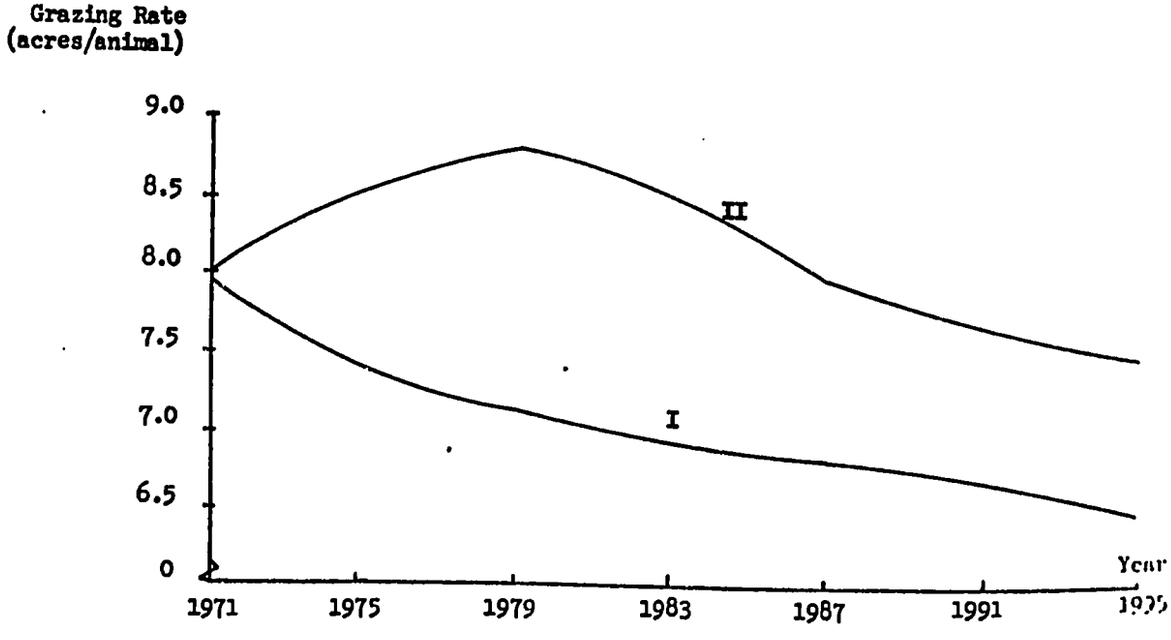

Figure 14 - Grazing rate through time for Base Run (I) and Fly Eradication Program (II)

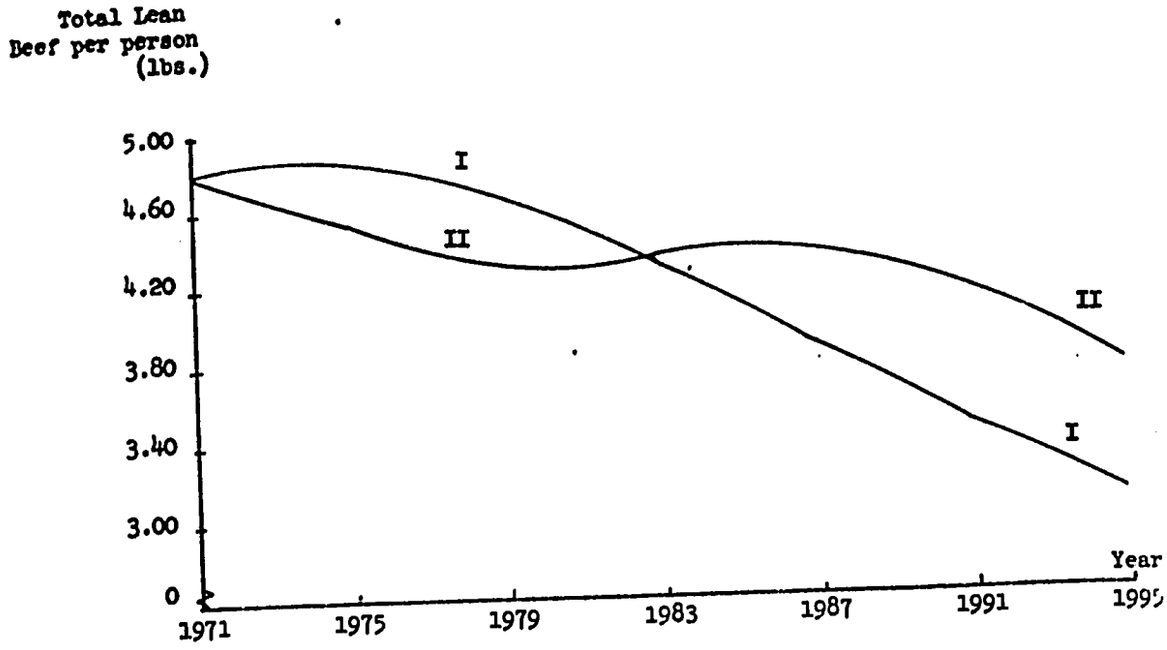

Figure 15 - Pounds of lean beef per capita through time for Base Run (I) and Fly Eradication Program (II).

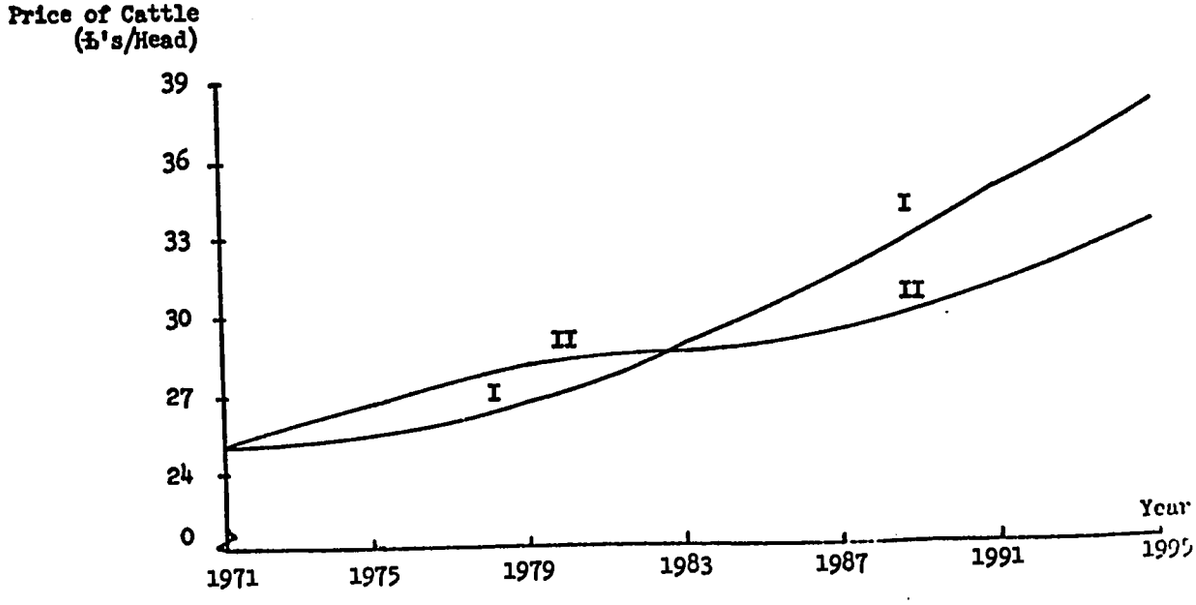

Figure 16 - Producer price of cattle through time for Base Run (I) and Fly Eradication Program (II).

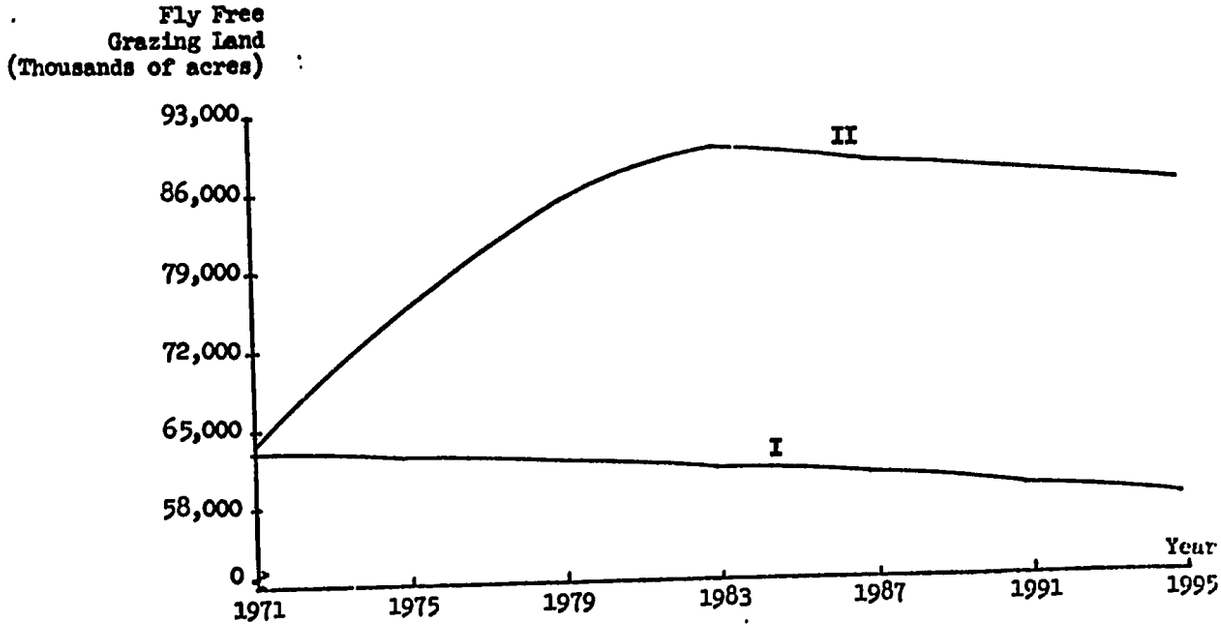

Figure 17 - Acres of fly free grazing land through time of Base Run (I) and Fly Eradication Programs (II).

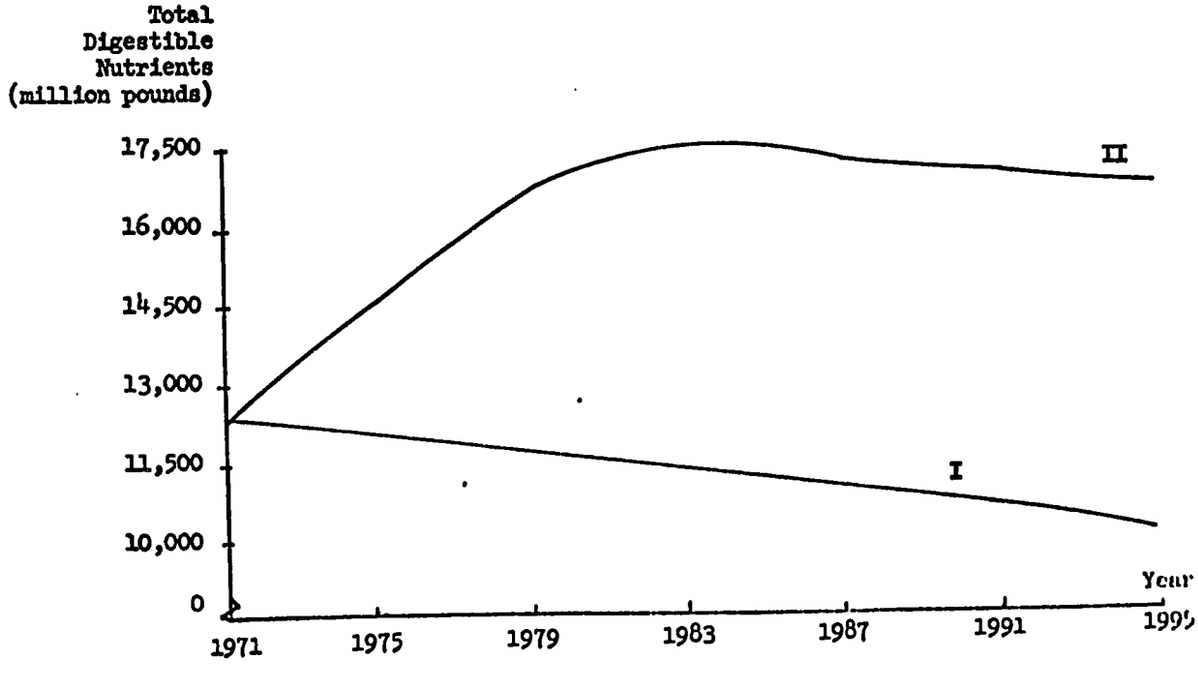

Figure 18 - Total digestible nutrients from Fly Free Grazing Land through time for Base Run (I) and Fly Eradication Program (II).

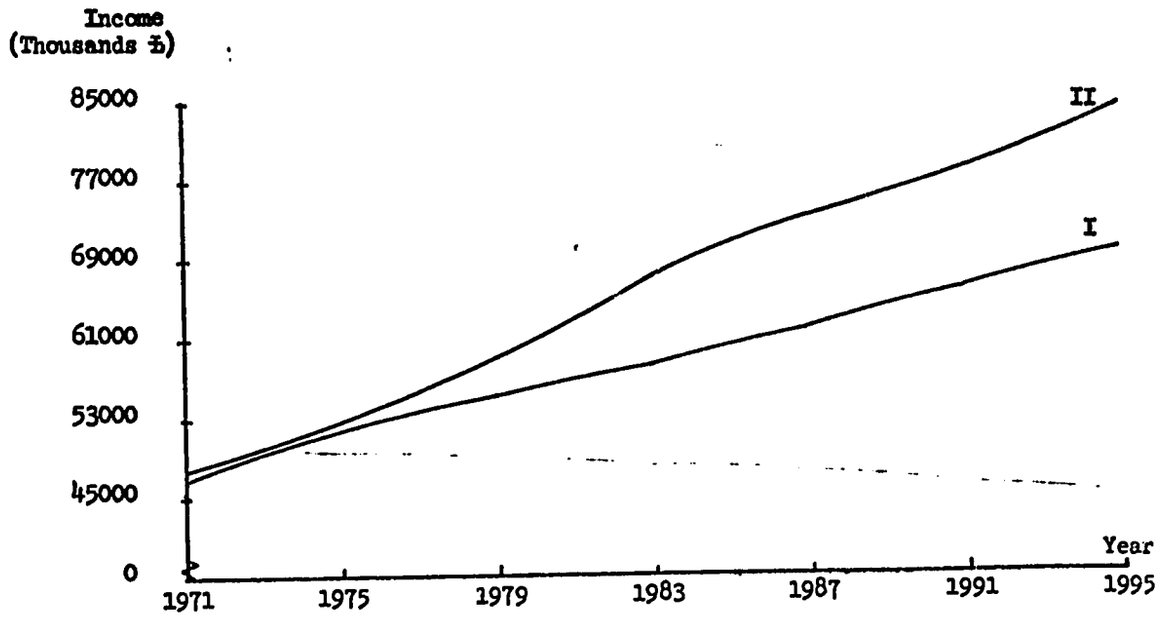

Figure 19 - Producer income from animal and milk sales through time for Base Run (I) and Fly Eradication Program (II).

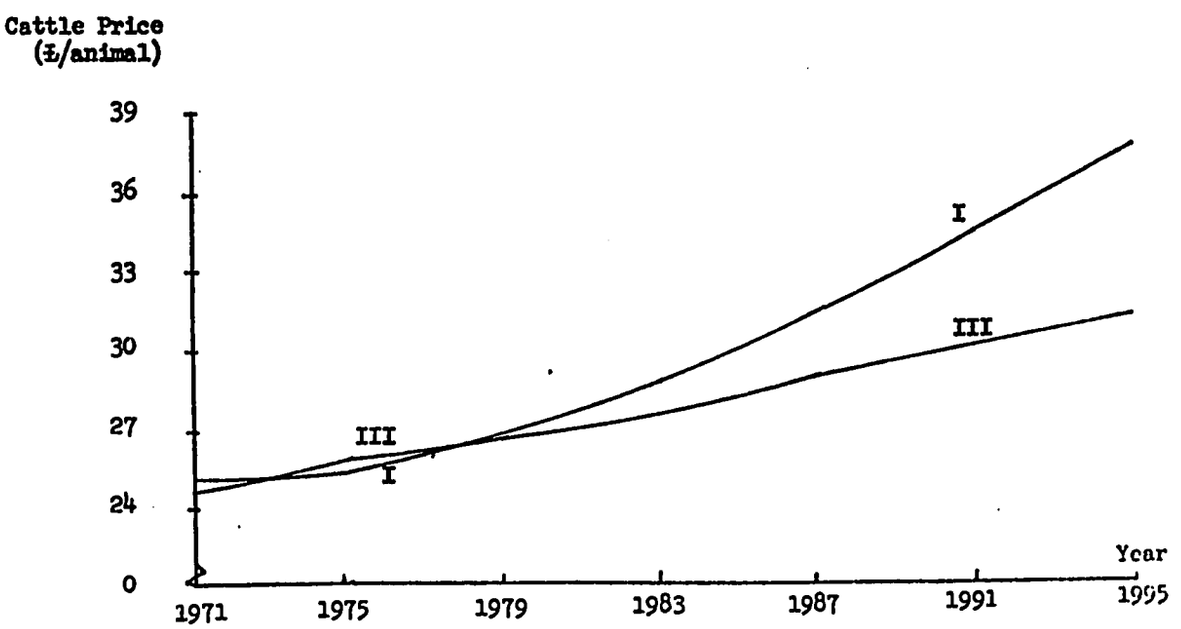

Figure 20 - Price of cattle through time for Base Run (I) and Price Import Policy Run (III).

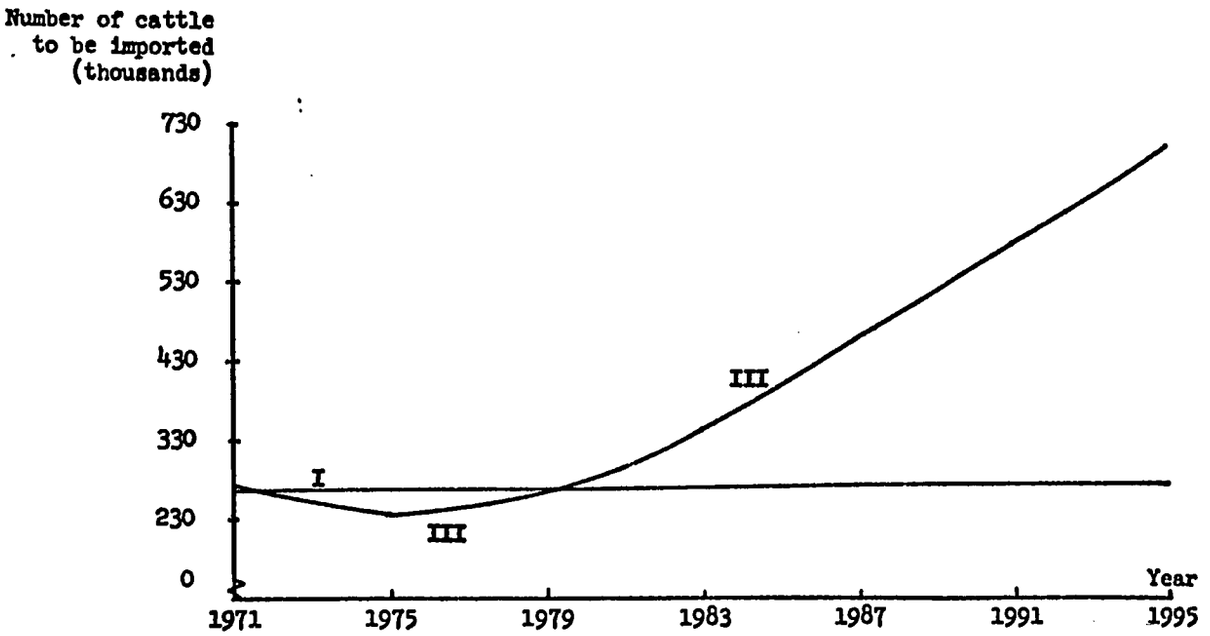

Figure 21 - Number of cattle imported through time for Base Run (I) and Price Import Policy (III).

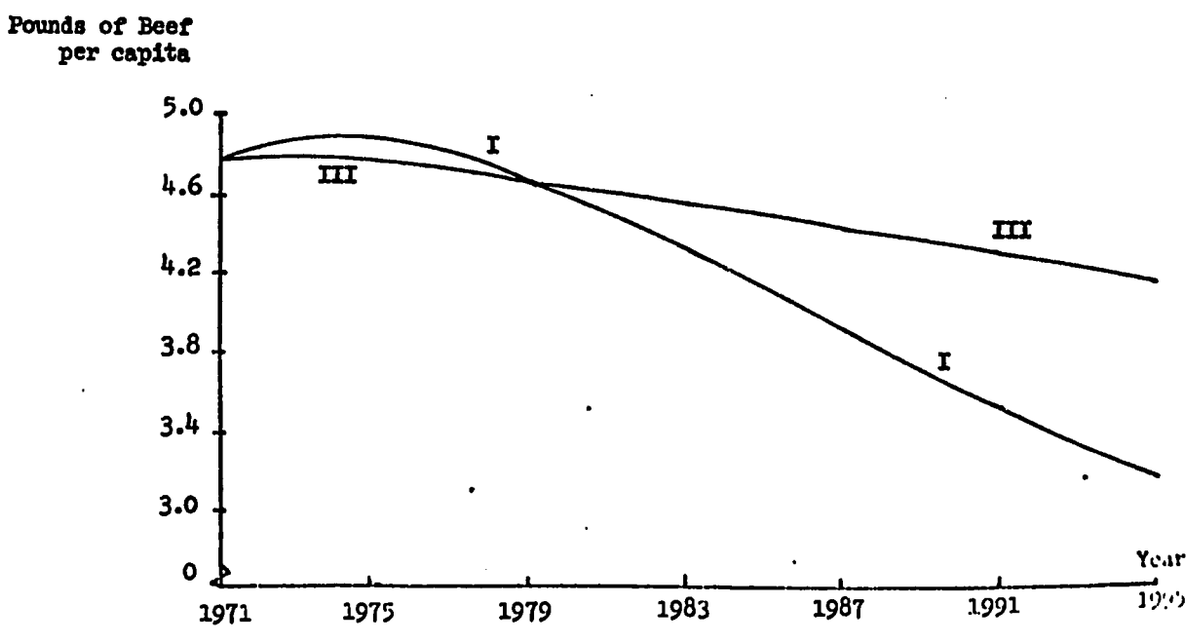

Figure 22 - Pounds of beef per capita supplied through time for Base Run (I) and Price Import Policy Run (III).

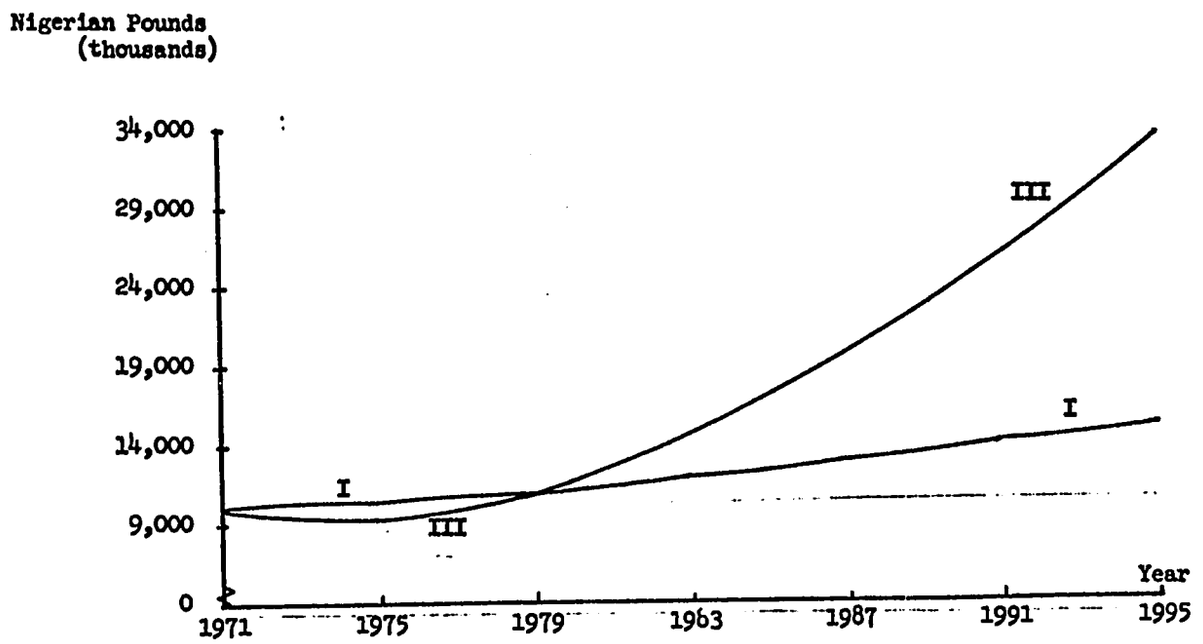

Figure 23 - Expenditures on imports through time for Base Run (I) and Price Import Policy Run (III)

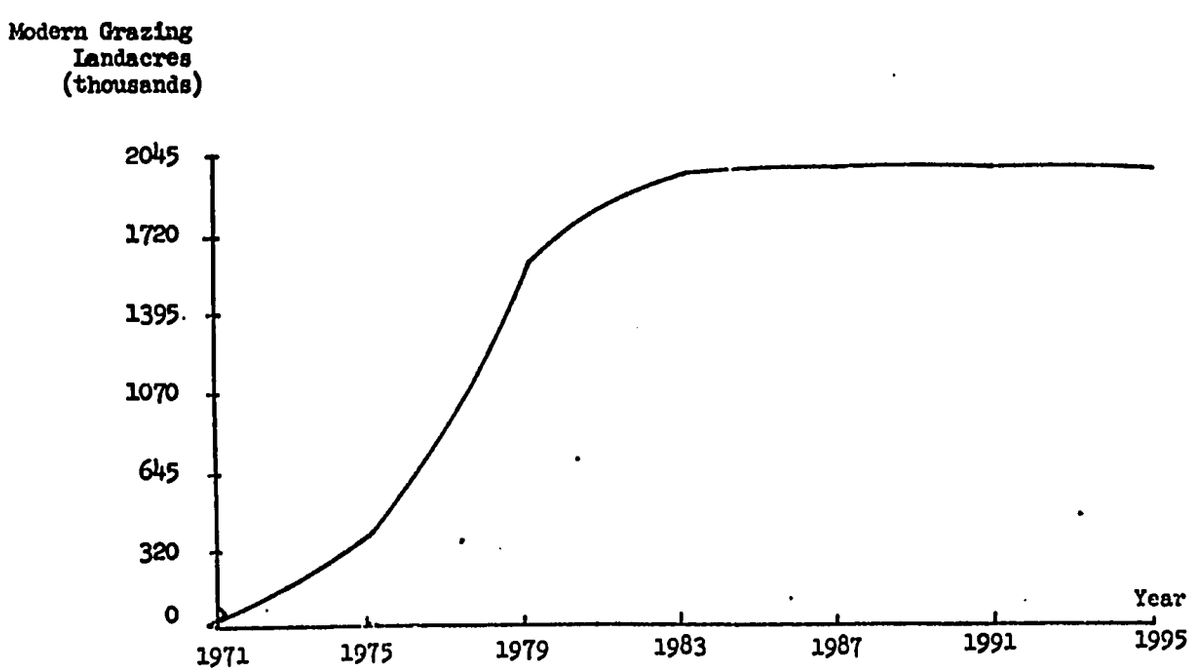

Figure 24 - Acres of modern grazing available through time for Grazing Reserve Program

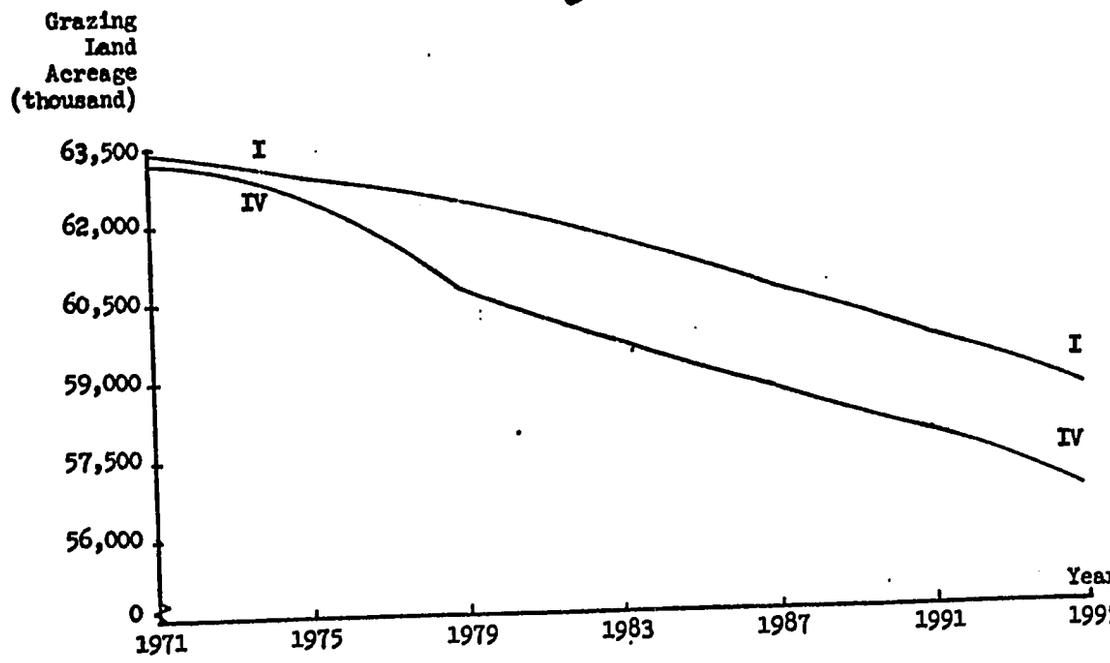

Figure 25 - Acreage of traditional grazing land through time for Base Run (I) and Grazing Reserve Program (IV).

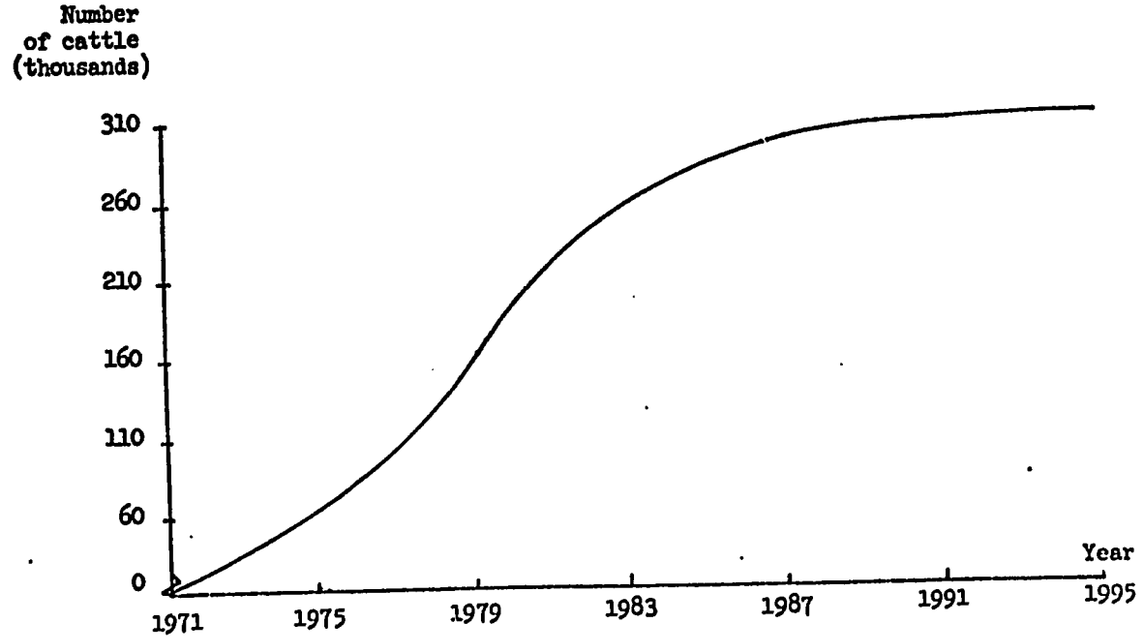

Figure 26 - Number of cattle in the modern herd through time for Grazing Reserve Program.

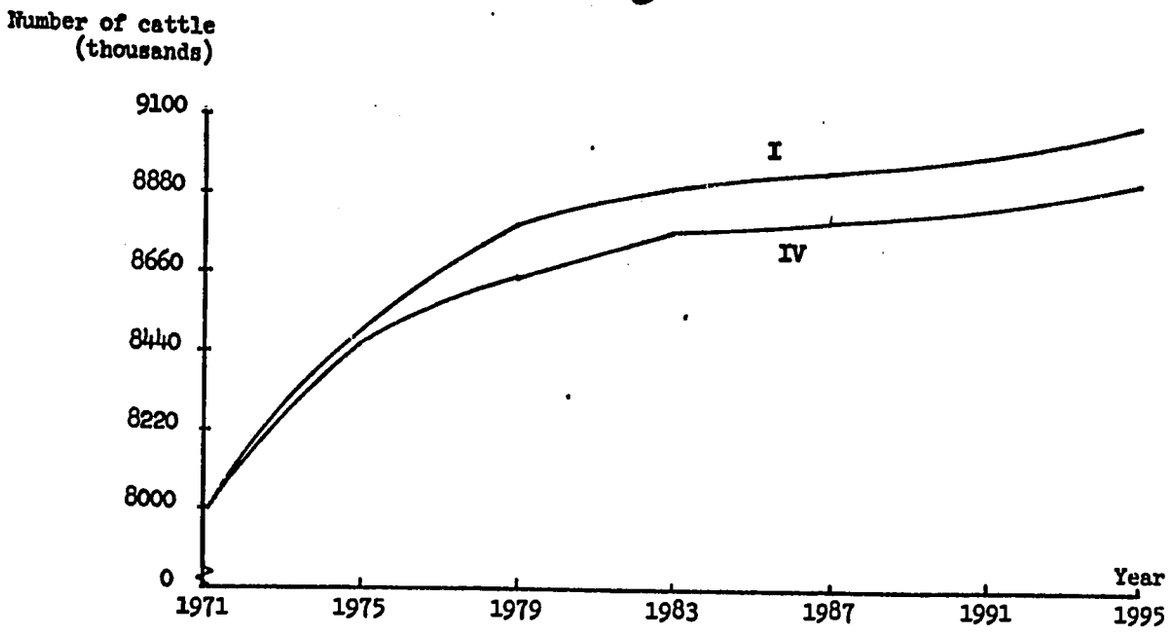

Figure 27 - Number of cattle in the Traditional Herd through time for the Base Run (I) and Grazing Reserve Program (IV).

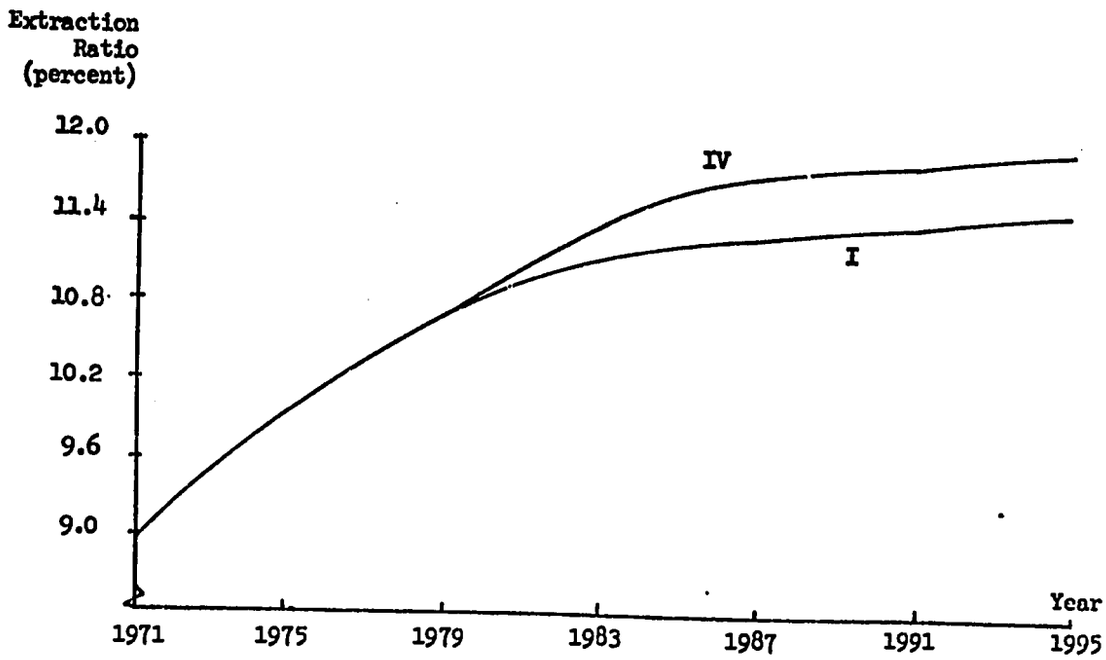

Figure 28 - Percent of total herd in Nigeria sold through time for Base Run (I) and Grazing Reserve Program (IV).

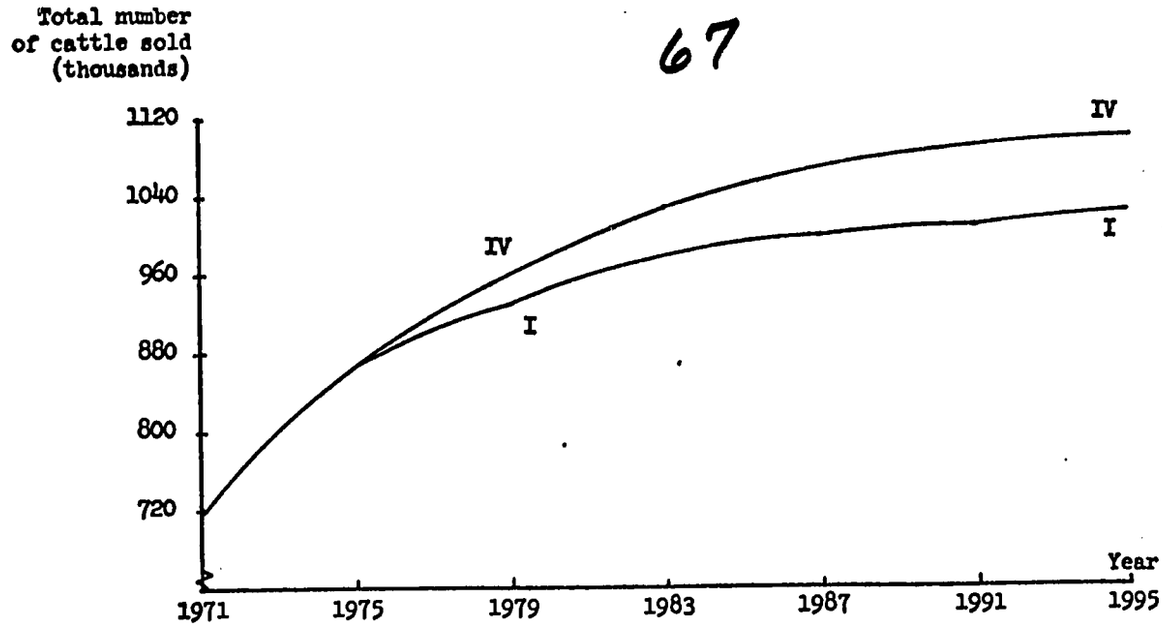

Figure 29 - Total number of cattle sold through time for Base Run (I) and Grazing Reserve Program (IV).

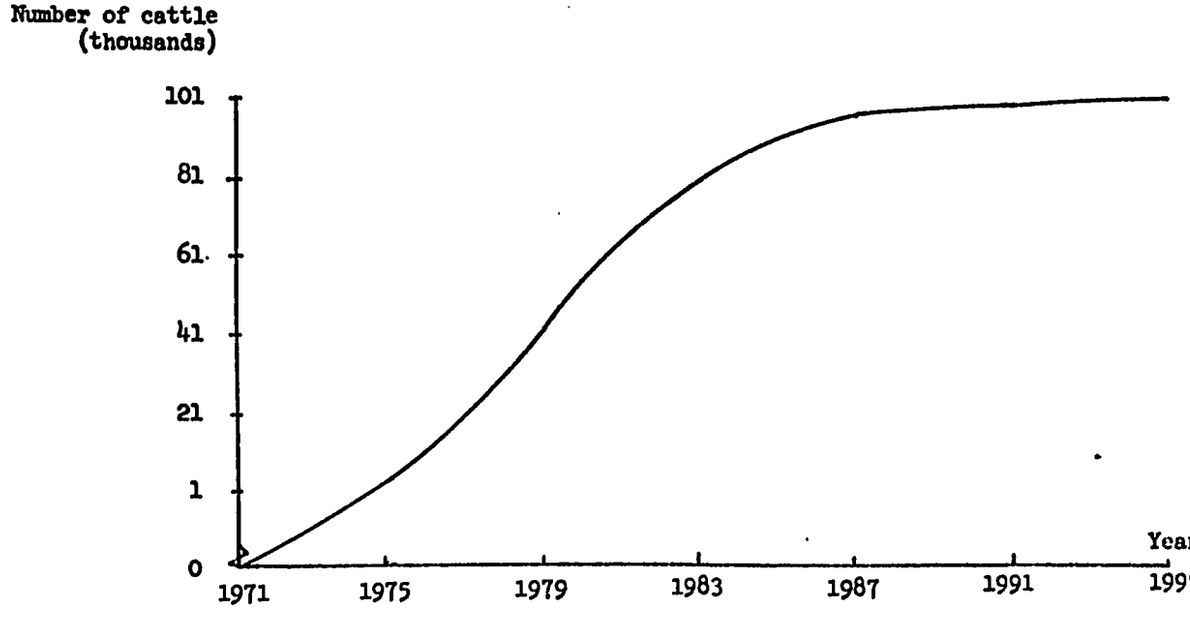

Figure 30 - Number of cattle sold from modern herd through time for Grazing Reserve Program.

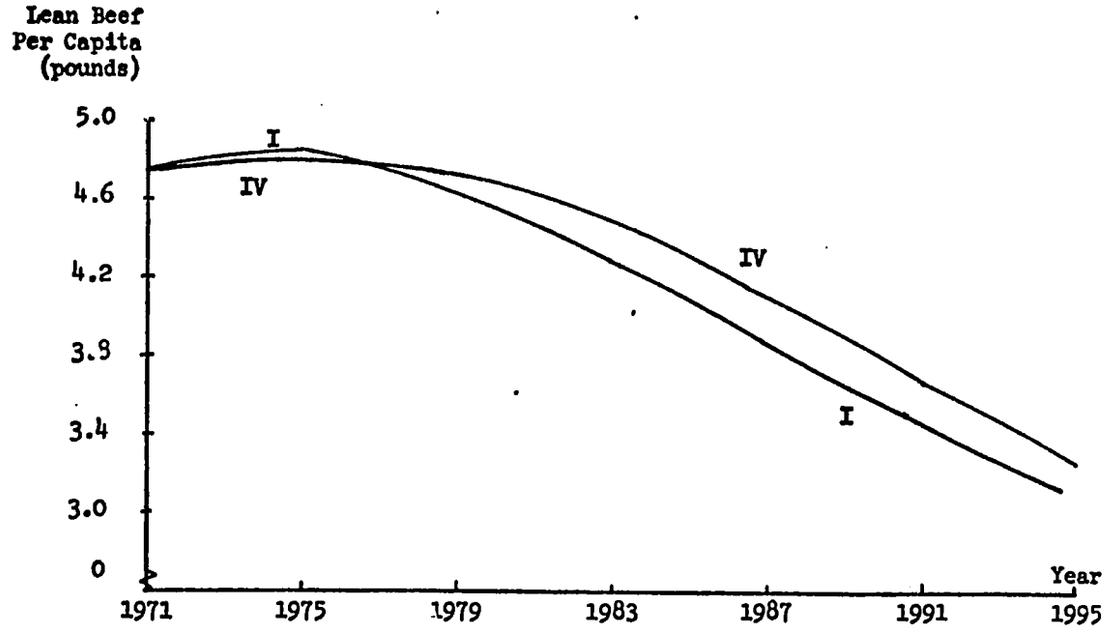

Figure 31 - Pounds of lean beef supplied per capita through time for Base Run (I) and Grazing Reserve Program (IV).

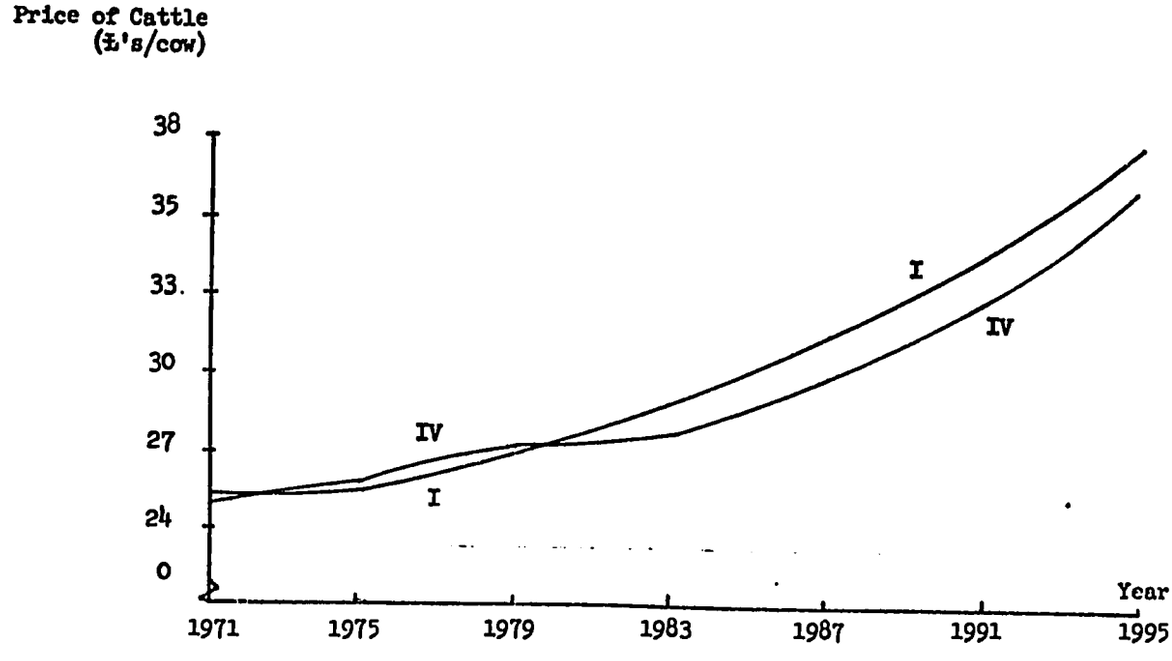

Figure 32 - Price of cattle through time for Base Run (I) and Grazing Reserve Policy (IV).

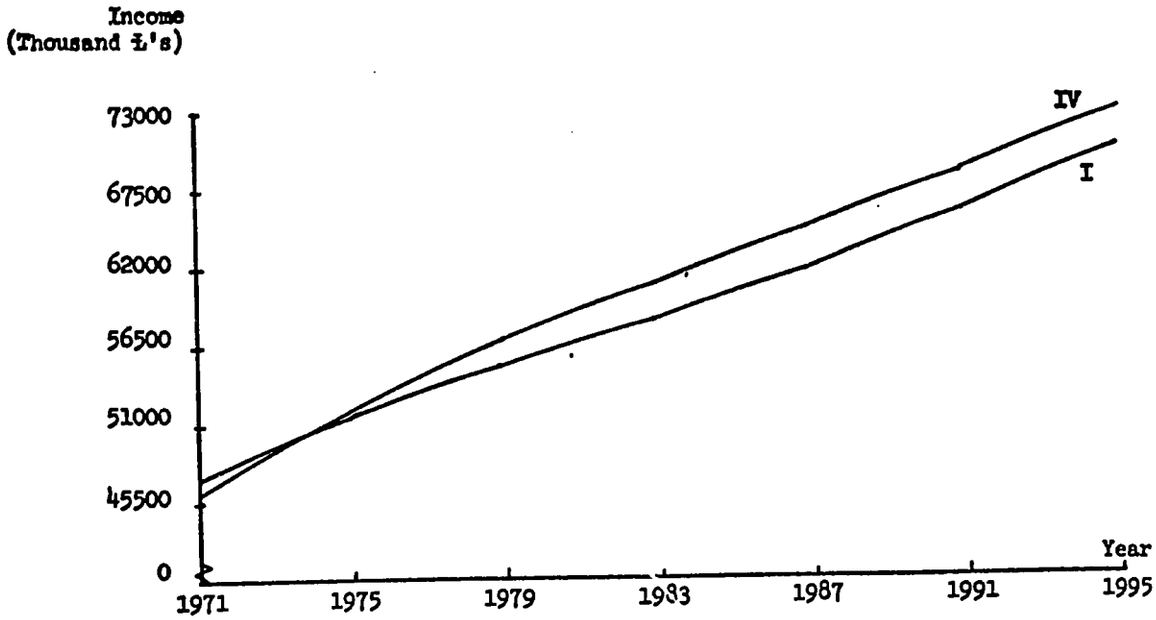

Figure 33 - Income from milk and cattle sales through time for Base Run (I) and Grazing Reserve Program (IV).

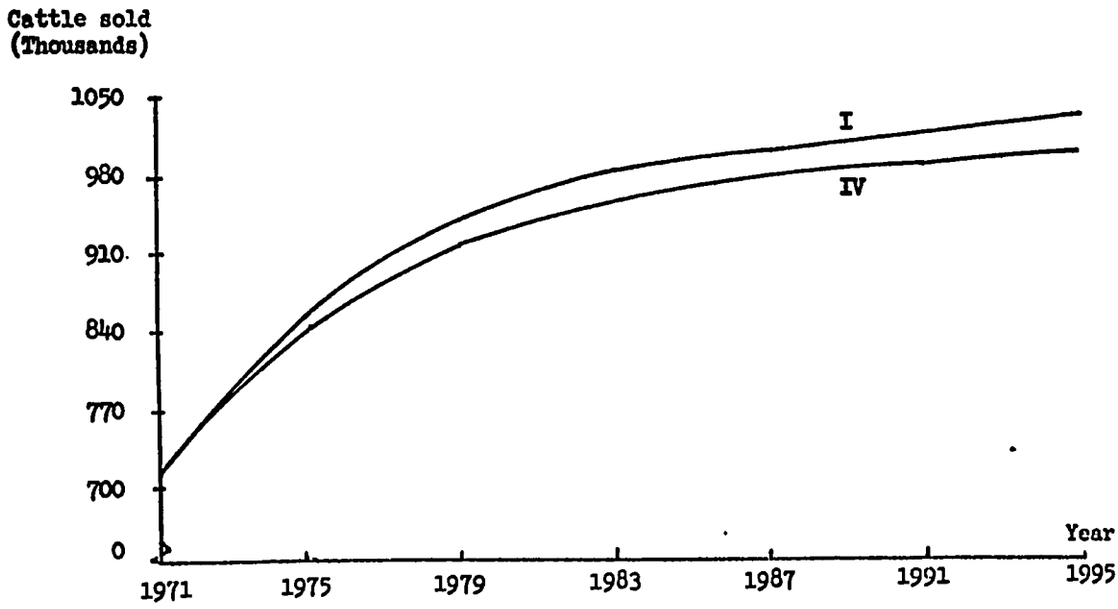

Figure 34 - Number of cattle sold from the Traditional Herd through time for Base Run (I) and Grazing Reserve Program (IV).

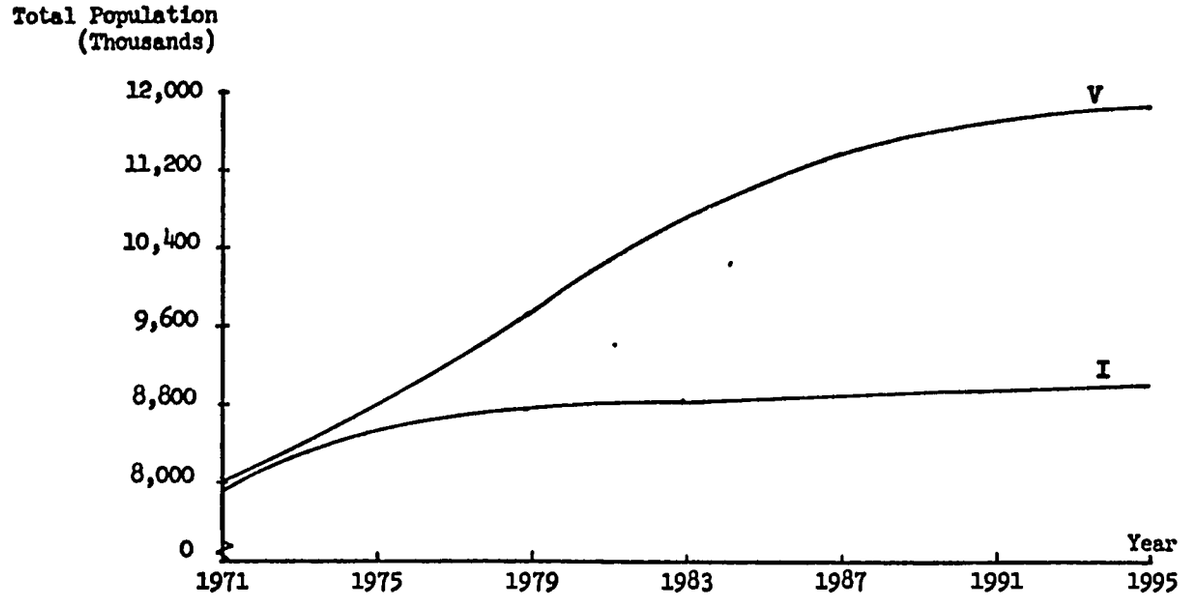

Figure 35 - Total number of cattle in Nigeria through time for Base Run (I) and Fly Eradication plus Grazing Reserve Program (V).

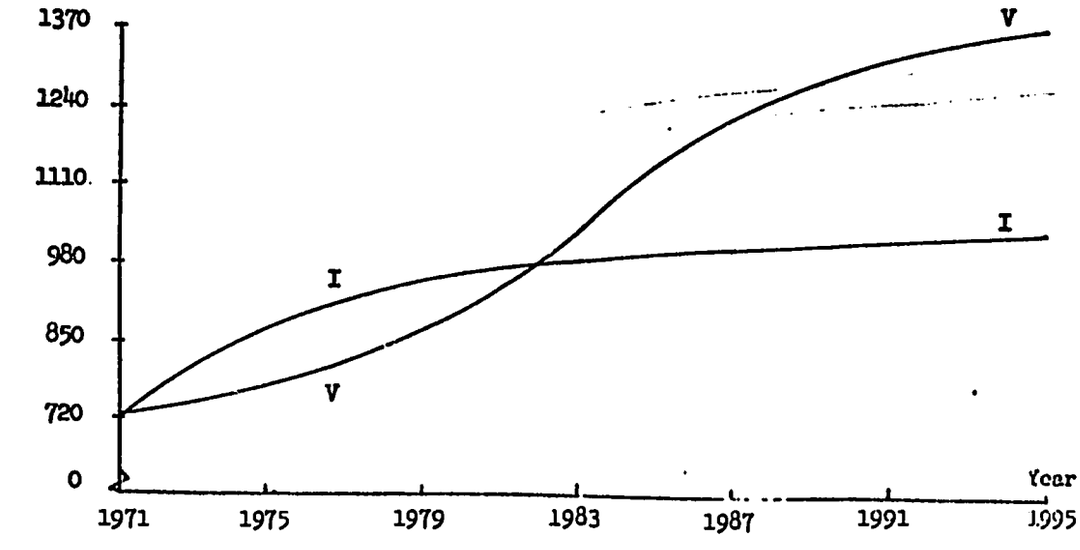

Figure 36 - Total number of cattle sold from Nigerian Herd through time for Base Run (I) and Fly Eradication plus Grazing Reserve Program (V).

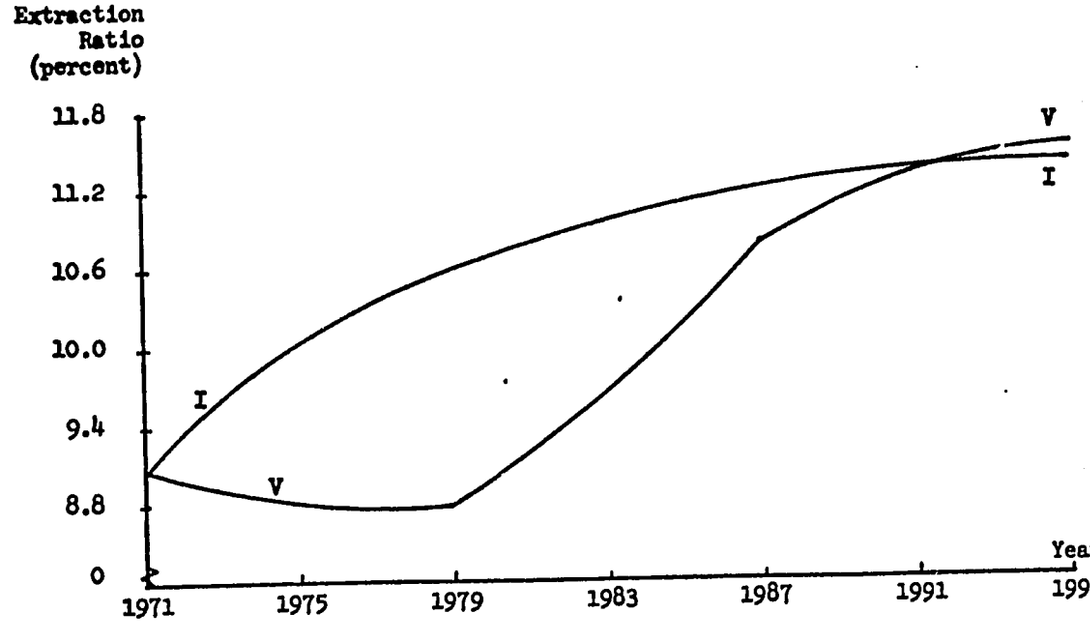

Figure 37 - Percent of Nigerian Herd sold through time for Base Run (I) and Fly Eradication plus Grazing Reserve Program (V).

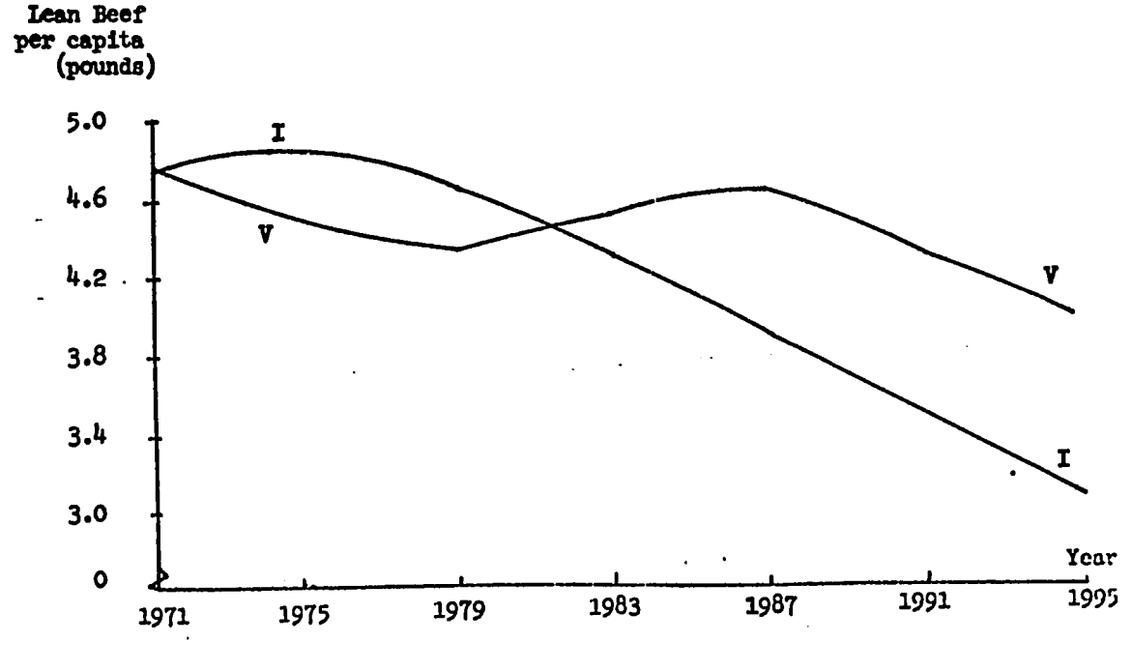

Figure 38 - Pounds of Lean Beef per capita supplied through time for Base Run (I) and Fly Eradication plus Grazing Reserve Program (V).

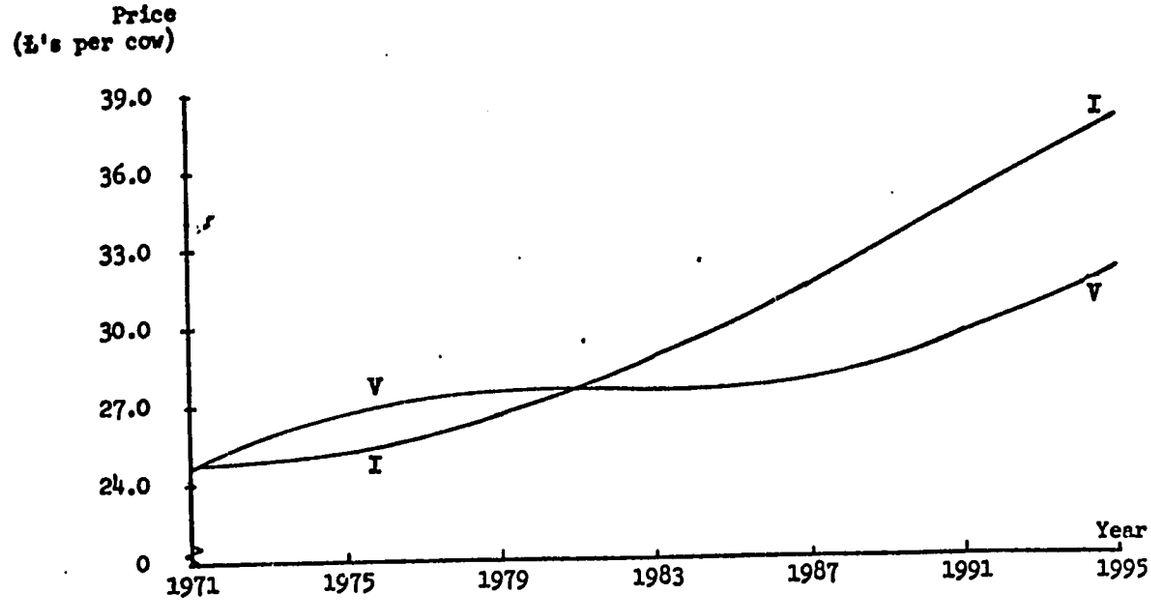

Figure 39 - Producer price of cattle through time for Base Run (I) and Fly Eradication plus Grazing Reserve Program (V).

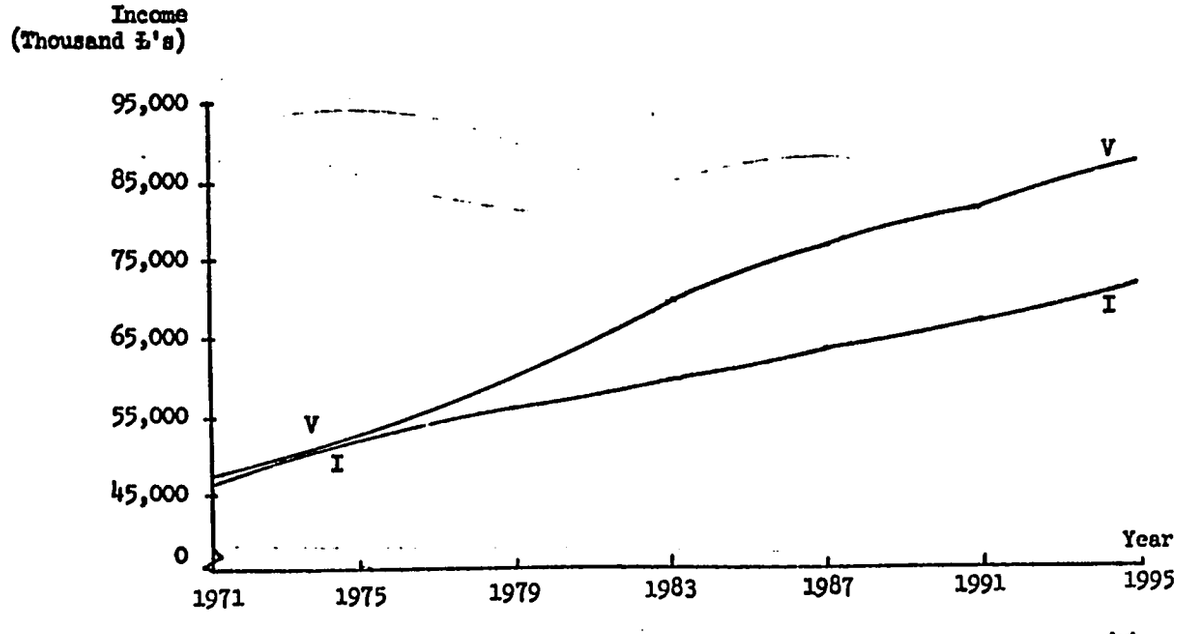

Figure 40 - Income from Milk and Meat Sales through time for Base Run (I) and Fly Eradication plus Grazing Reserve Program (V).

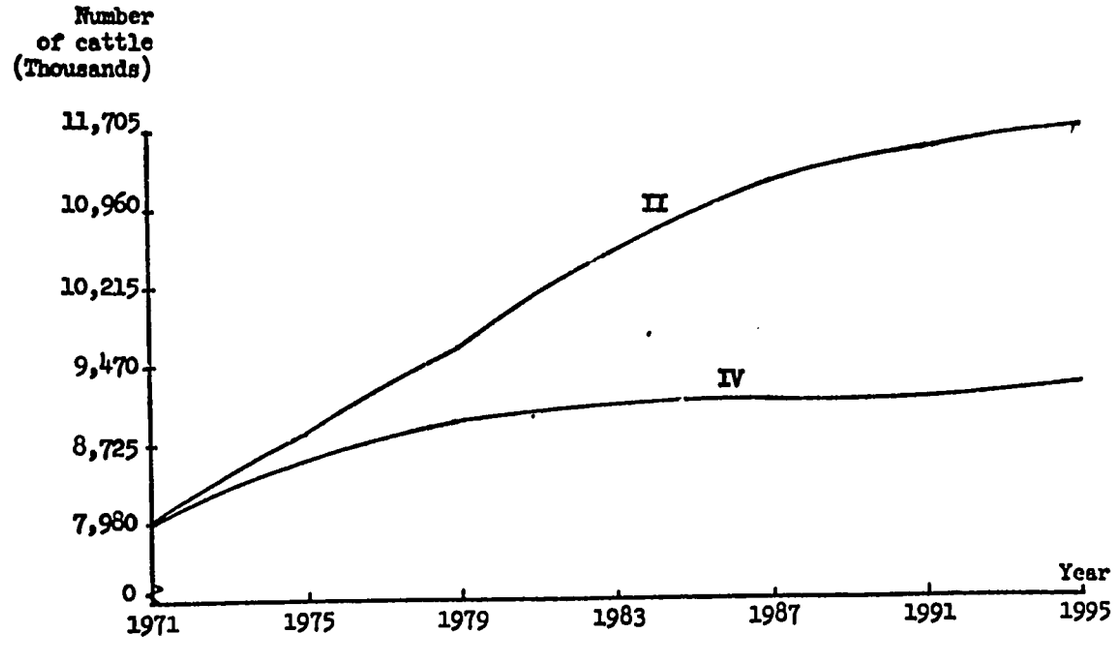

Figure 41 - Total number of cattle through time for Fly Eradication (II) and Grazing Reserve Program (IV).

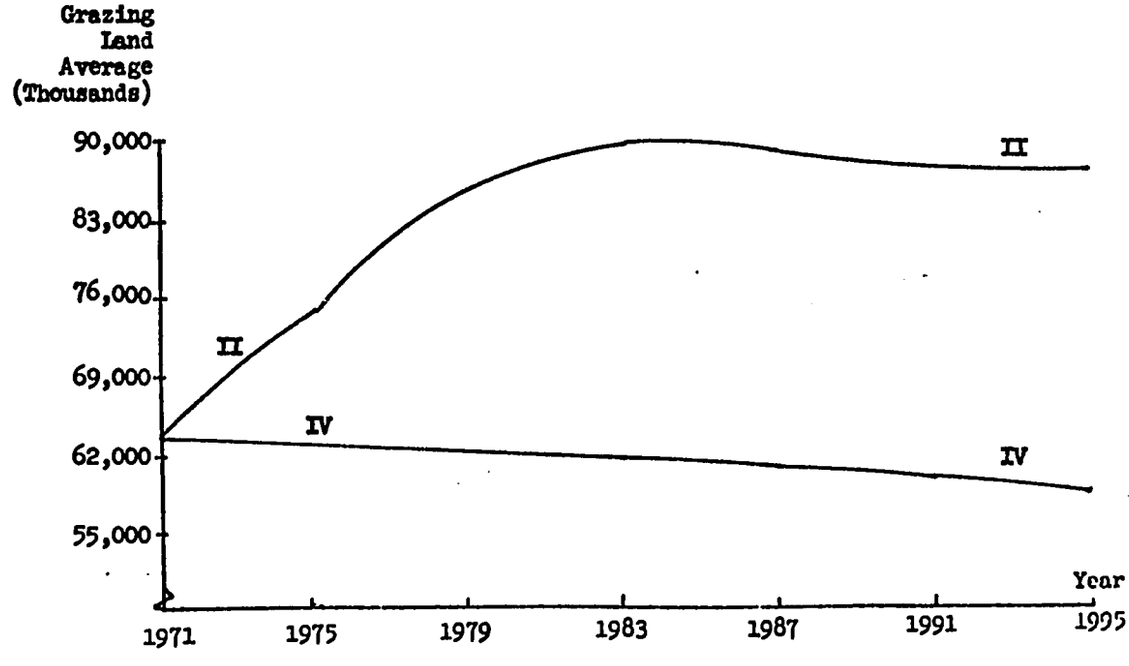

Figure 42 - Acreage of year around Grazing Land available through time for Fly Eradication Program (II) and Grazing Reserve Program (IV).

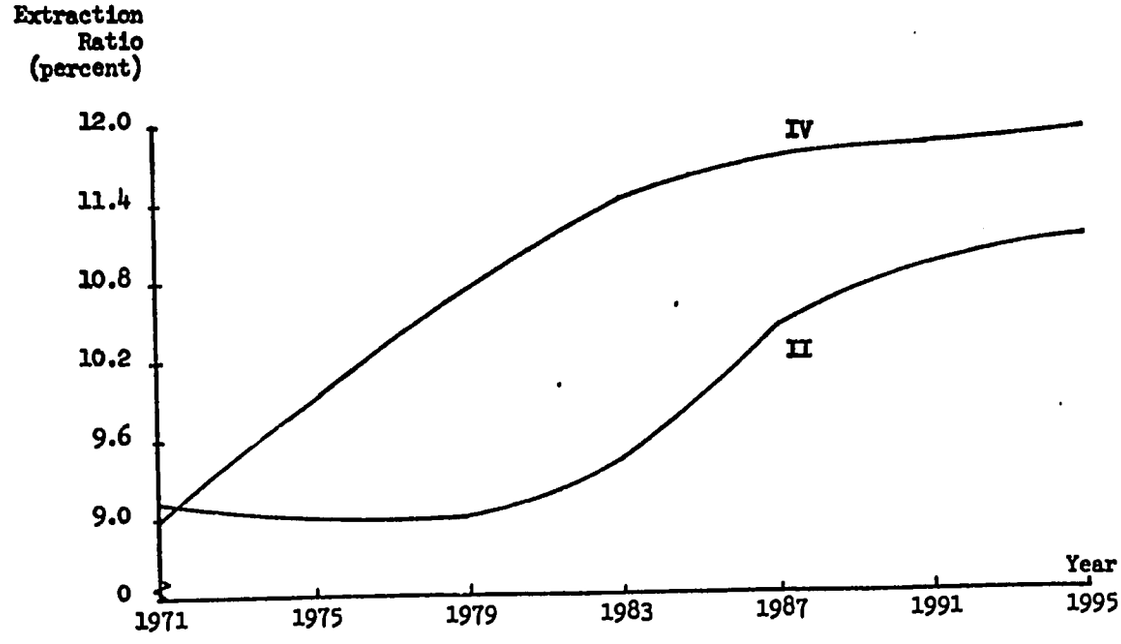

Figure 43 - Percent of total herd sold through time for Fly Eradication (II) and Grazing Reserve Program (IV).

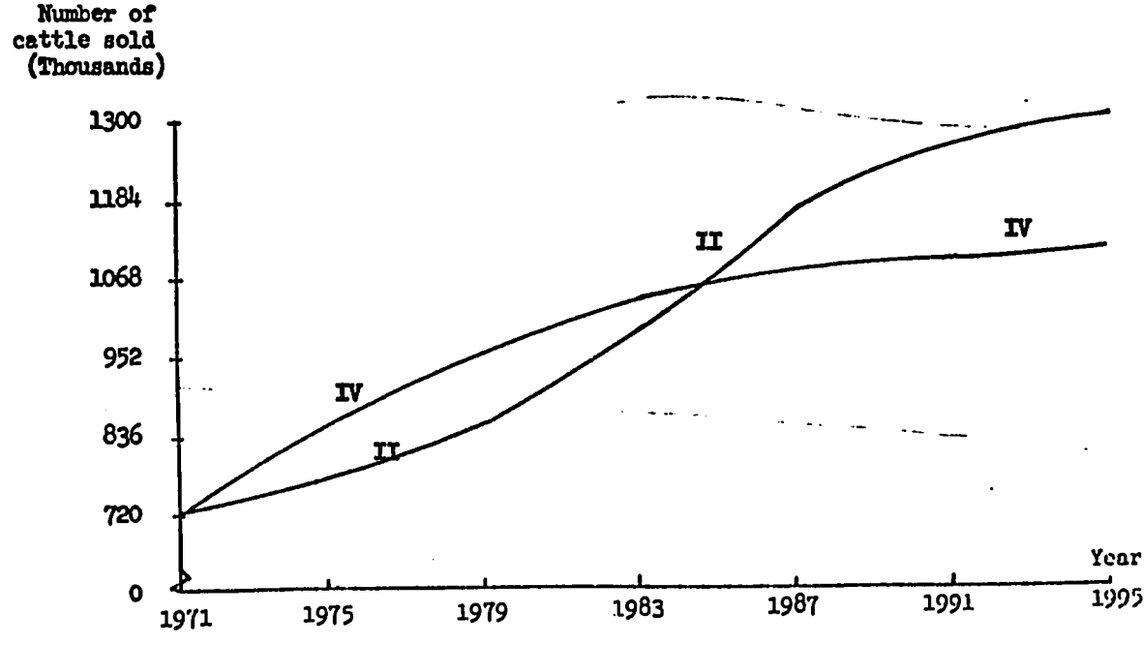

Figure 44 - Total number of cattle sold through time for Fly Eradication Program (II) and Grazing Reserve Program (IV).

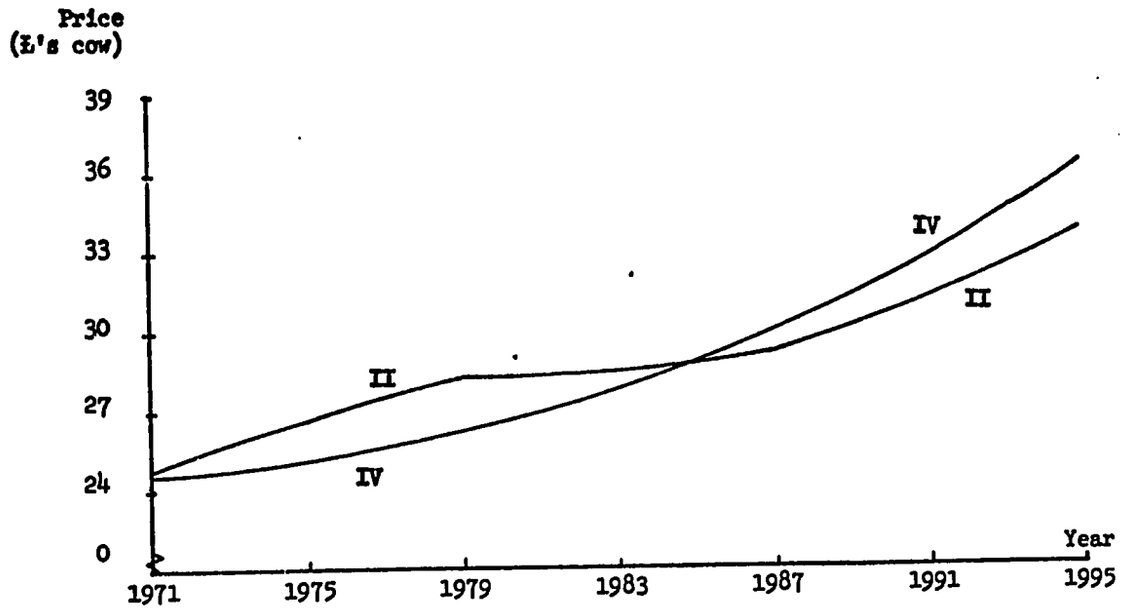

Figure 45 - Producer price of cattle through time for Fly Eradication Program (II) and Grazing Reserve Program (IV).

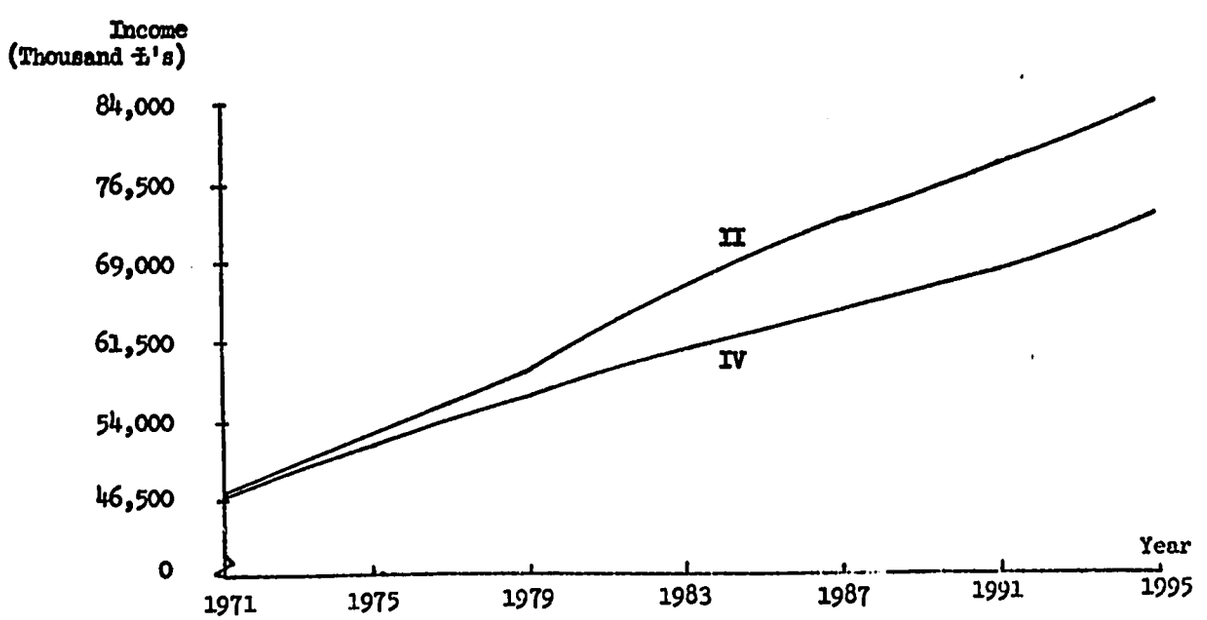

Figure 46 - Total producer income from milk and cattle sales through time for Fly Eradication Program (II) and Grazing Reserve Program (IV).

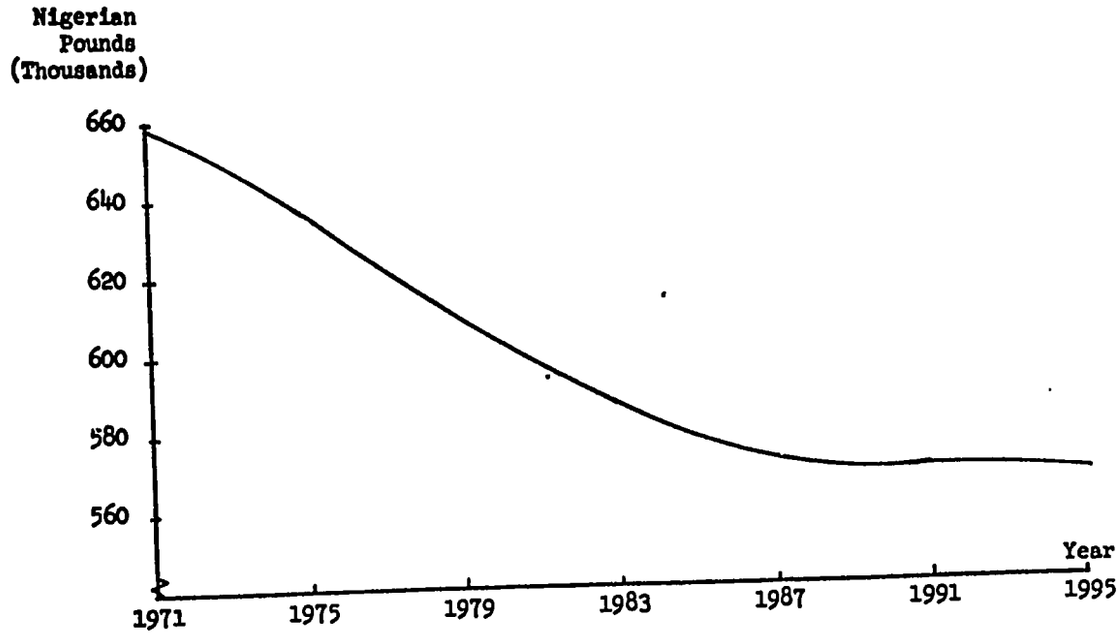

Figure 47 - Difference between Jangali Revenue and Sales Tax Revenue through time for Base Run.

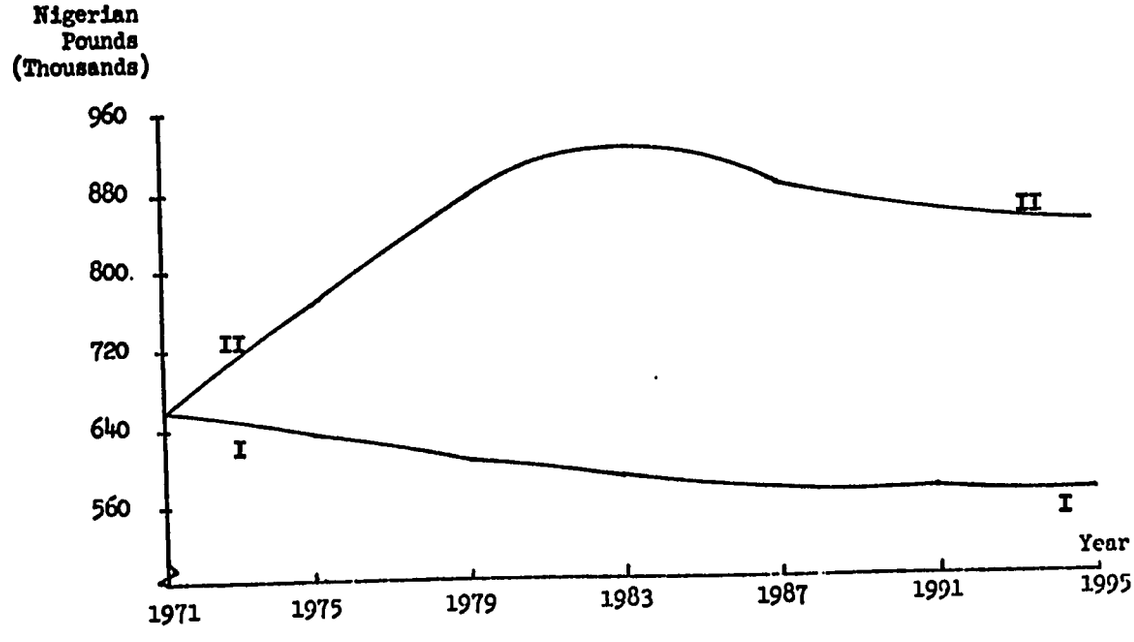

Figure 48 - Difference between Jangali Revenue and Sales Tax Revenue through time for Base Run (I) and Fly Eradication Program (II).

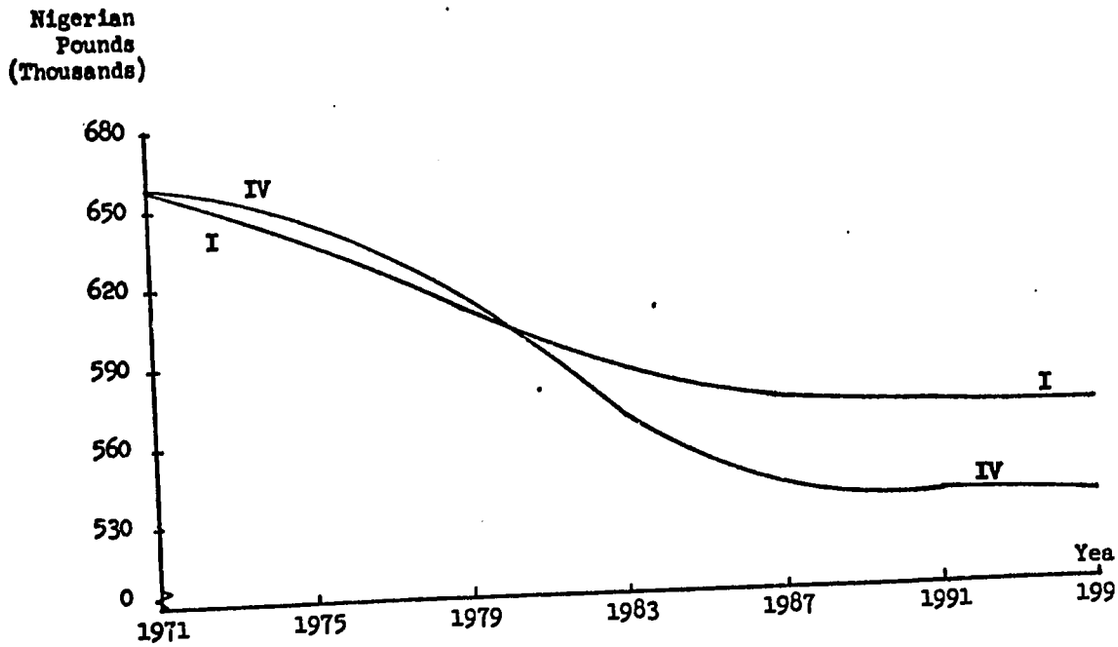

Figure 49 - Difference between Jangali Revenue and Sales Tax Revenue through time for Base Run (I) and Grazing Reserve Program (IV).

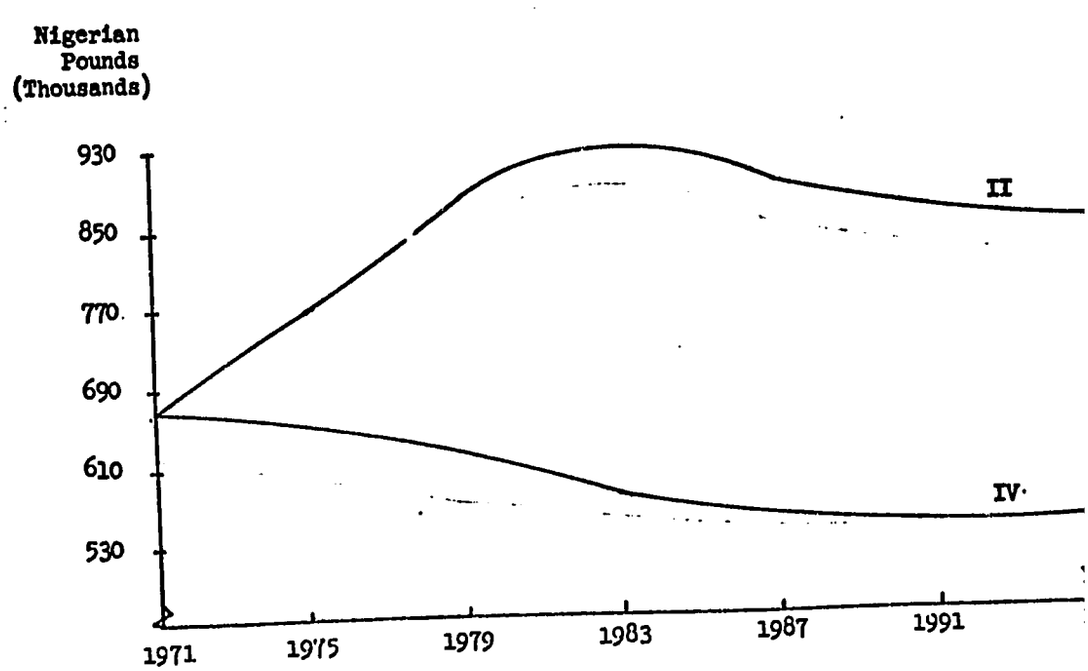

Figure 50 - Difference between Janjali Revenue and Sales Tax Revenue through time for Fly Eradication Program (II) and Grazing Reserve Program (IV).

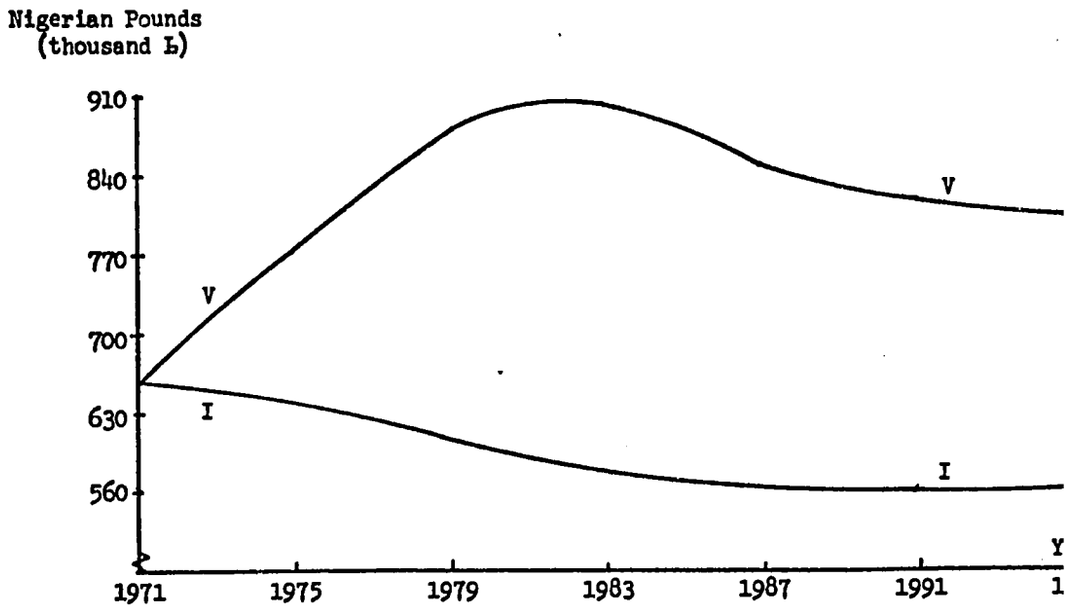

Figure 51 - Difference Between Jangali Revenue and Sales Tax Revenue Through Time for Base Run (I) and Fly Eradication and Grazing Reserve (V)

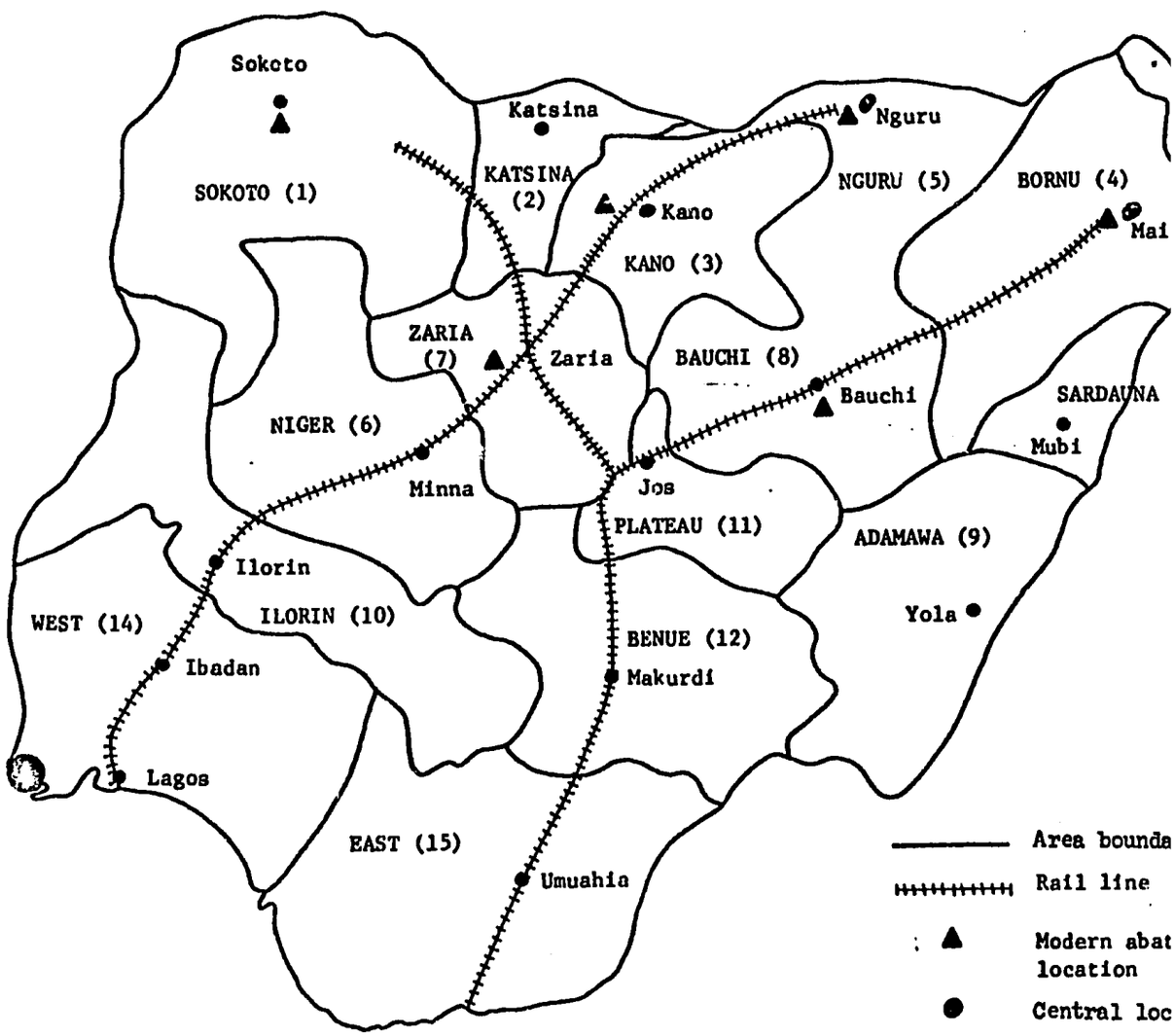

Figure 52. Designated Areas of Nigeria Used in the Transportation Stu

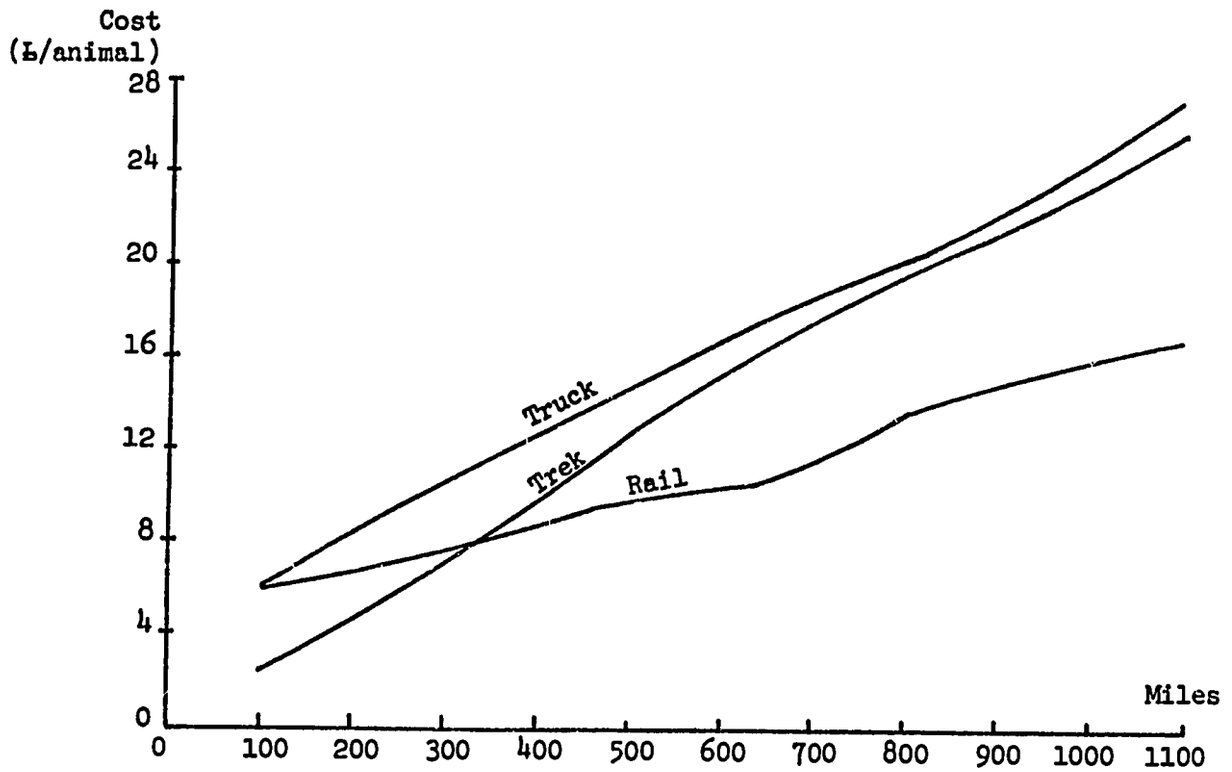

Figure 53 -- Costs of Transporting Cattle over Varying Distances by Truck, Trek and Rail