THE BEHAVIOR OF LIVESTOCK OWNERS IN SENEGAL: A MICROECONOMIC MODEL

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ABSTRACT

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The development of the Senegalese livestock subsector faces technical and economic issues that need micro-level research to provide firm factual bases for sound policy recommendations. After describing the subsector and reviewing the competing frameworks of analysis on the Sub-Saharan livestock production systems, the study uses capital theory to develop an analytical microeconomic model of the behavior of livestock owners in south Senegal. Based on secondary information, the decisions on optimal ages of sale for Ndama cattle (male and female), the herd demography and the impact of different management practices are simulated. The results suggest that producers are optimizing and that technical parameters such as calving and mortality rates have more important effects on herd management than economic parameters such as liveweight prices and costs. Finally, research data priorities are recommended in relation to the FSR methodology used to study the livestock component of farming systems in Senegal.

To my parents, Abdoulaye and Madeleine

who instilled in me the will, desire and fortitude

to succeed at such a task

and

to all my family.

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CHAPTER I

INTRODUCTION

Problem Statement

The traditional livestock production systems based on pastoral grazing methods are in various phases of disruption. Affected by the general constraints to food production and economic development, they also have a unique set of problems confronting them. They are threatened by weather fluctuations and desertification. In addition, there are periodic fodder shortages, which are aggravated by overstocking and lack of managed grazing patterns. Besides these intrinsic hindrances, the traditional systems are losing in their competition with cash and food crop production systems (Simpson and Farris,1982).

Such a situation characterizes the Sahel region and its neighboring regions. These problems have been compounded by the lack of sound regional policies in an environment where the social and economic practices and values that were introduced by the colonial rulers and their successors have been markedly changing. In particular, in Senegal, the livestock subsector is characterized by a price policy which subsidizes the cost

of meat for urban dwellers at the expense of incentives for producers. Furthermore, despite recent attempts to reorganize the agricultural sector, there is still a great need to be more specific about the policy decisions that need to be taken to encourage the development of livestock production and marketing.

In recent years, the structure of the livestock subsector has been changing from nomadism to nomadic pastoralism and mixed farming systems (Eicher and Baker,1982). Research on the economics of traditional livestock production systems is developing, and there is an urgent need to create a knowledge base supported by a structured research program in order to provide a firm factual basis for policy recommendations.

Numerous conceptual frameworks of analysis have been proposed for the understanding of African livestock production systems and their dynamics. These frameworks need, however, to be related to the specific environment where research must be done and the policy decisions that are being considered.

In addition, besides the ethnological and environmental studies that have been conducted, additional research is needed, especially at the micro level. By addressing the technical and economic issues faced by the livestock owner, an integrated research program will give insight into the micro-macro linkages that have important implications for policy and provide a better understanding

of the livestock producer decision-making process.

This is of particular importance in Senegal where livestock subsector development is planned on the basis of a stratification policy. Generally, stratification policies aim at a differentiation in land use, management systems and production methods, by geographic area (such as extensive grazing in one area, extensive crop production, mixed farming, reforestation and range conservation in others). In the case of livestock production, stratification is done according to the comparative advantages of the different socio-economic and ecoclimatic zones in the region whose production systems are being reorganized.In beef production,stratification leads to separate layers or stages. These include breeding cow-calf herds, growing out, fattening and processing (Ferguson,1976).

It is, therefore, critical to determine the economic differences among the production systems in various zones and their consequences for the livestock producer. Thus, as a contribution to the organization of research, it is useful to build an analytical model of the decision-making process at the producer level. Such a model permits us to determine what data are needed for a better understanding of the current and future economic and social changes in the Senegalese livestock production systems.

Objectives of the Study

The objectives of this study are as follow:

1-To describe the Senegalese livestock subsector, its current trends and its policy problems from a macroeconomic perspective;

2-To review the various proposed approaches of the Sub-Saharan livestock production systems and compare their strengths and weaknesses;

3-To develop an analytical model which can help economic analysts understand livestock producers' management decisions and examine the impact of different management practices;

4-To use the analytical model and test its usefulness in understanding the livestock component in farming systems and to identify research data priorities;and,

5-To link the findings with the development of policy recommendations for the Institut Senegalais de Recherches Agricoles (ISRA).

Organization of the Study

The work is presented in 7 chapters. Chapter 2 describes the Senegalese livestock subsector , its development and its policy problems. This chapter also contains a background description of the Ndama production system that is modeled in subsequent chapters. Chapter 3 reviews alternative conceptual frameworks that have been

proposed for analysing livestock production systems in Africa and suggests a synthetic framework for the economic modeling that is treated in Chapter 4.

Chapter 5 presents the model and data used. In Chapter 6, the results of the simulation and the basis for its validation are exposed. Finally,the research policy recommendations are presented in Chapter 7.

CHAPTER II

THE SENEGALESE LIVESTOCK SUBSECTOR

Trends in Sub-Saharan Africa

Livestock production in Sub-Saharan Africa experienced a significant growth between 1950 and 1970. The production of meat and milk increased by 2.3% and 2.1% per year respectively. However,these increases did not keep pace with the annual human population growth of 2.4%. This situation led to a decline in per capita production (Jahnke,1982).

Studying the same trends from 1960 to 1980,Anteneh reaches the same conclusion:

> " The livestock output situation in Sub-Saharan Africa is clearly very serious.The situation is doubly alarming in that not only has the rate of output declined over the last two decades, but also the percentage output growth attributable to productivity (i.e.,yield growth) has decreased."
>
> (Anteneh,1984b,p.15)

Place of the Livestock Sector in the Senegalese Economy

An examination of the statistics available shows the same trends in Senegal. During the French colonial administration, the livestock subsector was not a priority item in a setting entirely devoted to the economie de traite of groundnuts. The sector was of minor importance to economic

development and the growing involvement of farmers in the cash economy.

The drilling of deep-bore wells allowed a movement of the livestock away from the expanding cropping areas, especially in the Sylvopastoral region.Annual vaccination campaigns were organized and resulted in a rapid increase in livestock populations. Research was done on the Zebu gobra at the Dahra station but with no real application of the results. The livestock subsector was further stifled by a government head tax placed on livestock.

Following Independence in 1960, no major policy changes have taken place despite the steady annual contribution of the subsector to the GNP. From 1959 to 1971, the value of output was increasing by 2.4% p.a. in constant prices while the overall value of agricultural production was increasing annually by only 1.9% with very erratic movements (IBRD,1974).

During the ten-year period following Independence, the subsector did not exhibit any major change in production or marketing techniques despite favorable conditions and other factors. The population of cattle increased at a rate of 4.9% p.a. while that of small ruminants increased at 5.1% p.a. (Tables 1 and 2).

After 1970,the situation became serious, with successive herd contractions due to severe droughts.The extensive system of production based on perennial and

annual grass rangelands ceased to perform adequately. From 1970 to 1980, the annual growth rates in numbers of cattle and small ruminants were -1.4% and 1.7% respectively (Table 2).

These trends did not really change drastically the contribution of the subsector to the economy (Table 3). The value added to the overall economy by the livestock subsector was 4.5% in 1960. By 1975,it increased to 7.9% and reached 9.3% in 1980. The share of the value added by the livestock subsector to the total agricultural sector was 24.5% in 1970. It decreased to 19.9% in 1975 due to the successive droughts and then increased to 25.1% in 1980.

Such specific trends reflect an increasing supply of animal products. However, Senegal has become increasingly a meat and milk deficit area since the 1960's. Due to a continuous growth in the purchasing power of consumers and the urban population,there has been an important increase in effective demand. This is especially true in Dakar. The domestic production was predicted in the 5^{th} Plan of Economic and Social Development to satisfy only 70% of the meat demand in 1980. The government has been, therefore, spending foreign currency by importing milk, meat and live animals (Table 4).

Table 1. LIVESTOCK NUMBERS Average annual growth rates (%),Senegal(1960-1980)

	Periods		
Species	1960-1970	1970-1980	1960-1980
Cattle	4.9	-1.4	1.4
Goats,sheep	5.1	1.7	3.9
Pigs	14.2	5.5	13.8

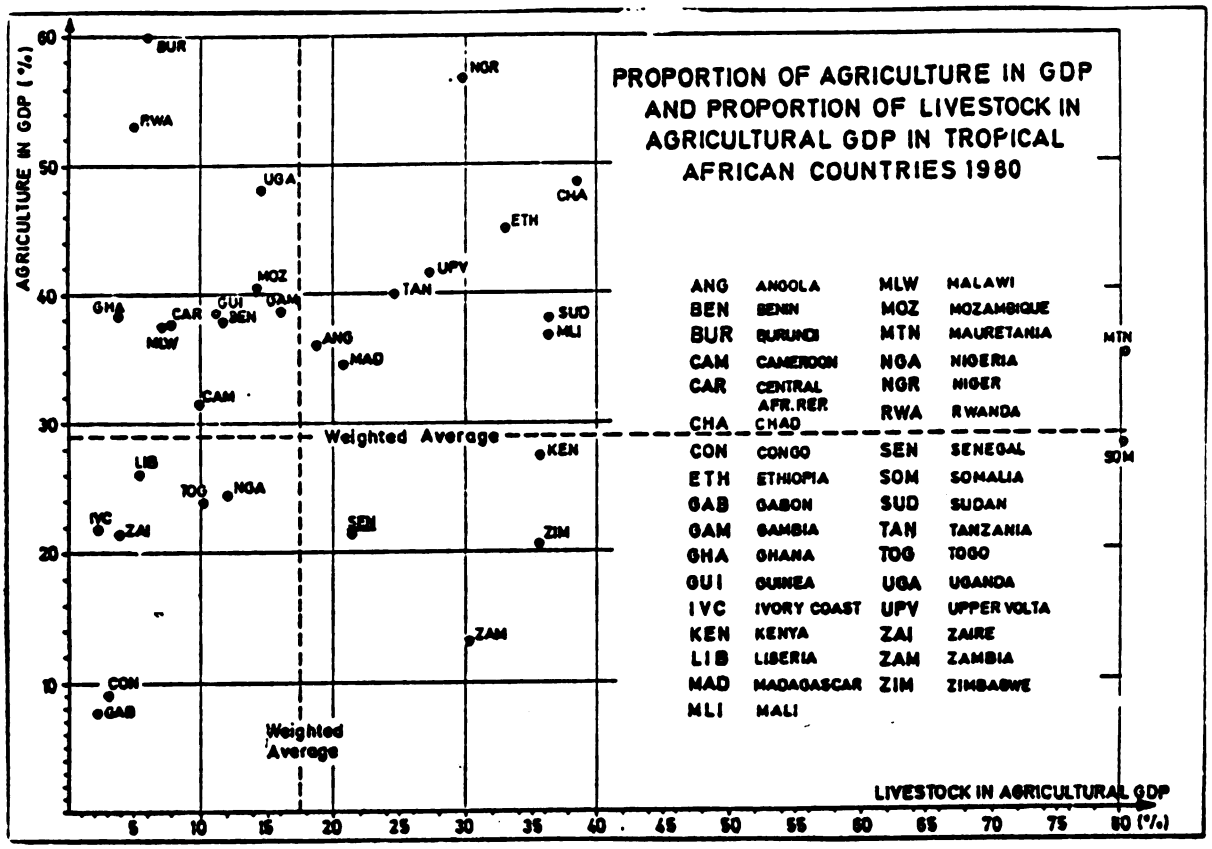
SOURCE: Appendix A

Table 2. MEAT PRODUCTION
Average annual growth rates (%),Senegal(1960-1982)

	Periods		
Species	1960-1970	1970-1982	1960-1982
Beef	7.1	-0.2	3.0
Goat-mutton	3.3	1.0	2.3
Pigmeat	10.0	4.2	9.1

SOURCE:Appendix A

Table 3. PLACE OF THE LIVESTOCK SECTOR IN THE ECONOMY



SOURCE: Jahnke (1982)

Table 4. LIVESTOCK TRADE
Quantities traded in MT, Senegal, 1980

SPECIES	IMPORTS	EXPORTS	NET EXPORTS
Cattle	25,000	140	-24,860
Goats-sheep	200,000	10,000	-190,000

SOURCE : FAO Trade Book 1981

The data base used to describe the livestock subsector is presented in Appendix A. It has been very controversial with respect to accuracy and consistency. Therefore,the main purpose of the present analysis is to identify overall trends for a better understanding of the problems. As stated by Jahnke (1982):

> " In summary, experience with livestock development to date is disappointing. Agricultural development as a whole has fallen behind overall economic growth and the shortfall is particularly serious for the livestock sector. The per caput availability of livestock foods in Africa has not improved and whatever increase in production it is mainly due to herd and flock increase rather than productivity increase.Traditional production systems have simply expanded maintaining traditional techniques."
>
> (Jahnke, 1982, p.46)

Arguments for Livestock Production Development

The priorities and basic requirements in a balanced human diet are subject to controversy. Crawford (1975) argues that many of the development and aid policies that have favored the increase in protein production may not have been based on sound reasoning. He further argues the world food problem is more likely related to energy nutrient shortages than protein shortages. On the other hand, Raimbault (1980) argues that we have a combination of protein and energy shortages which may affect as much as 75% of the world population.

Furthermore, the Food and Agriculture Organization (FAO) offers the following assessment:

> " There is ..... a general agreement that the increase in calorie intake should not always be

> obtained from an increase in per caput consumption of cereals, of starchy roots,which would still imbalance the diet but should come from those foods which would give a better balance to the present diet, namely, fruits, vegetables, pulses and nuts on the plant side, and still more important,the food of animal origin--milk, meat, fish and eggs."
> (FAO, 1976, p.1)

FAO also recommends that by the year 2000, individuals in developing countries should be able to consume 2400 calories per day . Total daily protein intake should at least be 70 grams, with at least 20 grams being animal protein (FAO, 1976).

These statements stress from a nutritional viewpoint that the production of animal protein is a necessity for developing countries in meeting nutrient needs. In addition, from ecological and efficiency viewpoints, livestock production, especially with ruminants, allows for beneficial use of wastes, byproducts, vegetation and land that are marginal for crop production.

Finally, the importance of the livestock industry is supported by the growing demand for livestock products With the increased urbanization in Senegal--32% of the population in 1976 lived in cities-- there has been an increase in family income level and a corollary increase in the demand for livestock products. Josserand (1983), for example, notes that in West Africa, the ratio of total meat consumption per capita in urban versus rural areas is 4 to 1.

Furthermore, relatively high demand elasticities with respect to income have been shown, such as 1.08 for meat

and 1.23 for milk (Table 5). In fact, Jahnke(1982) believes that the real income elasticities for livestock products are substantially higher than stated.

" An open question is the extent to which the income elasticities are overlain by price effects. Particularly in the case of livestock production, the shortfall in supply has led to rapid increases and curbed demand accordingly. There is reason to assume that the income elasticities of demand thoroughly corrected for that effect would be higher, possibly substantially higher."
(Jahnke, 1982, pp 48-49)

Table 5. AVERAGE[a] INCOME ELASTICITIES OF DEMAND FOR SELECTED CROP AND LIVESTOCK PRODUCTS IN WEST AFRICA

Region	Cereals	Meat[b]	Milk	Eggs
Sahel	.24	1.04	.53	.90
West Africa	.21	1.08	1.2	1.2
West Africa (Less Nigeria)	.33	1.08	1.23	1.1

a/weighted according to share in overall consumption of food products ; average of projected elasticities over the period 1975-2000.
b/excluding edible offals;including game

SOURCE: Jahnke after ILCA (1981)

Applying "conservative" coefficients, Josserand (1983) projects the annual rate of growth in per capita demand in West Africa from 1975 to 2000 at : 1.2% for meat, 0.8% for milk and 2.2% for eggs.

Such data are not currently available for Senegal and could only be derived from further study.

Projections (1984 - 2000)

It is important from a policy making standpoint to base a long-term vision on projections about possible outcomes. With respect to the serious situation of the Senegalese livestock subsector, such projections enable us to perceive with more detail the long-term trends and relative changes required to satisfy the projected needs.

In this study, the projections to the year 2000 are made according to the methodology followed by Simpson (1984). They permit a long term vision that highlights the urgent need for production improvements if, at a minimum, the current level of consumption is to be maintained. Table 6 presents in a summary form the projections generated from the currently available data.

The projections show that important change in production patterns and intensity must occur to satisfy the coming needs in Senegal.

The Development Process

Following Gallais'(1972) viewpoint, it is useful to recall the major phases of the socio-historical evolution of the agropastoral societies in West Africa.

Table 6. PROJECTIONS OF BEEF, VEAL, MUTTON AND GOAT MEAT CONSUMPTION AND CATTLE, GOAT AND SHEEP INVENTORY REQUIREMENTS . SENEGAL . 1984-2000

Items	Units	Values
Per capita consumption,1980		
Beef and veal	kg	5.6
Mutton,lamb and goat meat	kg	1.8
Total population		
1980	Millions	5.9
2000	Millions	10
Total consumption,1980		
Beef and veal	1,000 MT	33.04
Mutton,lamb and goat meat	1,000 MT	10.62
Total consumption,2000		
Beef and veal	1,000 MT	56.00
Mutton,lamb and goat meat	1,000 MT	18.00
20% increase in per capita (0.9% annually)		
Beef and veal	1,000 MT	67.00
Mutton, lamb and goat meat	1,000 MT	21.60
Indigenous production,1980		
Beef and veal	1,000 MT	29.00
Mutton,lamb and goat meat	1,000 MT	8.00
Ratio of indigenous production as a proportion of total consumption 1980		
Beef and veal	ratio	.88
Mutton,lamb and goat meat	ratio	.75
Indigenous production per head of inventory,1980		
Beef and veal	kg	13
Mutton,lamb and goat meat	kg	2.5
Inventory,1980		
Cattle	1,000 Head	2,238
Sheep and goats	1,000 Head	3,170

Table 6 cont'd.

Items	Units	Values
Inventory required to keep 1980 ratio of indigenous production to total consumption, 2000[a].No change per capita consumption		
Cattle	1,000 Head	3,800
Sheep and goats	1,000 Head	5,400
20% increase in per capita consumption		
Cattle	1,000 Head	4,500
Sheep and goats	1,000 Head	6,300
Indigenous production per head of inventory required for no increase in inventory to meet consumption projection,2000[b].No change per capita consumption		
Cattle	kg	22
Sheep and goats	kg	4.3
20% increase in per capita consumption		
Cattle	kg	26.3
Sheep and goats	kg	5.1
Annual growth rate in production per head of inventory required for no increase in inventory to meet consumption,2000. No change per capita production		
Cattle	%	2.6
Sheep and goats	%	2.6
20% increase in per capita consumption		
Cattle	%	3.6
Sheep and goats	%	3.6

a-Total consumption in 2000 divided by indigenous production per head and the result multiplied by the ratio of indigenous production to total consumption.

b-Total consumption in 2000 times the ratio of consumption to indigenous production divided by 1980 inventory.

SOURCE:Simpson(1984);FAO Production Year Books (various issues); IBRD(1983)

Until the end of the last century, there was a permanent adjustment in the human and animal populations through wars, epidemics and droughts. The Sudanic agropastoral economies were first dominated by the Sudano-Sahelian empires of Mali and Sonray (XII to XVI century A.D).Their decline led to a strengthening of the pastoral societies living at their margins. These pastoral societies were typically Fulani, having a high degree of organization in land use and a close integration of pastoralism and agriculture (Swift,1979).

During the reorganization of the economy that accompanied colonization various changes occurred. First, crop production areas were extended without an integration of crop and pastoral techniques.This situation led to ecological disasters such as bush fires, deforestation, reduction of fallows, wind erosion and uncontrolled drainage. Second, one-sided development attempts (animal health and water supply) without concommitant land and pasture improvements created a disequilibrium in the pastoral systems. Finally, an important development in human and animal growth was made possible by medical breakthroughs, especially the control of the rinderpest.

The major economic, social and political problems faced by herders reached their most intense level with the 1970 drought, whose consequences are still being felt. However, as Ware (1979) points out, herders in Senegal

have adapted to the drought by devising innovative strategies. In particular, they have diversified their traditional productive activities with crop production and there has been an increased desire to sell milk through non-traditional distribution channels. Is has also been shown that migration southward and toward the urban areas are phenomena of growing importance (FAO,1977).

A broad historical review would not be complete without special attention being given to two major factors besides climat that affect the livestock subsector: government policy and development projects.

Livestock Subsector and Development Policy

Goals

The government orientations defined in the 5th Plan of Economic and Social Development for 1977-1981 have been retained in the current 6th Plan (1981-1985).The goals related to the livestock subsector include :

- a reduction of the strong dependency on international markets to satisfy the internal demand for meat and milk products;

-the development of an integrated system of animal production (mainly cattle and sheep) based on the complementarities and comparative advantages of the eight ecological zones found in the country;

-an increase in the per capita consumption of meat from about 13 kg in 1974 to 15.7 kg in 1985. For such a goal,the desired rate of growth per year was set at 2.5% for cattle, 4.6% for small ruminants and 11.5% for poultry; also in 1985, the meat production objective is set at 100,200 MT, with 54,900 MT beef and 10,000 MT mutton-goat, the remainder being poultry and pigmeat (Societe Africaine d'Edition,1983). These goals were assumed to help satisfy the growing urban demand, reduce the protein gap for the poor and assure a reasonable farmer income.

Policy Responses

Surveying the problems raised by African government policies toward the livestock and pastoral subsectors, Sandford (1981) concludes that they have been defective because of either wrong, contrary or non-existing policies with respect to the land use, the pricing of commodities and the overall organization of the sector. The Senegalese case confirms that general critique since the livestock sector has not been among the priorities in terms of investments, policies and organization.

For instance, from 1965 to 1971, the subsector received only 1% of the government's current budget.In constrast, the other rural sectors received 7% of the budget (IBRD, 1974). Futhermore, although the operating

budget of the Direction de la Sante et des Productions Animales (DSPA) grew at a rate of 6.6% p.a. from 1965 to 1979, only 2.1% of the government's investments was for animal health and production related expenditures in 1979, even though in that year the share of livestock in the contribution of agriculture to the GDP was 21%. Paradoxically, a sharp decrease occurred after 1973 (in the drought period) when taxes on cattle at the producer level were abolished.

As can be seen by studying the composition of the DSPA budget in Table 7, there has been a significant decrease in non-staff expenditures from 1965 to 1978. Operating and investment expenditures represented an extremely low percentage of the total national expenditures in those categories. Operating expenditures for livestock were 0.8% of the total operating expenditures and investment expenditures for livestock were 0.1% of total investments (Anteneh,1984a).

In the 6^{th} Plan, 17.5% of total investment in agriculture has been planned for the livestock subsector with 0.1% going to the traditional government livestock, agencies and 16.4% going to the development projects (Societe Africaine d'Edition,1983). Such trends have placed impossible financial burdens upon the public agencies despite their important roles in providing yearly vaccinations. Furthermore, the lack of equipment and personnel leaves the DSPA unable to intervene adequately

at the level of the producers and, most important, give strength to their cooperatives.

Table 7. COMPOSITION OF THE DSPA BUDGET
Senegal,1965-1978

Years	Staff budget(%)	Non-staff budget(%)
1965-66	69	31
1968-69	65	35
1969-70	77	23
1970-71	75	25
1971-72	70	30
1972-73	74	26
1973-74	80	20
1974-75	83	17
1975-76	84	16
1976-77	85	15
1977-78	85	15

SOURCE : Anteneh (1984a)

The producer cooperatives have been in existence since the early 1950's, but they remained very marginal until the 1960's. At that time, they developed with the Mouvement cooperatif inspired by the government. In 1971, 6,355 individuals belonged to 86 cooperatives.However, these cooperatives did not have any real impact on the supply and marketing of meat.

N'Diaye and Ba (1972) attribute the failure of the livestock cooperatives to several different reasons. Their structure and functioning were not appropriate since they were replications of the crop cooperative schemes. At the beginning, created under the control of the Office National

de Cooperation et d'Assistance au Developpement (ONCAD), they became the responsibility of the DSPA in 1972. A major constraint was the cooperatives' difficulty in obtaining credit, unlike the crop-oriented cooperatives, which were fully supported by the credit system embodied in the Programme agricole. Moreover, the Banque Nationale de Developement du Senegal (BNDS), the main supplier of credit to the rural sector, had a guarantee system for cattle raisers' cooperatives, butchers and traders identical to that for small entrepreneurs in the industrial sector (IBRD,1974). This system required important collateral assets and charged higher interest rates than those charged crop cooperatives; these practices greatly reduced incentives to invest in the livestock subsector. Finally, the cooperative participants were unable to create a lobby for their interests because of their dispersion throughout the country and their lack of information.

Since the 1970's, more efforts have been directed toward the development projects and the parastatals managing them (Societe de Developement de l'Elevage dans la Zone Sylvopastorale (SODESP), Projet de Developpement de l'Elevage au Senegal Oriental (PDSEO), Projet USAID de Bakel). These institutions are expected to play an important role in the stratification of the livestock production system thanks to a differential pricing system.

Besides these projects, there is a heavy reliance

on foreign aid for the supply of feedstuffs in case of emergency. For example, in 1984, the Operation Sauvegarde du Betail permitted the government to provide 68,000MT of feedstuffs in emergency areas at a price of 15 FCFA, which represented solely the cost of transport. Although this program provided temporary relieve for drought stricken livestock producers, such actions are not a serious remedy and are not a viable solution in the long run because they do not address the basic feed constraint in the country.

In terms of price policy, price control measures are employed at the meat retailer level. That aspect of the public sector policy is analyzed in relation to the marketing system in the following section.

The Marketing System

Organization

One of the research priorities of ISRA is to conduct an extensive study of the livestock marketing system. Except for some regional analyses (SODESP,1984; SOMIVAC,1982), there is a lack of information on the performance and efficiency of the marketing system, its structure and the conduct of its participants.

However, because conditions throughout West Africa are similar, the available description of the livestock marketing systems in the rest of the region may be used

when studying Senegal (Shapiro,1979;Herman,1980).Particular emphasis is given here to the factors affecting producers.

The traditional marketing system satisfies 90% of the demand in the main consuming area in Senegal, Dakar, and entirely meets demand in the other areas of the country. Numerous problems affect the efficiency of the system. Conflicting relations between the government and the meat suppliers have created many boycotts by the latter during the last decade. The strong interventions of the Societe d'Exploitation des Ressources Animales du Senegal has, without doubt, various effects on the competition and conduct in the sector since the beginning of the 1980's.

An intense development of black markets has been noticed as well as the subsequent worsening of health hazards for the consumers. Each year, there is also an explosion of prices and a great strain on the marketing system for sheep at the Moslem holiday Tabaski.

A brief analysis of the system shows also different levels of integration and complementarities among the producers,the intermediaries ('diula','tefanke') and the butchers.The 'diula' or bush collector is supplied directly by the producers or at small collection markets. These weekly markets play a growing role nowadays. The animals are then driven to regroupement markets , from where they are then sent to the terminal markets of the major consuming areas. The 'tefanke' plays a more

important role in the last parts of the marketing channel.

All slaughterings must in theory be conducted under government supervision. The meat is provided to wholesale butchers, retail butchers and peddlers of raw and cooked meat.

Complex interrelationships exist among the supplies of beef, lamb, mutton, goat meat and fish, a major substitute. Analyzing the marketing of small ruminants, Josserand (1983) shows that supplies of mutton and goat meat have a countercyclical pattern when compared to the supply of beef. Due to more frequent offtake, sheep and goat meats usually "take up the slack in domestic beef supply" (Josserand, 1983, p.7).

Prices

This analysis is based on the main consuming area, Dakar. After a period of stability, the prices of cattle, goats and sheep increased by 60 to 80% between 1967 and 1971 because of feed shortages during the drought period and the decrease in livestock coming from Mauritania at that time (IBRD, 1974). That period corresponds with the lowest producer prices ever recorded, 50 to 55 FCFA per kg as producers tried to liquidate their dying herds. However, the important rates of mortality greatly reduced the number of animals supplied to the Dakar market and caused shortages that led to high consumer prices. With respect to the current situation, the most important

characteristic of the marketing system is the official ceiling on retail prices for meat that is set by the Ministry of Commerce and the Ministry of Rural Development. Two sets of prices are fixed for beef and mutton: wholesale prices ('cheville') and retail prices (SODESP, 1984). Due to religious factors and consumer's preferences, there is a premium for lamb and mutton, which are more expensive than beef.

Conversely, there are no price guarantees at the producer level. Therefore, the price fixing and the carcass weight force the wholesaler to buy live animals at very low prices to obtain any safe marketing margin.

In 1984, prices averaged 350 FCFA/kg liveweight for fattened animals and 250 for regular animals at the terminal market of Dakar. Such prices determined producer prices estimated at 250 and 200 FCFA, respectively (SODESP, 1984). At the retail level, traditional butchers are officially allowed a margin of 12% over the wholesale price. SODESP (1984) considers, however, that the value of offals covers the processing and storage costs at the wholesale level. The modern butchers, who are allowed higher retail prices (averaging 2050 FCFA/kg) get a margin of 46% over the wholesale price which is fixed at 1100 FCFA/kg.

An important research topic is to determine how these sets of prices affect the supply of both live animals and meat. In effect, following Girardot-Berg

(1982), it can be expected that the official retail prices are too low in relation to the free market prices and their market clearing levels. Such a situation is very likely accompanied by other problems:

- the depression of the producer prices is correlated with disincentives for increased supply and production improvements;

- there is a transfer of revenues from producers to urban consumers and a concommitant excess demand with respect to the available supply;

- retailers, especially traditional butchers, invest less in hygiene and quality because of low profits from trade and processing; and,

- defined weights and standards of quality aiming at improving the efficiency of the system are generally opposed by the participants because they may reduce their marketing margins.

Government Levies

Cattle head taxes were abolished after the 1970 drought due to, according to the government, welfare considerations. However, other probable reasons included the practical administrative difficulties and irregularities in the collection procedures; and the counterproductive effects on censuses, vaccination campaigns and other development efforts.

Anteneh (1984a) shows, however, that regardless

of the reason, the abolition gave livestock services a weaker claim on available funds and, thus, caused a sharp drop in the financing of the subsector.Meanwhile, other government levies are still in practice. They include import and export duties on live animals; trade licence and market fees for butchers, wholesalers and traders ; slaughtering fees; sanitary taxes; veterinary certificates; and treatment costs and vaccination charges except for rinderpest and bovine contagious peripneumonia. Even though a systematic study of these levies has not been done in Senegal, it is very likely that some have adverse effects on the efficiency of the marketing system, as shown by Herman (1981) for a very similar situation in Burkina Faso.

Beside the retail price ceilings, the livestock development projects are major elements of the government intervention in the subsector.

The Livestock Development Projects

At present, the livestock development projects are a major tool in government policy. Since the six-year period from 1968 to 1974, there has been an increased interest on the part of international donor agencies in providing technical, managerial and financial assistance in range and livestock development. A very abundant literature refers to the characteristics of and evolution strategy for the resulting livestock programs in Sub-

Saharan Africa (Teitelbaum,1975;Stryker,1984;Teele, 1984; Atherton, 1984;Jahnke, 1983;Josserand, 1983;Behnke, 1983).

Unfortunately, the projects have been inherently top-down intervention schemes aiming at an increase of commercial livestock production (mainly cattle) through the transformation of subsistence pastoralists into commercial ranchers via herd modifications and improved animal nutrition. The general consensus is that those projects constitute an "unrelieved failure" (Behnke,1983) due to various reasons.

For instance, basic misconceptions at the design stage have resulted from focusing solely on land and animals instead of the human populations. In addition, highly capitalized interventions were expected to create social changes and a new economic behavior thanks to a process of "social engineering" that would suspend the normal functioning of the indigenous economic systems and replace them with more modern ones.

Two more reasons for failure were the lack of concern on the part of planners for existing and potential interactions between animal husbandry and cropping and the bias they showed for strategies that favored high cattle and meat output rather than more integrated benefits. A fifth reason was their lack of interest in small ruminant development, even though, as Josserand (1983) notes:

" One should recognize that investment in small

> ruminants will show much quicker payoffs [due to biological parameters] than in the case of cattle." (Josserand, 1983)

Furthermore, land use schemes were inadequate due to the communal land tenure and the high spatial mobility involved in herding activities (Styker, 1984). Finally, wrong assumptions were made with respect to the role of women in livestock production and marketing. Safilios-Rothschild (1983) shows from various case studies the importance of including women in project design, and the factors related to the women's role in agriculture and animal production. The productivity-oriented interventions often overshadow the family welfare requirements in the subsistence function of the herd, the returns on women's labor and the sexual differentiation in claims and ownership rights over the herd (Sollod,Wolfgang and Knight, 1984).

The Nouvelle Politique Agricole

Since 1983, major changes have been occurring in the Senegalese agricultural sector under the name of Nouvelle Politique Agricole (NPA). The NPA is similar to the emerging policy responses to food problems in many African countries (Christensen and Witucki, 1982). Unfortunately, these policies are due to pressures from international financial institutions, a deep crisis in public finances and a deterioration of the balance of payments rather than strategic policy choices. As in

other countries, they are characterized in Senegal by :

- a reorganization of the marketing system for cash and food crops, with a larger role granted to the private sector in marketing agricultural inputs and products ;

- a new definition and role for the producer cooperatives, with less reliance on public rural credit agencies;and

- a pricing differential in favor of production and consumption of local cereals that includes increased retail prices , a phasing out of subsidies and increased fficial producer prices for cereals above world market prices.

However, the available literature and information make no reference to the livestock subsector, despite its importance. It appears that, in terms of policy definition, crop production remains the sole preoccupation despite the need for more consistency with respect to the overall agricultural sector and each of its components and despite the potential that integrated farming could have on crop production. More attention must be given to the livestock subsector due to the constraints slowing down its development, its current dynamics and ,above all, the goals set in the government planning.

An attempt is made here to suggest a consistent global perspective on the issues related to the subsector based on the international experience as seen through the literature on livestock development.

Guidelines for a Livestock Development Program

Four basic goals must be set for any national food policy according to Timmer, Falcon, and Pearson (1983). First, an efficient growth in the food and agricultural sectors must be assured. Second, an improved level of income and employment ought to be guaranteed. Third, the nutritional status of the population should reach a minimum acceptable level. Finally, food security has to be properly handled.

These goals imply considerable policy trade-offs between producer income and consumer welfare, between fiscal restraints and government subsidies, and between public interventions and market forces, especially for the livestock subsector (Girardot-Berg,1982). The complexities of the trade-offs increase when combined with the differential weighting of short-run and long-run requirements. It becomes crucial to develop tools and an analytical framework for doing the sectoral analyses that are the foundation of a consistent food policy (Timmer, Falcon and Pearson, 1983).

It is, therefore, important to concentrate in this study on the development constraints in the Senegalese livestock subsector. As background context, the Ndama production system of the Casamance region is presented with its main characteristics. This information is used later in the simulation exercise to verify the validity of the microeconomic model proposed in this

study. After describing the Ndama production system we will address ways of improving livestock policy and actions that could be initiated for the necessary development of the subsector.

Constraints

> " Livestock production and livestock in Africa rest squarely on a combination of ecology, economics, biology, and sociology."
> (Pratt, 1984, p.39)

We cannot analyze here all the constraints that are specific to the Senegalese livestock subsector. A general overview is presented , based on the literature on the livestock subsector in West Africa. A general summary of the important constraints facing the subsector is presented by Atherton (1984). The specifics of how these constraints are manifested in any other country requires further investigation. The constraints cited are:

- inadequate government policies and programs;
- an inappropriate information base for technical packages, particularly with respect to range management;
- a paucity of animal feed;
- inadequate animal health services;
- difficult access to markets;
- limited skills for new technology adoption ;
- a bad understanding of the existing system rationales;

- the lack of clear definitions in economic terms of feasible technical packages applicable on a general basis; and
- poor institutional capacities.

Other constraints related to the overall situation in the agricultural sector may be added. There are increasing labor shortages. The general low productivity of the agricultural base combined with the large exogenous capital inflows creates relatively high returns to urban labor, thereby favoring a fast rate of urbanization, such as in Dakar, with a growth rate of 4.8% per year. Urban lobbies and other organized political forces favor agricultural taxation and income transfers from the rural sector (Dumont and Mottin, 1982; Delgado and Mellor, 1984; Christensen and Wituki, 1982).

Besides these constraints, new phenomena are occuring that introduce greater complexities. Especially in the case of the Sahel production systems, changes in the structure of the herds are the results of difficult reconstruction phases between the drought years. Also, there is a new geographical distribution of the herds, with more pressure on the southern boundaries of the dry ecological zones. The potential of mixed production enterprises is growing and it gives more importance to animal traction and fattening operations. With the strengthening of the commercialized economy, small ruminants are increasingly a source of cash. In greater

numbers, nontraditional owners, who have strong profit-maximization motivations, are entering the subsector. Finally, changed price ratios between animal products and cereals may lead to a new pattern and nature of exchanges in the rural economy (FAO,1977).

These general constraints mark the Senegalese livestock production systems, in particular, the Ndama production system existing in the south of Senegal. An overview of this specific system is provided in the following section. This description will be used as the background for the microeconomic modeling of the Senegalese livestock owners' behavior in Chapter V and VI.

The Ndama Production System

Description and Distribution of the Breed.

The Ndama is a Bos taurus breed derived from the Hamitic longhorn ancestral type. Its present origin is the Futa Djallon. Despite some phenotypic variability between 'Ndama petite' and 'Ndama grande' in Senegal, the Ndama is a single breed (ILCA, 1979).

According to Doutressoule (1947), the Ndama increased rapidly in the periods following the rinderpest epizootics of 1890-91 and 1918. At these times, the Ndama replaced herds of other types in Senegal and the French Sudan. The actual total population in Africa is estimated around 3.5 million head (Starkey, 1984).

In the Gambia, the south and southeast of

Senegal, the Ndama is the predominant breed, after an intermediate belt of Djakores, a mixed breed of Zebus and Ndamas. The distribution of Ndama is superimposed on that of the Tsetse flies (Glossina spp.) (Figure 1).

It is estimated that 46% of the Senegalese cattle population is composed of Ndamas and Djakores.

Performance.

The main feature of the Ndama is its reduced susceptibility to trypanosomiasis, hardiness, survivability and water conservation ability (Starkey, 1984). In comparison with the Zebu, the Ndama shows significant production potential, more biological efficiency in its dispersion areas and a high economic profitability in both traditional low input-low output systems as well as improved ones. Furthermore, it has been used widely as a draught animal due to its natural amenability to training and draught work (Starkey, 1984; Doppler, 1980; ILCA, 1979).

However, information gathered under station conditions is much more available than under village conditions (ILCA, 1979; ILCA, 1982; Landais, 1983). A great effort has been provided by ILCA to develop an information network about trypanotolerant livestock. In-depth investigations are just beginning in Gambia and Senegal, in particular (Trail, Murray and Wissocq, 1984).

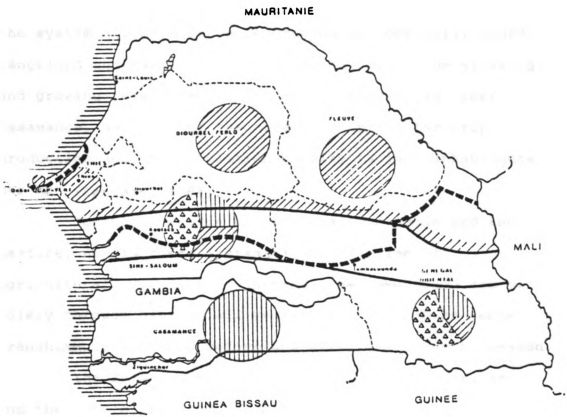


Figure 1. Breed Distribution in Senegal
Source: ILCA, 1979

Production Environment.

Several characteristics of the semi-extensive traditional system with Ndama cattle stand out. First, the system allows free range grazing on communally owned rangeland and pastures or seasonal fallows. The stocking and grazing rates are not yet major issues. In Upper Casamance, only 21% of the area is occupied for crop production and the population density is 18.7 inhabitants per km^2 (Landais, 1984).

Second, there is no management of rangeland and pasture, nor is there systematic utilization of agricultural byproducts. Instead, the feed needs are met solely through grazing all year round, with short range transhumance patterns before and after the cropping season.

The Fulani ethnic production system is dominant, and the cattle are used for a mixed dairy-beef-draft-manure enterprise, which is essential for the subsistence economy. The cattle population is estimated at 280,000 head (Landais, 1984) and a very low offtake rate (Dumont and Mottin, 1982). The productivity and performance are low despite the good genetic potential. In part, this is because of a poor management that increases susceptibility to diseases. These diseases include trypanosomiasis, with various levels of geographical infestation density; fascioloses; brucellosis and anthrax. The annual growth rate of the herd is estimated at 1.5% (Landais, 1984).

In addition, besides the yearly vaccination

campaigns organized by the government animal health services and some actions toward ox-cultivation by the Societe pour le Developpement des Fibres Textiles (SODEFITEX), there is no real livestock development project in the area.

Finally, station research is done by the Centre de Recherches Zootechniques de Kolda as well as some on-farm general investigation (Gueye, Ly and Diallo, 1981).

Policy Guidelines

For enumeration purposes and a better integration, Jarvis(1982) argues for the categorization of any livestock development policy into two sets of policies: technical aspects and economic aspects.

Technical Aspects

Ecological constraints remain the most basic and pervasive among the many determinants of the technical problems faced. Effective range management strategies have been tested for protection against drought, for restoration and carrying capacity amelioration (Pratt, 1984).

Penning de Vries and Djiteye (1982) state that soil fertility, more than precipitation, is the key factor in rangeland productivity because it is the principal cause of the meagre production of forage and its usual low quality. Furthermore, various options for increasing

rangeland productivity while protecting the environment are possible, but under current price conditions they are not economically profitable except in the case of simultaneous intensification with agriculture.

The International Livestock Center for Africa (ILCA) also refers to development of animal production thanks to an improvement in the traditional husbandry system, i.e., improved management practices, veterinary care packages and upgraded breeding stock (ILCA,1979). Despite problems such as chronic malnutrition and low quality feeds that permit animal just to maintain a subsistence level of nutrition which restrains the expression of the genotypes, Mc Dowell (1984) shows that prospects are rather promising in terms of appropriate technology. From a technical point of view, numerous developments in animal science, especially those involving use of by-products, are applicable in the Sahel provided that their costs are lowered and constraints are reduced, such as the constraints on labor availability and lack of credit and extension support (Mc Dowell, 1984; FAO, 1982). Hence, economic considerations appear to be the main determinants of which technological improvements already possible are likely to be adopted and of which types of technical research are going to produce applicable results.

Economic Aspects

Delgado and Mellor (1984) argue that, on the production side, raising prices only "is not likely to be a sufficient condition for accelerated agricultural growth" (Delgado and Mellor, 1984, p.6). Christensen and Witucki (1982) show also the limitations of a policy solely based on the "right prices". Among the numerous reasons for that, are the generally low elasticity of supply due to the poor state of the agricultural infrastructure, the inefficient input distribution systems, the difficult production conditions and the low level of technologies. Also, while the elasticity of supply with respect to labor is probably unitary in the current conditions of production due to the low productivity, the labor supply for agricultural production is affected by shortages at decisive peak-level periods.

On the consumption side, food prices are critical short-run links in a general equilibrium framework since they determine mainly the relative and absolute real incomes of the urban and rural participants in the food system. With the intersectorial linkages permitted by the market system, they contribute to the macroperformance of the food system. Futhermore, they influence the allocation of products and factors according to their elasticities of substitution.

Also, Delgado and Mellor (1984) consider that a sustained acceleration of agricultural growth can be

promoted by economic policies working after a structural change. Thus, growth depends upon technological innovations that cut per unit costs, especially labor costs. That has to be accompanied by good input delivery systems, rural infrastructure, a productive agricultural research and extension system and an increased supply of efficient decision-makers.

Another perspective is the Induced Innovation Model defended by Ruttan and Hayami(1984). These authors state that economic growth ultimately depends on the flexibilities and efficiency of society in transforming itself in response to technical and economic opportunities. Without rejecting the importance of an exogenous supply of technology, Ruttan and Hayami emphasize that appropriate technological change is endogenous to any real development process. However, the attractiveness for the new technological options and the correlative output generation are possible only if the resource endowment and economic environment are favorable. In particular, economic distortions have to be corrected, and also, the allocation and use of resources and factors made more flexible and efficient. Thus, technology, by playing a deterministic role in the growth process, induces and reinforces the necessary institutional changes.

Criticizing the technological determinism of that view, De Janvry (1984) argues that scientific and technological capacity are important and necessary but

they should be understood as social products determined by social and institutional variables. Therefore, development of any subsector in a developing economy is influenced by the distribution of economic and political power at the national as well as the international level. The determinants of the price milieu and the departures from economic efficiency are not only due to imperfect knowledge and foresight. The distortions among prices and the relative scarcities of factors or products as well as repercussions in the market also reflect political preferences and distributional decisions. They are generated by the institutional arrangement, the different "opportunity sets" constituting it and the structure of power it represents (Schaffer, 1984).

A complementarity can be found in the divergent emphases of the Induced Innovation Model and the Radical approaches. These models allow us to find an operational and workable determination of the nature of the relationship technological changes/institutional changes or, in other words, development of the productive forces/social relations of production.

The Induced Innovation Model and the Radical models point respectively to each side of the relationship and show its role in the explanation of rural stagnation and the definition of a development policy. They demonstrate, at the end, their necessary dialectic relationship instead of a monolithic determinism from either approach.

For instance, the Senegalese livestock subsector needs a reorganization based on economic rationalty with respect to the technical aspects, the resource endowment and scarcities but also social and distributional considerations that should be clearly defined by the policy makers. Such institutional considerations are beyond the scope of this study. The focus is rather on the understanding of the subsector dynamics and the research needs that can help in the determination of a successful policy for the subsector.

CHAPTER III

CONCEPTUAL APPROACHES OF LIVESTOCK PRODUCTION

Introduction

Understanding of the pastoral economies has long been hindered by the "perception gap" (Baker,1981,p.369) of outsiders. The failure to appreciate the many roles of livestock in the traditional economy and society often led to policies that caused a shattering of the traditional ecological relationship and established no economic and social substitute that could provide a safety valve for the growing pressure on the traditional livestock production system (Baker, 1981).

The first attempts to develop frameworks for analyzing livestock systems were made by anthropologists, who limited their analyses to the dominant social and cultural anthropological paradigms (Schneider, 1979; Baker,1981;Dahl, 1981; Grandin, 1980). "Pastorology" (Dahl, 1981) concentrated on the pastoral values and attitudes instead of the economic aspects, according to the structural functional theories in the anthropology of the 1950's (Schneider, 1979). This led to the stereotypes, strengthened by colonial administrators, on "cowdolatry","cattle complex","boumanie" and ritualistic associations between men and beasts.

By the 1960's, the limitations of the structural analyses in social anthropology were reduced with the Malinowskian influences which attributed all social behaviors to economic causes. However, the resulting economic interpretations were limited by their bad handling of temporal and spatial differences among societies. The ethnocentric biases remained strong (Schneider,1979; Baker, 1981). Furthermore, the economic explanation of overstocking and the general low supply of livestock by the traditional producers led to the prevalent idea of an economic irrationality and backward-bending supply curves of effort and output in the African pastoral societies.

Nowadays, different schools present competing frameworks for the economic interpretation of pastoralist behavior. Their discussion allows us to present, at the end of the chapter, a synthetic interpretation.

The 'Strategies for Security' Interpretation

Dahl and Hjort (1976), after simulating the effects of drought on livestock systems, show that the main characteristics of the pastoral production system are determined by strategies for security and, in particular, adequate food production. These strategies require, however, an intensive labor use that the system is unable to provide nowadays because of a shortage in supply, especially, at the peak periods of watering.

The main strategies cited are :

- mobility. This procedure is declining due, especially, to labor shortages, loss of land to crop production, ecological accidents and national boundaries;

- herd diversification and dispersion. A greater reliance on small ruminants, goats, has been noticed as well as smaller herd units under the same management; and,

- maximization of size. That explains the permanent building up of herds and the reluctance for destocking.

The policy implication of such a framework is that, by increases in crop production and soil conservation practices, livestock development needs will be served, since grains will be substituted for pastoral products. This will create more intense voluntary destocking. However, Little (1983), referring to a study in Kenya, shows that opposite results can occur. Increased crop production did not result in decreased livestock holding because it did not undermine the investment aspect of livestock. This was particularly true for wealthy herd owners for whom sales went down and grain production was used for supporting livestock holdings.

Criticizing Dahl and Hjort's simulation of required animal numbers for milk subsistence production, Schneider (1979) states that pastoralists are not people

chasing protein across the landscape and that the rationale of cattle raising cannot be located solely in the maximization of milk production. Rather, he says, it is better to think of production as focused on utility. Utility is defined to mean a combination of all things that are considered goods, whether they are food, repositories of values, or anything else.

The 'Commons' Framework

According to the 'commons' framework, the central issues in pastoral production systems are the actual land tenure institutions and the derived individual incentives that shape the resource use decisions (Hopcraft,1981; Widstrand, 1975). The producer behavior is, therefore, not culture bound or determined by a cattle-complex irrationality. It is a predictable response to two sets of incentives:

-an external incentive system implied by the trade and economic relations with other producers and other sectors of the national economy; and,

-a set of internal management incentives whose interrelationship with the first explains the producer behavior.

The 'commons' framework has been described by Hardin and Baden (1977) and Foxall (1979) in terms of the inevitability of the depletion of natural resources with an expanding population and an unrestricted access to

their use. In such a context, the positive utility gained by an individual from an incremental use of the resource is almost plus one. Conversely, the negative utility imposed on each other user is a fraction of minus one since the deleterious consequences of overuse are widely shared.

In the case of traditional livestock production systems, grazing land is a communally owned resource. However, the private individual or familial ownership of milk, offspring and stock enables the individual or family to derive personal benefits from the land. This leads to a strategy of choice based on herd size maximization, whereby the future of the commons is discounted at a very high rate. This strategy of herd maximization may reduce individual risk in case of ecological disaster and allows individual herder to maintain enough stock to rebuilt their herds. There is an opportunistic use of the land by overgrazing and no incentive to reduce stock numbers.

Pastures and feedstuffs are not used in an efficient manner by the growing inventories. In addition, for nutritional reasons, their value declines and the overall increase of output from the sector is constrained.

Hopcraft (1981) describes such a situation as a poor way of storing the community wealth because of high maintenance costs and negative interest rates. In the long

term, the situation becomes a "tragedy" where:

> "Freedom in a common brings ruin to all."
> (Hardin and Baden,1977, p.20)

This framework has been the guiding line of many livestock development projects in Sub-Saharan Africa (Lawry, Riddel and Bennet, 1984; Hopcraft, 1981;Crotty, 1980). Its policy implication is the development of private exclusive property rights for an internalization of externalities.

This approach has been criticized as inapplicable to many livestock management situations since for the vast majority of cattle producers the circumstances, besides the sociocultural background, require maintenance of some forms of communal tenure. These circumstances are: the average small herd size and institutional constraints for matching them with discrete small pieces of land; and the need for a quick response to highly variable rainfall patterns and low productivity range (Lawry, Riddel and Bennet, 1984).

According to Runge (1981), there has been also a misdiagnosis in the modeling of the "Tragedy of the commons" and, furthermore, a limitation in the institutional alternatives proposed. The "Tragedy of the commons" is not a N-person variation of the prisoners' dilemma with a non-cooperative assumption, strict dominance of individual strategies, separability of individual cost functions and the need for a compulsory

enforcement by an outside authority for any solution. Rather, reconsidering the short-run profit motive as a causal agent, Runge (1981) argues that the problem of the commons is one of decision-making under uncertainty where strategic interdependencies and non-separable externalities determine the marginal conditions for profit maximization in grazing decisions and herd numbers. For Runge, the institutional answer to overgrazing lies in devising mechanisms that guarantee that choices will be made collectively; these choices will lead to a security of expectation or assurance that the cooperative institutions will act as "endogenous responses to the uncertainty of social and economic interaction" (Runge, 1981,p.601).

In a case such as Senegal, there are currently no such institutions even though in the past there had been a traditional regulation of access to pasture, especially for the Sudanic agropastoral economies (Swift, 1979 p.59). Unfortunately, that regulation broke down long ago as a result of population growth,technological changes,cyclical climatic disasters and the power shift during the colonial era (Lawry, Riddel and Bennet, 1984).

The Marxist Anthropology Analysis

Bonte (1977) provides an extensive study of Sahelien herders in an attempt to model their behavior and its evolution. The following viewpoint is an application to the herder situation of the general analysis elaborated by the French School of Marxist Anthropology (Eicher and Baker, 1982). Such a Marxist approach is based on the "theory of value" in relation to the herd and its functions or values.

In summary, the value of the herd has three components that influence the herder's behavior toward the creation of a surplus:

-a use value, i.e., a value as a consumption good for immediate use, cash need and food security ;

-a value as a means of production, in which future production is expected depending on reproduction parameters, diseases, droughts, etc; and,

-a social value, expressed through formation and reproduction of social relations, cooperation and cohesion, reflections of social differences and the distribution of power and influence.

These three components are interchangeable directly and immediately because of the distinctive characteristic of animal husbandry in contrast to other techniques of production. There is a perfect technical identity between animal products, means of production and social value repositories. That identity permits, at any moment, one of the components to dominate.

However, Bonte (1977) insists that the interchangeability appears only in the circulation process (exchange of products) among producers. Also the circulation process involves specific production decisions by the livestock owner. These decisions involve various tradeoffs since each use influences the value of others and reduces their possibility of occurring.

From these premises, it is argued that livestock ownership do not only involve joint consumption and production decision making but also simultaneous reproduction of social relations within and between families or domestic groups, ie.,the community. Therefore, the ultimate goal of traditional livestock production is not only the satisfaction of the subsistence needs but, by the production of social value, the formation of social relations.

The subsequent strategy for the livestock owner is the maximization of his production capacities, which include his herd size and his family-supplied labor. Such a maximization is subject to environmental contraints, the herder's technical ability and the limits in the development of his domestic group. The competition developing between domestic groups for higher social status creates the need for a surplus and what has been described as the irrational behavior of herders.

Bonte (1977) also shows that the same economic and social structures are found from pure nomadic pastoralists

to agropastoralists. However, for agropastoralists, since the production process is not only determined by animals, there is a preeminence in the social value of the livestock. Since land cannot be circulated among producers, livestock becomes fundamental as a means of production and in the formation of social relations. These viewpoints are corroborated by findings from Sullivan (undated) and Grandin (1980).

Bonte (1977) concludes that in recent years the herder had less and less control over the outcomes of his strategy and that the pastoral production system has been under an irreversible process of change. These changes have been caused by ecological disasters and diseases worsened by a technological backwardness, on one hand; and, on the other, by the insertion of herders into the world and national markets activated by colonial policies (taxes, sedentarization, territorial limitations). This creates a new environment where the herders are more integrated in the market economy.

Incentives from the market and ecological risks lead to competition between the strategies of maximizing herd numbers and accumulating monetary values through animal sales, ie., a maximization of revenues. More and more, the importance of the social value of the animals is decreasing and the increasing dominance of monetary relations inhibits the former uses of the herd. Migrations of herders to urban areas are frequent because they lost

or have been disposessed from their means of production. This permits a liberation of productive labor that can be used in capitalist relations of production. Finally, there is a trend of sedentarization for nomadic herders and a growing importance of crop production for agropastoralists since it provides less variance in food and revenues.

The critiques that are directed to this analysis refer to its strong viewpoints inspired by Marxist ideology and its radical interpretations of social phenomena. These criticisms correspond to those presented by Eicher and Baker (1982): abstract theorizing, neglect of empirical economic research at the micro level and absence of workable policy guidance.

The 'Repository of Value' Framework

Schneider (1974), the main proponent of this framework, bases his viewpoints on a cross-cultural analysis of money that includes both integrated market systems in Western economies and non-Western economies. Using the concept of "primitive money", which was first developed and analyzed by Einzig (1949),Schneider (1981) shows how livestock fulfill the three most relevant functions of money: medium of exchange, store of value and unit of account. Also, livestock are a good whose high demand often makes them the medium through which all other goods are traded, as has been the case in many places in

the world.

From these premises, Schneider (1984) critiques the cattle complex hypothesis in its consideration of cattle as the sole expression of wealth for East African herders but not as money. In effect, besides a competing use for subsistence, cattle have financial functions, are repositories of value and should be taken as money in pastoral societies. The monetary role is also emphasized by Crotty (1980), Shapiro (1979) and Konczacki (1978).

From that monetary role of livestock, Schneider theorizes a political economy of pastoralism whereby "pastoral capitalism" (Schneider, 1979,p.221) explains the relations of production and the distribution or acquisition of power. In this framework, pastoralists are constantly involved in investment decisions. They manage a pastoral capital for subsistence and make reinvestment decisions and capital gains from sales (Schneider, 1979). This is, however, done in terms of inferior or "primitive money". Therefore, a shift to beef production, where cattle becomes a simple commodity, corresponds to a radical revolution in the rationality of the cattle owner for whom the animal is not comparable to the modern and superior forms of money (Schneider, 1981).

The main critiques to this approach refer to the overemphasis on the monetary role of cattle and the inadequate analogies made between herders and businessmen or specualtors in a stock market. Also, the business

cycle type of evolution related to the consequences of both herd contractions and expansions over time(Schneider, 1979) has been considered inadequate (Livingstone, 1977).

Shapiro (1979),describing the role of livestock in West African pastoral societies, gives a more balanced approach by referring both to cultural maintenance and social relationships and to production and exchange. In these societies, livestock contribute to subsistence and crop production and provide financial services by acting as investment goods that are easily convertible to cash and portable media of exchange, and that also yield a moderate rate of return. Livestock also offer options for decreasing risk through dispersion of herds or building large herds.

The 'Production Rationales' Framework

The preceding analyses and frameworks can be updated and their strong points included in a synthetic analysis that enables us to shed light on the herders' environment.

Due to the nature and circumstances of traditional livestock production in West Africa, in many cases there is no superior alternative to the traditional man-cattle-land relationship established after a long process of adjustment. Wherever changes are expected despite the climatic constraints, it is important for research program and policy decisions to be based upon a

correct perspective of the traditional pastoral system.

The 'Production Rationales' framework proposed here is an attempt to capture the strengths and avoid the weaknesses of the frameworks of analyses described above. It provides an understanding of the decision-making environment and subsequent behavior of the livestock owner.

The starting point lies on the joint household-herd or household-farm decision-making process, whereby the herders allocate their resources to food and production for cash in the context of social relations that determine the producers'own knowledge, their access to productive inputs, the prices for their output, and their abilty to improve their individual or family welfare. Therefore, in the current production systems, due to severe stresses brought about by ecological problems as well as economic and institutional pressures, production rationales are changing.

There is a general reorientation of the herders' economic interest away from strict subsistence production toward engagement in a more integrated economic system dominated by world and national market forces (Lawry, Riddell and Bennett 1984; Behnke, 1983). This creates different tendencies that have been described by the frameworks above. In summary, the two main tendencies are:

-The dissolution of the traditional regulatory management of the commons, implying a widespread "tragedy

of the commons";and,

-the increased use of external markets, with an attempt to maximize private rather than collective benefits since accumulation of social value in livestock has been overthrown by monetary appetite (Marxist anthropology).

Changes occurring now in livestock production parallel those changes that were brought about by the introduction of cash crops into subsistence agriculture. However, in pastoral production systems, there has been more flexibility in the adaptation and response to economic change due to the biological characteristics of the production process, the social role of cattle and less control from government marketing networks. Lawry, Riddel and Bennett (1984) refer to a greater decision-making autonomy that is leading herders to choose divergent responses or differential production orientations, management styles and investment practices. This is also emphasized by Little (1983), who adds that social differentiation among pastoralists is a determinant factor in the choice of production rationales .

Such differential production orientations persist because of the uncertainties linked with the ecological variables and an unpredictable commercial environment. The pastoralists manage to exploit the new market opportunities without, however, committing themselves irrevocably to them. This leads to a hybrid management system (combining

traditional and modern practices) that characterizes the livestock production system in Senegal, for instance.

According to Behnke (1984), such a situation is a reflection of the transitional phase underway in the process of commercial change in pastoral Africa. His model considers the current phase of development as one of open ranching in the continuous shift from the subsistence system to the capital intensive and fenced ranching system. The dynamic variables in such a shift, however, at different levels in different areas, are:

- the transformation of livestock into a commodity and a reduction of its social value due to the changes in the economic and institutional incentives faced by the pastoralists;

- the development of a commercial livestock production system at the margin of the market dominated economy; and,

- the development of new political issues related to the reallocation and control over water and pasturage resources (Behnke, 1983; Behnke, 1984; Lawry, Riddel and Bennett, 1984).

This framework has important implications for policy. In effect, the transformation of the traditional production system and the weakening of its mechanisms of biological equilibrium in favor of a more profit-oriented system implies very serious disequilibria. As it has been true for the Sahel, the impact of these disequilibria on

producers' welfare is great, especially when the ecological conditions deteriorate.

Therefore, important equity considerations are at stake, in terms of the participation of subsistence-oriented pastoralists in the commercial system. Also, in situation where fencing has been proposed as a solution to the deterioration of the productive resources, such as pasture, the question of who will have access to them and/or control them will have important welfare implications.

The analysis of the different conceptual frameworks of analysis leads to the conclusion that in order to face its short-term challenges as well as achieve its long-term economic transformation, the dominant traditional livestock production system needs to undergo important changes. Each of the different frameworks reviewed is based on specific problems leading to related policies.

An integrative approach guided by the 'Production Rationales' framework suggests the need for urgent changes in the Senegalese livestock subsector. The institutional setting should not be kept from transforming, but guarantees should exist against the dispossession of herders and further deterioration of the environment. Ideally, we seek cooperative solutions that are self-sustaining mechanisms, that permit the maximization of aggregate livestock production from the land over time and

also allow a preservation of the pastures and investments for their improvement.

In addition, as in the other agricultural sectors, it is required that the policy makers improve, in real terms, the economic incentives faced by the producers. Finally, technological improvements have to be introduced on large scale with an emphasis on the integration of the husbandry techniques with crop production to allow better joint economic returns.

CHAPTER IV

ECONOMIC MODELING OF LIVESTOCK OWNERS' BEHAVIOR

Livestock Production System Modeling

Numerous bioeconomic simulation models of animal production have been developed with emphases either on biological or economic characteristics. Basically, these models are a series of simultaneous equations that trace the flow of energy through the plant-animal system. The equations model the feed production, the intake of feed, the maintenance requirements and the production performance of the animals in the system under study (Levine, 1982).

Besides their use in analyzing herd structures and making projections, these models focus on beef grazing systems. They aim at an analysis of the consequences over time of improved pastures, higher technological systems or different management and organizational structures. However, these models are demanding of data and, when doing sensitivity analysis, often require wide variations in the model parameters. They have also a very limited value in the absence of a large data base on the agroclimatic environment (Levine, 1982). Chudleigh and

Cezar (1982) show also the costly nature of building such models and the need for a breakthrough in how the models are structured in order to achieve greater operationality.

Various models of African livestock production systems,are available (Abassa, 1984; Doppler, 1980; Dahl and Hjort, 1976; ILCA, 1982). Generally, these models do not include economic components such as cash flow series, investment criteria, net present values, internal rates of return or economic comparisons of different situations. (Exceptions include Maxwell (1980),Powers (1975) and Ngategize (1982).

Furthermore, various kinds of simulation have been done in the modeling of small-farm systems. The models used vary from simple computerized budgets to detailed representations of the complex and interrelated biological, economic and social processes in small-farm production (Hardaker, 1979).

In contrast to sophisticated biological models, Levine (1982) shows the operationality of economic models describing livestock production components or overall production systems. In dealing with other types of problems,they are less demanding in biological coefficients. Furthermore,simple economic models allow a conceptualization of the research problems before too much data collection is undertaken. That leads us to an improved allocation of research resources, a move toward the decisive steps of getting research underway and, finally,

a perspective on later studies focused more sharply on the crucial data.

Decision-Making Analysis of the Livestock Small-Holders

Hardaker (1979) shows the role of positive and behavioral studies based on a modeling of the decision-making of small farmers. From these studies, predictions on the responses to specific incentives, new technologies and policy changes can be derived. Mellor (1969) also states that policy oriented production economics in low-income countries is concerned with discovering in sequence: what decisions farmers make, why farmers make the decisions they do, and what must be changed in their environment so that it is profitable for them to make different decisions which will increase production?

Problems with the Assumptions on Decision-Making

Analyzing the farm management research methods for small farm development in developing countries, Hardaker (1979) notes that in addition to the general lack of relevant and reliable data, there is also the important issue of how farm system performance in subsistence and semi-subsistence agriculture should be measured. General problems related to the assumptions of profit maximization and rationality have been raised by Naylor and Vernon (1979). In addition, Timmer, Falcon and Pearson (1983) argue that pure profit maximization is an

extreme case of rational behavior not likely to be found in the complicated world in which farm-households make decisions. In addition, Shapiro (1976) insists on the precautions to be taken when assuming the "Schultzian efficiency hypothesis".

Thus, the traditional farm development analysis and a significant part of farm management economics have been treated as misleading when applied to "peasant" or small-holder agriculture. Its many differences with commercial agriculture create the need for new approaches in concept and application (Hardaker, 1979).

Such views are similar to those of Eicher and Baker (1982) who stress the great potential for building models that more accurately represent farmers' decision-making by including multiple goals, resource constraints and sequential adjustments to stochastic events, particularly rainfall.

Reviewing the political economy dimension of West African farmers' decision-making, Berry (1980) proposes a new "dynamic analysis". That analysis encompasses the static concept of maximizing the expected utility based on profit maximization and subject to risk aversion. Berry proposes that West African farmers follow a strategy of economic diversification based on a portfolio of assets and under the constraint that the different categories of farmers have different access to markets.

Other concepts, such as targeting and economic

strategizing (Little, 1983) can be added to the many behavioral assumptions or models already presented in Chapter III.

Furthermore, greater complexities arise when one recognizes that in West African pastoral systems the differences between ownership and management are very unclear. Numerous rights and social obligations exist among the managers of herds and the owners of animals. The main rights are the rights to sell, dispose or slaughter stock and the obligations to make decisions over management, care and herding. The right to milk or to control the distribution of the milk produced daily is essential in the subsistence role of the herd (Dahl, 1981; Hopcraft, 1981; Behnke,1984).

Hence, the difference between the owners and the manager of the herd creates difficulties in the modeling of producers' behavior and supply responses. Moreover, that difference adds other constraints to the development efforts when more investments and new management procedures are required.

The Supply Response of Herders

The aggregate behavior of herders is at the center of the debate about African producers' supply responsiveness to price structure and, in general, economic incentives. Low (1980) presents a systematic review of the question.

Contradictory price responses are not exclusive features of traditional African herders since, even in North America where livestock data are more reliable, conflicting price responses have been obtained. Examples include the cyclical price-quantity behavior in beef and hog markets over the past century,which is still persistent in the U.S.A. Such cycles are described as rooted in rational expectations and adjustments of producers to biological constraints on production. These cycles are coumpounded by the changing age distributions in the herds caused by precedent perturbations in the economic variables (Rucker, Burt and LaFrance, 1984).

In such a context, when hog or cattle prices change, the ranchers' decisions are determined by the investment demand for a large size herd, on the one hand, and the consumption demand and concommittant sales for profit, on the other hand. These two types of demand lead over time to different paths of inventory build up and supply of beef or hogs and also opposite responses in the short term and long term (Jarvis, 1977).

In relation to the African situation, Low (1980) concludes that:

> " Although lack of adequate data will often limit the univocity of the results obtained, a clearer understanding of the theoretical and data problems involved with the analysis of traditional herders' supply response to price should contribute to less contradictory interpretations of available data. However, even where unambiguous results can be obtained, price response information alone cannot be used to determine the extent to which African cattle

> owners' behavior is based on objectives other than income maximization."
>
> (Low, 1980, p.2)

Besides the supply response studies, the literature presents numerous resource allocation studies specific to livestock production, mixed farming systems and animal traction. Different economic analyses are used to support and interpret the results. Among them, capital theory emerges as a valuable economic framework for understanding the decision making of herders and livestock small-holders.

Capital Theory Modeling

Introduction

Capital theory modeling is based on the assumption that cattle, or livestock in general, are "unusual capital assets" (Perrin, 1972,p.60). They are treated as durables, in other words, resources whose services are not all extracted during one time period. Such a treatment can be done since it is the time interval used by the analyst that distinguishes between durables and non-durables in economic analysis.

After use and passage of time, durables do not perform the same service as efficiently as they did earlier. Thus, the rate of increase in their value slows, and so the time to disinvest becomes essential in a decision-making process seeking an optimization of the

economic lifetime of durables. The problem is, therefore, one of selecting the particular production period which, over a specified planning horizon, yields the maximum net present value of future profits in a situation where resource constraints, such as land and pasture availability, are not yet binding and production conditions not fixed. However, when production alternatives are planned on the same fixed resource, such as a private livestock farm or a cattle feedlot, capital budgeting procedures should be implemented as shown by Harsh, Connor and Schwab (1981). These procedures adjust the accumulated net discounted income during the planning horizon with an amortization factor. Thus, the problem becomes one of selecting the most profitable annuity or standardized income generated from the fixed resource Different adjustments are also made for stochastic inputs and outputs, continuous and discrete time processes, or random elements (Burt, 1965; Chisholm, 1966; Perrin, 1972).

In the context of a traditional livestock production system, the key question for the decision maker is when to convert his naturally growing piece of capital into a consumer good, i.e, to slaughter or to sell. Reviewing the main economic models in the analysis of the cattle sector, Porter (1979) shows the complexities arising from this approach and its fundamental differences with the wine production model or the tree-growing model. The main differences are: the demographic aspects of the

herd,the biological processes involved,the non-homogeneity of the unit of study due to sex, the continual decisions with respect to physical input streams and the biological requirements, the cash flow complications, the uncertainty considerations, playing a crucial role in the raising of livestock, and the influence of the environment (over-stocking, competition with food growing areas).

Jarvis (1977) presents a series of micro-models that treat cattle as capital goods and producers as portfolio managers for a theoretical framework for an econometric model of the Argentina cattle sector. He states that cattle are considered to be capital goods, i.e., potential future monetary values, which are held by producers as long as their capital value in production exceeds their slaughter value. This happens in the context of a large scale cattle production system that is essentially commercial and that has a correct valuation of capital costs.

The review of the competing conceptual approaches of the African livestock production systems in Chapter III has revealed a unanimity in relation to the role of live-stock as a capital good, even though that it is not livestock's only role. This implies the need to look closer at a replacement theory framework that allows us to consider in more detail the multipurpose nature of livestock in the traditional African farming systems and the impacts of age on costs, quality of meat, different

uses and revenues.

Jarvis' microeconomic approach has been also used in the analysis of the status of cattle and the 'commons' problems in Swaziland. In response to Doran, Low and Kemp (1979), Jarvis (1980) uses his model to show how , under a communal range system, herders find it profitable to hold onto animals, therefore creating a negative short-run price response to cattle slaughter. Crotty (1980), Ariza-Nino and Shapiro (1984) also use capital theory frameworks in their different economic models of decision-making by cattle keepers.

Theoretical Bases

Livestock are a form of capital asset whose physiological ability allows their manager or owner to consider two strategies:

- the accumulation of capital goods creating, through physiological reproduction, other capital goods that are themselves sources of value; and,

- the management of an asset that is able to convert feed into meat, milk, draft power, manure, hides, prestige and religious or social values.

These functions also require costs in the form of maintenance, mortalities and foregone interest or return on alternative investment opportunities. The net expected present value of the services provided by the livestock asset is a function of the time the asset is held and

corresponds to the difference between returns and costs, all discounted and adjusted for death loss. At the beginning of its life, the net expected present value of an animal's services is negative since only costs are incurred . Then, it increases over time until reaching its maximum, which corresponds to the optimal age for sale. After that moment, the net value decreases until the death of the animal.

It is assumed that the asset owner compares the opportunity gains from keeping the current asset for another time interval, such as a year, with the opportunity gains which could be realized from its liquidation during the same period (Perrin, 1972). The relative value of the future stream of gains is expressed in terms of present earnings by the discounting procedure.

The discounting procedure allows the owner to compute the value at birth of the livestock asset as the present discounted net value of the services provided by the asset during the production process associated with it (the livestock asset). This is so assuming perfect knowledge and no risk. The discount rate is the conversion factor of future streams of value to present values. It can be determined by either the cost of capital, the return on the best alternative investment or the preferences in the timing of personal consumption and, finally, the risk involved in the economic enterprise undertaken.

As it relates to an economic evaluation based on the marginal principle, such a model suffers from the general criticisms that are raised with respect to modeling decision-making in traditional production systems. Furthermore, the assumption of homogeneity in animals and farms is also a problem in an economic setting exhibiting an important dispersion of types. Also, as pointed out by Jarvis (1982a), the joint product problem faced in the modeling becomes (analyzing the contribution of different products and services produced by the herd to the value of the stock) too complex when a high number of products is involved. In such a case, Jarvis recommends a dissaggregation of the production process and activity analyses to obtain better solutions. These major limitations restrict the model accuracy but the model remains a useful tool for conceptualizing hypotheses concerning herders' decisions, for sketching out issues and for deriving second-best solutions. In addition, these investigations can be done cheaply while still providing indications about what further data need to be collected to test specific hypotheses.

Finally, with its examination of the livestock asset profitability, The capital theory approach makes it possible to study the relationship between the structure and sex composition of the current herds and their current uses . Thus, it contributes to our understanding of the livestock subsector dynamics, the economic bases in the

pattern of livestock holding and management and the means for their improvement.

Mathematical Model

In this section, we will focus only on cattle production systems, assuming that simple adjutments can be made for other livestock, such as small ruminants.

The mathematical model presented is a partial equilibrium model of a pastoral production system or the cattle component of a mixed farming system. Although it results from a combination of different studies, it is inspired mainly by Jarvis' approach (Ariza-Nino and Shapiro, 1984; Jarvis, 1977; Jarvis, 1980; Jarvis, 1982; Panayotou and Tokrisna, 1982; Porter, 1979).

The general mathematical model is as follows:

$$
\begin{aligned}
(4.1) \qquad Pr(a) = {} & p(i,a).w(i,a)\, e^{-ra} && \text{Price and growth component} \\
& - c_i \int_0^a e^{-rt}\, dt && \text{Cost component} \\
& + \sum_{t=1}^{a} Cv(i,t)/(1+r)^t && \text{Calf stream component} \\
& + po \int_{a1}^{a} d(i,t)\, e^{-rt}\, dt && \text{Draft power stream} \\
& + pmk \int_{a2}^{a} mk(i,t)\, e^{-rt}\, dt && \text{Milk stream} \\
& + pma \int_0^a ma(i,t)\, e^{-rt}\, dt && \text{Manure stream} \\
& + \text{Social Value}
\end{aligned}
$$

Where:

Pr(a) = Present discounted profit from an animal at age a;

p = Price of meat, which is a function of i and a;

i = Bundle of daily inputs;

a = Age of the animal;

w = Weight, which is a function of i and a;

r = Discount rate;

t = Time;

c_i = Cost of input i (feed,shelter,fences,machinery, veterinary care,herding);

Cv = Expected value of calf born in year t, assuming the cow has received input stream i;

po = Unit value of d;

d = Amount of draft power that is a function of i and t;

a1 = Age at which draft services begin;

pmk = Price of milk or per unit value;

a2 = Age at first lactation;

mk = Amount of milk used for sale or consumption and produced by a cow aged t and receiving input i;

pma = Price of manure or per unit value; and

ma = Manure produced by an animal aged t and receiving the input stream i.

Taking ther first order conditions of equation 4.1 provides the optimal age of sale and input stream for an animal, given known growth curves.

Complexity can be added by considering price expectations, by letting p = p(i,a,t), whereby the price of meat is not only a function of the inputs and the age or quality of the animal but also seasonal time trends. Also, more interestingly, such factors as climatic variations and the impact of diseases can be included in the growth function with w = w(i,a,b), where the weight is a function of the inputs, the age of the animal and a coefficient measuring biological efficiency. By adjusting weights for the fluctuations occurring seasonally, this coefficient enables us to obtain a curve fitting more precisely the real world age-weight relationship and the production conditions.

By satisfying the first order conditions for an optimization of Pr(a) or Pr(i), the optimal economic lifetime of the "durables" and the optimal input stream can be analysed and the replacement or liquidation rule determined on the basis of net present values. Furthermore, inferences can be made about the directions of change in the optimal age of sale and the herd structure that will result from changes in policy and technical variables.

The solutions to such a model are theoretically accessible but have many mathematical complications along

the way. As stated by Naylor and Vernon (1979), it is possible to conceptually formulate a mathematical model describing the behavior of a dynamic, multiprocess firm operating under uncertainty, but present-day mathematical techniques are simply incapable of yielding solutions to a problem of this magnitude in an efficient manner. The time involved in solving such a problem through calculus and the various sources of computational errors make them inappropriate for practical use. Decision-makers are interested in faster solutions to more complex problems. Therefore, for a numerical analysis based on decision rules, a simulation by computer is of great help.

After this rather abstract but necessary introduction on modeling using capital theory,the following chapter presents a more operational approach with a practical application to a specific livestock production system, the Ndama cattle production system in the Upper Casamance.

CHAPTER V

PRESENTATION OF THE MODEL AND THE SIMULATION METHODOLOGY

Characteristics of the Model

A basically classical nomenclature and approach are used in this study for the model and simulation methodology (Dent and Blackie, 1979). The simulation technique is taken as a numerical representation of the conceptual model of the herders' behavior over time as embodied in the capital theory approach.

The model is more mechanistic than predictive. Its main goal is to assist in the understanding of the problem under study rather than making projections on the behavior of the system. As with any model, it has limitations in representing the complex interrelationships and dynamics of the phenomena it seeks to represent.

For the purpose of our study, it was not possible to collect detailed primary data to use in the model. Thus, the available information on the Ndama production system, reviewed in Chapter II, is used for the qualitative and quantitative description of the model. Also, a stochastic specification could have been useful since it takes into account the uncertainty implied by

unexplained events, truly random elements and the environment's unknown influence. Stochasticity can be introduced by generating random variables in the modeling exercise. However, as shown by Dent and Blackie (1979), stochastic specification is important in bioeconomic simulation but it should be introduced with caution due to the complexities of the processes being modeled and the lack of knowledge about the probability distributions of data collected.

Because of the lack of information on probability distributions of the major variables in the model, it is not possible to incorporate stochastic features in this study. The model used is deterministic. It is assumed that the most likely situations are the ones where all random factors take on their average values. This applies to prices, weather, human behavior and physiological processes such as growth, disease frequencies and intensities.

In addition, one of the major problems in simulation is the inclusion of time since computers are sequential processors. In this work, a time-stepping procedure is used. The dynamic characteristic of the real world situation is introduced by a time-varying discrete procedure used to approximate the movements of factors that vary continuously. Time is advanced by single fixed units of one year.

Finally, the model does not include explicitly

resource constraints. It is assumed that the system is not yet bound by constraints on the main resources, such as pastures and managerial capacity. However the levels of calving and mortality rates create limits against the infinite expansion of the animal population.

Description of the Model

Optimal Age of Sale Component

Equation

The profit function used is :

$$(5.1)\quad Pr(a) = p(a).w(a)e^{-ra} + \int_0^a f(p,t)e^{-rt}dt - c\int_0^a e^{-rt}dt$$

In this equation, Pr(a) is the net present worth of the stream of benefits from the animal from birth to age a, that is, it is the discounted total profit a herder would receive from an animal that was sold at age a. Pr(a) is the amount that, if invested at the rate r, would have the same value at time t = a as the animal sold on the market at time t.

$p(a).w(a)e^{-ra}$ expresses the market sale value of an animal whose weight and price are both functions of age a.

$\int_0^a f(p,t)e^{-rt}dt$ expresses the flow of benefits other than meat production from the animal from birth until age a. These benefits are functions of their prices

(or equivalent unit values) and time that is the age of the animal at the moment of their production.

$c\int_0^a e^{-rt}dt$ is the flow of costs over time.They are taken as fixed here, i. e., costs are assumed to be the same for both sexes and for all age categories. Only sufficient data would allow us to consider cost as a function of age and sex, especially for the cows, because of the nutrition and veterinary requirements related to their reproductive function. So, cost would be expressed as

$\int_0^a f(c,t)dt$, that is, a function of their unit value and the time where they are paid. The sensitivity analysis in Chapter 6 examines the case of reproductive cows presenting a changing cost structure over time.

e^{-rt} allows the discounting procedure, as shown in Appendix B. r is the discount factor used. It permits us to consider the one-period losses caused by not selling the animal and investing its value in another better alternative opportunity.

Decision Rule

In the conventional marginal analysis, the decision rule is :

Do not sell if

Expected gains in one extra year > Expected costs for the corresponding year.

Algebraically, the decision-maker is faced with the comparison of:

$$(5.2) \qquad wdp/da + pdw/da + f \gtrless rpw + c \ .$$

This relation means that the change at each age in sale value due to quality and weight plus the flow of benefits from holding the animal one extra year, are compared with the sum of the interest foregone by not investing value of the animal (pw) at the interest rate r and the costs incurred by keeping the animal during this same period. This relation is valid only if there is a declining rate of gain in the animal growth over time and also a declining level in the price per kg of the animal as it ages (second order conditions).

In our study, the decision rule that has been described is translated to more simple terms with the comparisons of net expected present values. The decision maker reaches the goal of profit maximization with the sale of animals whose net expected present values are at their maximum.

This approach is based on the assumption of an optimizing pastoralist. It also refers to animals presenting average performances in terms of meat, milk and calf production. The variations due to performance differentials are examined in the sensitivity analysis in

Chapter 6.

With this model, the optimal age to sell for the producer can be derived as well as the differential impact of parameter changes upon the capital value of animals of different ages and sexes. In this study, a generalized approach is used. There is just a consideration of males and females instead of the different categories of cattle. A more subtle differentiation could, however, be done if data were available.

Finally, optimal age of sale are used as the key variables in the herd structure component of the model which derives the herd size, age/sex composition, offtake and herd productivity.

Data

The main objective of the model is to suggest the most likely effects of changes in cattle management and the nature of the relationships among technical and economic parameters in the context of southern Senegal. Firsthand data are not available and also could not be collected. Therefore, all the data inputs are based on secondary information , experience and assumptions on the semi-extensive and traditional Ndama cattle production system that was described in Chapter II.

Liveweights

Due to the unavailability of weight-age relationship data from birth to adult age, a growth model is used in this study to generate age-specific weights for both sexes.

Various growth models are available in the literature (Brody,1964; Brown, Fitzhugh and Cartwright, 1976; Aguilar, Friedli and Canas,1983; Landais,1983; Abassa,1984). Despite the variation from breed to breed, the overall shape of the weight curve is sigmoidal and related to the maturation patterns under given environmental conditions. Thus, it is assumed that, within each breed, the variations due to seasonal short-term fluctuations in body composition average out when a year-stepping model is used.

In this work, the intent is not to test the growth models, although a realistic and accurate one is needed. The Gompertz curve has been chosen. Its limitations stem from the assumptions of a fixed inflection point and the tendency to overestimate early weights (Brown, Fitzhugh and Cartwright, 1976). In addition, it does not provide us with a good fitness of the curve at very late age for the female. In effect, the assymptotic adult weight used in the computation does not represent well the decreasing trend in cow weights after 10 years. Nevertheless, the Gompertz curve provides a good fit at the ages of impor-

tance in the valuation of the animals and requires only three parameters for its computation. A slight over-estimation of female weights around 15 years has only a minor influence on the total expected present values of the cows. The bias would have been more serious in the case of the males, for whom weight plays an essential role in the determination of the optimal age of sale.

After manipulation, the general form of the Gompertz curve is transformed to (see footnote at the end of the chapter):

$$W_t = W_0 \exp.b(1 - r^t)$$

W_t is the liveweight at age t

W_0 is the birth weight

b and r are coefficients derived from the mathematics.

The initial data regarding weights and the age at the inflection point have been chosen as the average values for these parameters in the Upper Casamance (Table 8).

The resulting equations are :

For the male, $W_t = 18 \exp.2.966(1 - .580^t)$

For the female, $W_t = 17 \exp.2.605(1 - .528^t)$

Figure 2 presents the two curves generated with the Gompertz methodology.

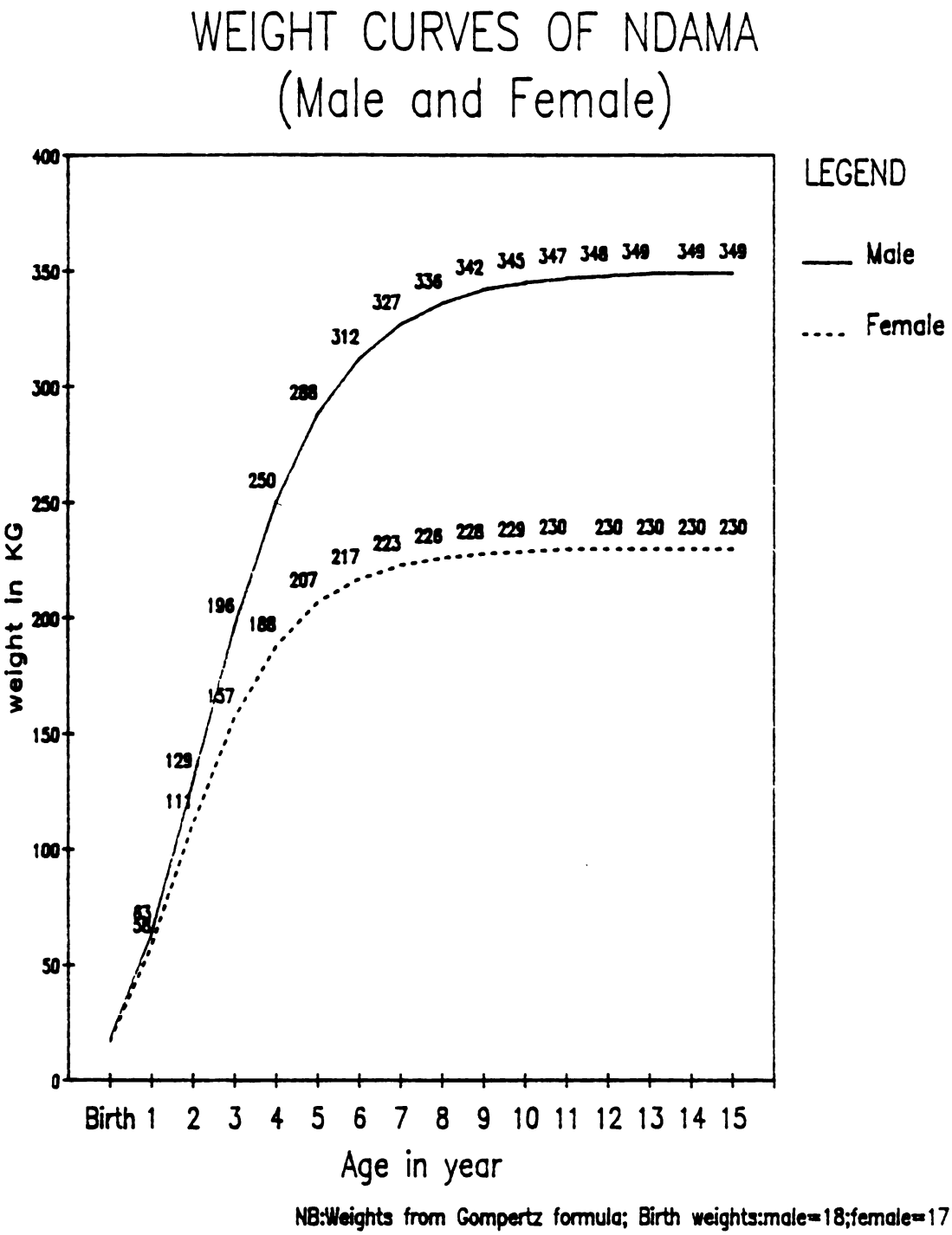


Figure 2. Weight Curves of NDAMA

Table 8. GROWTH DATA FOR THE GOMPERTZ CURVES (Ndama cattle; male and female; Senegal)

Data	Sex	
	Male	Female
Birth weight(KG)[a/]	18	17
Adult weight(KG)[a/]	350	230
Age at inflection point[b/] (year)	2	1.5

SOURCE : [a/] ILCA, 1979
[b/] age at puberty (assumption)

Mortality Rates

ILCA (1979) refers to an overall mortality rate of 12% in the region. The data provided by Ariza-Nino and Shapiro (1984) are used in this study. They describe the mortality occurring in a breeding herd (Therefore, slaughtered animals are not acounted in the number of deaths occurring in each age class and sex category in the calculation of these mortality rates). The pattern of age-specific values reflects very high mortality rates at early ages followed by a stabilization at adult ages (Table 9 and Figure 3).

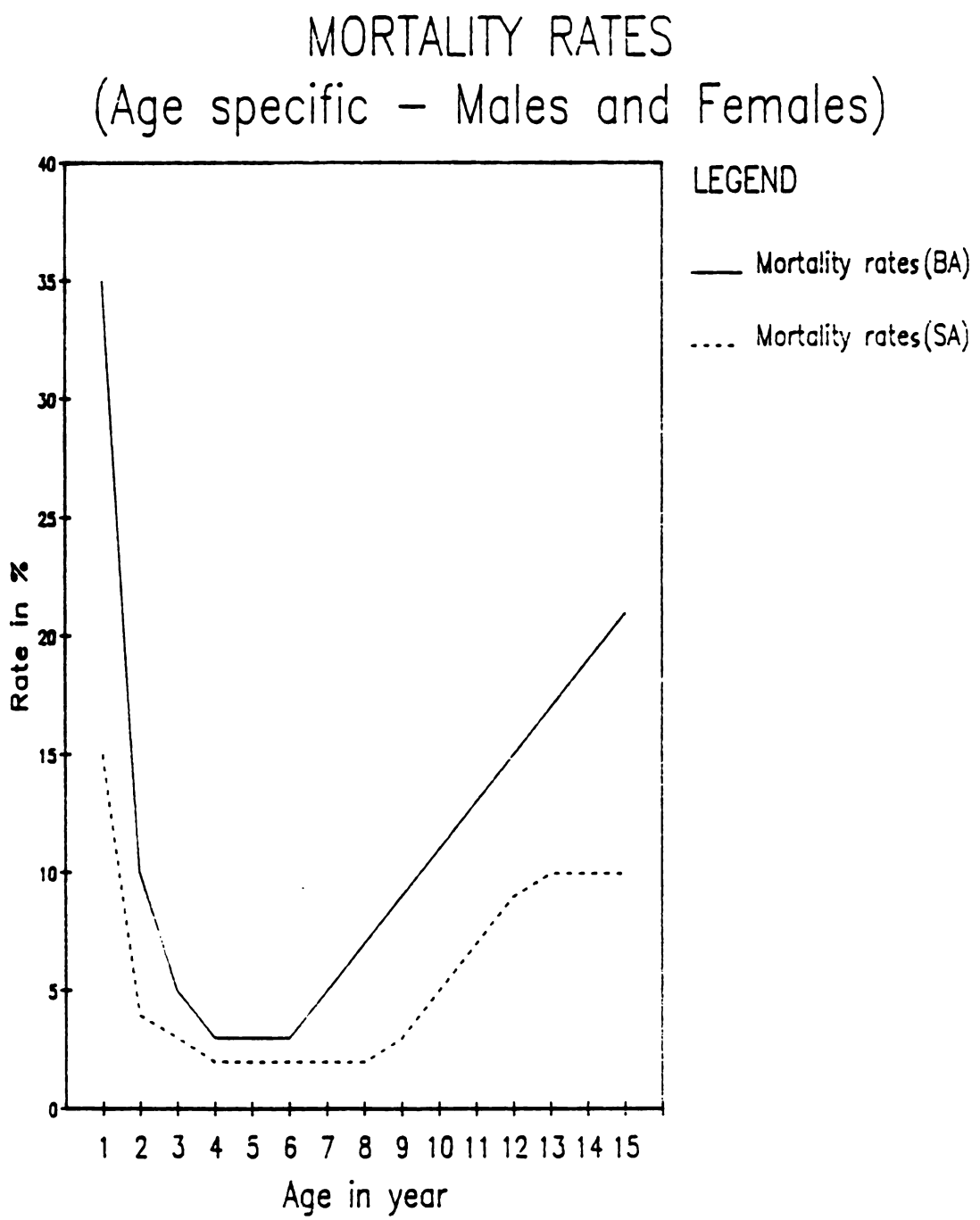


Figure 3. Mortality Rates

Calving Rates

The available data refer only to aggregate birth rates, which are given as 56% (ILCA, 1979) and 46% (Starkey, 1984). In Upper Casamance, estimates ranging from 50 to 55% are reasonable (ILCA,1981). Considerations of the productive life of cows permit us to draw age-specific calving rates. The data used are based on a conservative overall calving rate (Table 10 and Figure 4).

TABLE 9. MORTALITY RATES
(Ndama cattle; male and female; Senegal)

Age (year)	Death rate (%)	
	(1)	(2)
0 - 1	.35	.30
1 - 2	.10	.15
2 - 3	.05	.05
3 - 4	.03	.02
4 - 5	.03	-
5 - 6	.03	-
6 - 7	.05	-
7 - 8	.07	-
9 - 10	.09	-
10 - 11	.13	-
11 - 12	.15	-
12 - 13	.17	-
13 - 14	.19	-
14 - 15	.21	-
Overall rate	.12	.12

SOURCE : (1) Ariza-Nino and Shapiro, 1984
(2) ILCA, 1979

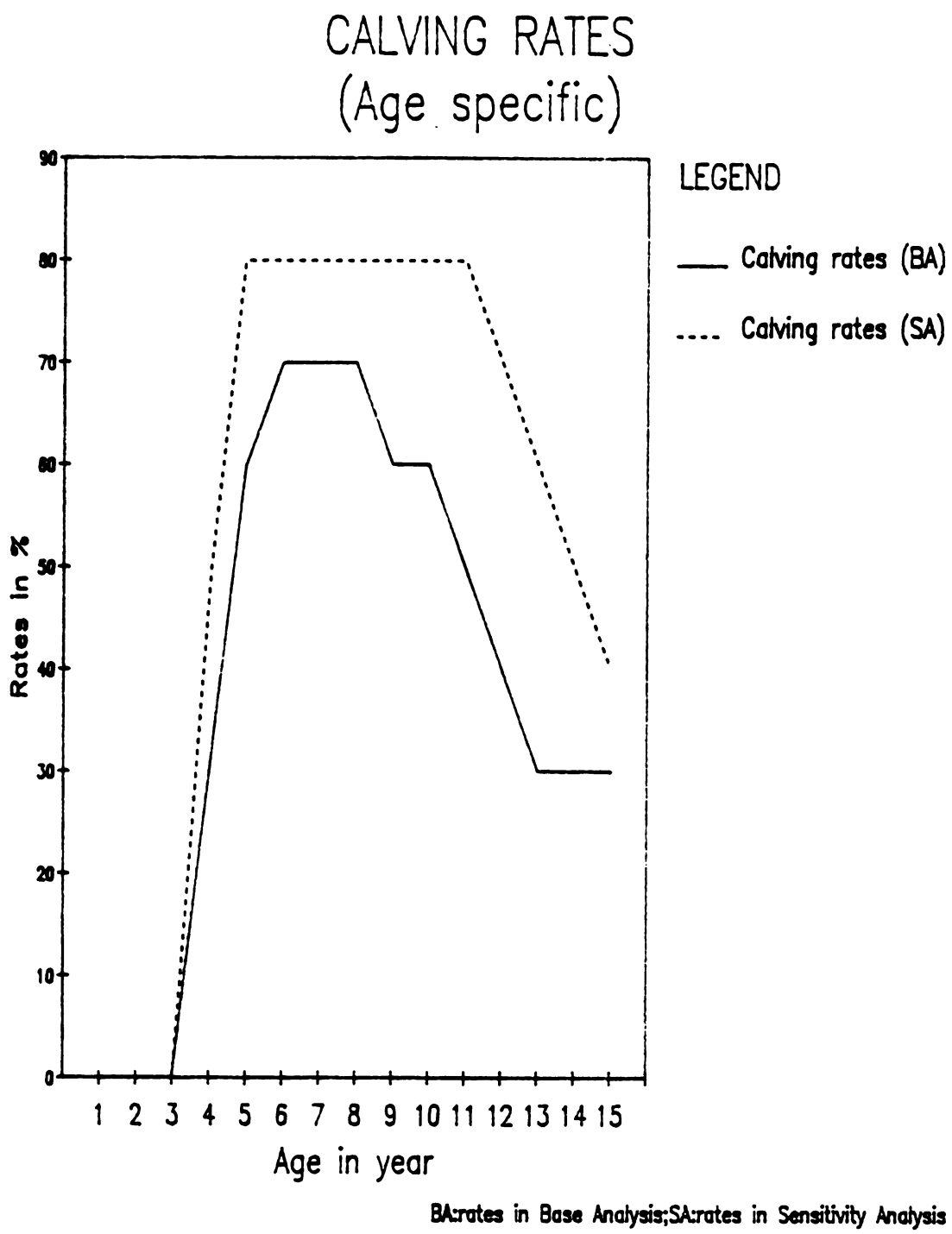


Figure 4. Calving Rates

Table 10. CALVING RATES
(Ndama ; Senegal)

Age (year)	Calving rates (%) (1)	(2)
0 - 1	0	0
1 - 2	0	0
2 - 3	0	0
3 - 4	.30	.30
4 - 5	.60	.60
5 - 6	.70	.70
6 - 7	.70	.70
7 - 8	.70	.70
8 - 9	.70	.60
9 - 10	.65	.60
10 - 11	.60	.50
11 - 12	.55	.40
12 - 13	.50	.30
13 - 14	.45	.30
14 - 15	.40	.30
Overall rate	.56	.50

SOURCE : (1) Ariza-Nino and Shapiro (1984)
(2) Data used with a conservative assumption

Milk Yield and Value

Various lactation results recorded on stations with Ndama cows are available in the literature (ILCA, 1979; Landais, 1984). However, few investigations have been done on farms. Starkey (1984) refers to a full lactation averaging 500 to 600 kg. The lactation yield of 500 kg can be used as a conservative assumption which

takes into account the general decreasing productivity in Upper Casamance in the last decade.

These data do not consider the lactation fluctuations over the cow's life. Different quantities are produced at each lactation according to specific trends. Such trends are a function of not only the environment (water, health), but also the number of past lactations. These variations definitively have a strong impact on the economic returns from each cow. Research is still very much needed to provide data on traditional dairy production.

Meat Value

Producer prices vary considerably depending on the area of production, the place of sale and the age of the animal (SOMIVAC, 1982). It is, therefore, inaccurate to consider a single price based only on weight in the estimation of per kg liveweight prices (Shapiro, 1979). Prices can also vary according to the quality of the animal.

In Upper Casamance, variations from 120 to 160 FCFA per kg liveweight are usual. The price structure used in this study is based on the information available from the public agencies (SODESP, 1984; SOMIVAC, 1982). Average prices that have been collected from 1978 to 1984 are presented in Table 11 and Figure 5. The derived market values of the animals for their meat values are

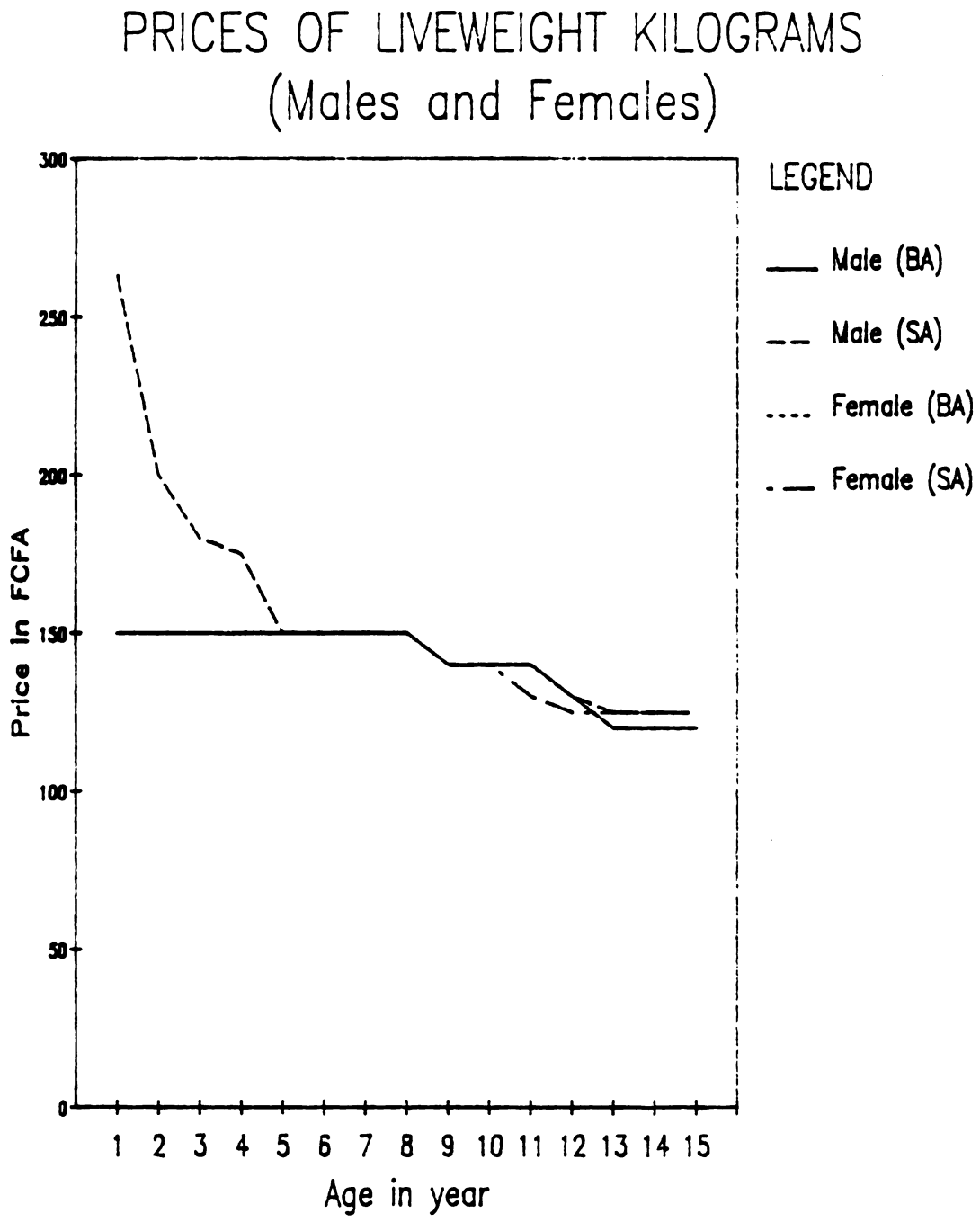


Figure 5. Prices of Liveweight Kilograms

correlated to their growth pattern as shown in Figure 6.

Table 11. PRICES
(Liveweight; Casamance; Averages from 1978-84)

Age (year)	Prices (FCFA/KG)
0 - 1	150
1 - 2	150
2 - 3	150
3 - 4	150
4 - 5	150
5 - 6	150
6 - 7	150
7 - 8	150
9 - 10	140
10 - 11	140
11 - 12	130
12 - 13	120
13 - 14	120
14 - 15	120

SOURCE : SODESP, 1984; SOMIVAC, 1982

Costs of Production

The opportunity costs of land, pastures and agricultural residues are assumed to be nil. In reality, the land may have some income-earning potential without livestock production, and incorporating that opportunity costs into the model would reduce the net benefits from livestock production somewhat. Furthermore,the pastoralist uses them as communal property without paying any direct costs.

Labor is used for supervision, watering and

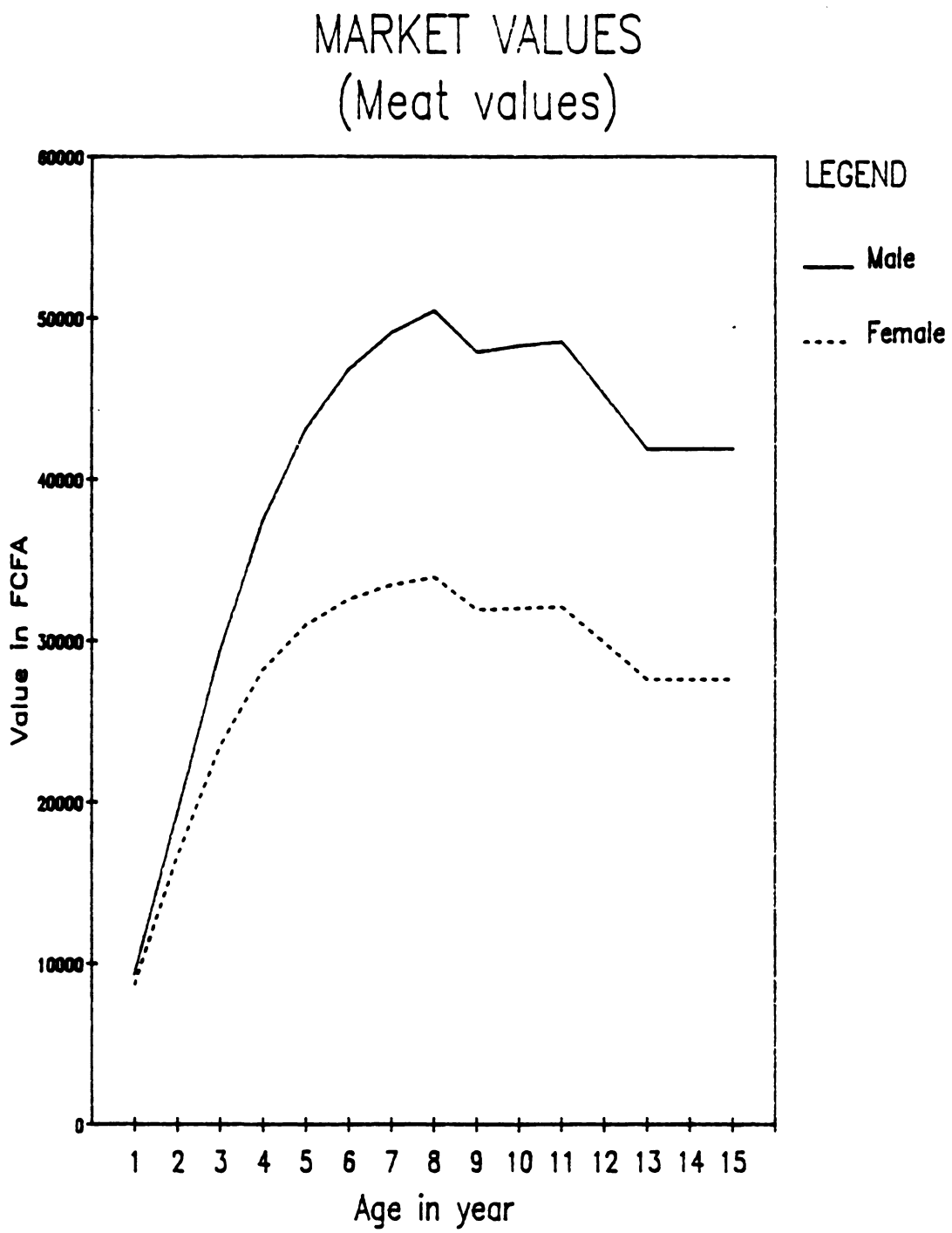


Figure 6.. Market Values

milking. The labor need is very important and is solved by relying on members of the family (children or unemployed persons). The valuation of labor is a major area of research and there is no objective estimate available for crop production. In the case of cattle rearing in the area of Upper Casamance, where the stocking rate is not critical and the competition with crop production low, it is reasonable to consider that the labor costs are very low in terms of financial analysis. Thus, for the base run no value is given to the labor cost.

There is a minimum cost of 375 FCFA for vaccinations and eventual veterinary care (SODESP, 1984).

Conceptually, death losses are an element of cost and the cost inputs for the modeling should explicitly incorporate them as well as their effects on past income (Shapiro, 1979; Panayotou and Tokrisna, 1982, Ariza-Nino and Shapiro, 1984). In this study, death losses are included in the computation indirectly by using the probabilities of survival for each age and sex category. The survival rates are used to adjust expected present values for death losses. Therefore, the cost figures of the input data do not contain the death component, but all expected present values have been obtained with the consideration of death losses and other monetary costs.

Interest Rate

The Senegalese farmers had, until the NPA (Chapter II) access to substantial amounts of credit for crop production through the Programme agricole and various credit schemes offered by the development agencies. The credit programs were extensively subsidized and created significant inflationary pressures. The efficiency of the formal credit system was also plagued by the high fungibility of the loans and bad repayments from the lenders.

As shown in Chapter II, the livestock subsector was not directly affected by the formal credit institutions. Therefore, estimates of the real interest rates are based on data from the informal credit market.

In a study of the formal and informal markets in Senegal, Tuck (1983) shows that 67% of the households surveyed borrowed at least once during a year. That figure expresses the intense activity of the informal market, which has been described as a primary source of financial services for farmers. Loans are usually short-term. They are not for agricultural production but rather for consumption and recurrent annual expenditures. Tuck concludes that these loans are use to solve resource budgeting problems caused by a lack of savings or a mismanagement of cash flows.

Even though Moslem tradition forbids charging interest, very high average annual interest rates are used

(Table 12).

For our modeling, the forgone interest on the current value of the animal is estimated at 20%. Such a high value is in the range of the simple interest rate found by Tuck (1983) in Casamance and is also confirmed by Shapiro (1979), who estimates the opportunity cost of capital between 20% and 25% in West Africa. It is considered a reasonable estimate reflecting, in particular, the time preference for money, the risk component for the lender and his/her costs for providing such services.

Table 12. AVERAGE ANNUAL INTEREST RATES
(Informal markets; 1982-83; Senegal)

	Regions	
Rates(%)	Senegal	Casamance
Simple interest rate[a]	34	16
Average interest rate[b]	79	40

/[a] including loans without interest
/[b] 44% of loans being interest bearing

SOURCE: Tuck (1983)

Herd Structure Component

The starting assumption in the herd structure component of the model is that any change in the use of an animal of a given age and sex has repercussions on the use of the other animals and, thereby, on the age and sex structures of the herd (Jarvis, 1981). Studying the herd structure, on the one hand, and its transformations under various parameter changes, on the other hand, help us understand producer destocking decisions. Potentially, the model could be elaborated to study the sale response differentials for various categories of animals (feeder calves, fattened steers, etc.). This would allow us to derive a ranking of the sale elasticities of the different categories.

In this study, the herd structure component is a simple demographic model. The aim is to evaluate the trends in offtake, growth and productivity correlated to the management decision taken. The model is ,therefore, limited to a simulation of the demographic processes generated under given initial technical and economic conditions and their evolution under the influence of alternative management decisions.

The initial herd structure is generated by applying a cumulative survival rate of the different age classes on 1000 animals (males and females). The ideal initial starting population is in the range of 70 to 90 animals, which is that of the average herd size in the

area of study (ILCA,1979). However, to reduce the effects of rounding errors, the simulation was done on 1000 animals. The aggregation of 10 to 12 herds should not create serious aggregation biases.

Once the initial herd structure has been generated, then in each succeeding year, calves are added according to a sex ratio of .5, the age-specific calving rate and the number of productive cows. After that, each year, the surviving animals in each age class are transfered to the following age class animals reaching the optimal age of offtake are removed from the herd.

Finally, the growth rate and productivity of the herd are calculated for each year as well as the average herd growth rate for every 4 years. These production parameters allow an overall appreciation of the herd evolution over the simulated period of 25 years.

All the data on technical and economic parameters are the same as that for the age of sale component. The optimum age of sale is incorporated as an input in the determination of the offtake in the herd evolution.

Block Diagrams

The block diagrams presented are sets of boxes indicating the major components of the model and linking arrows indicating the interrelations and flows of material or information. Figure 7 describes the cattle production component, the overall mixed production system and the

various measures of performance that are used for analyses at the microeconomic and macroeconomic levels. Figure 8 presents the determinants of the herd demography.

Figures 9 and 10 show the dynamics of the two components of the model, following the nomenclature chosen by Dent and Blackie (1979).They specify the interrelationships among the exogenous variables , the rates of changes and the state variables.

Computer program

The computer program is written in FORTRAN. It constitutes an approximation of the mathematical models used to represent the real world with restrictions related to the inclusion of time and stochasticity and the data availability. The program with comments and variable directory is presented in Appendix C.

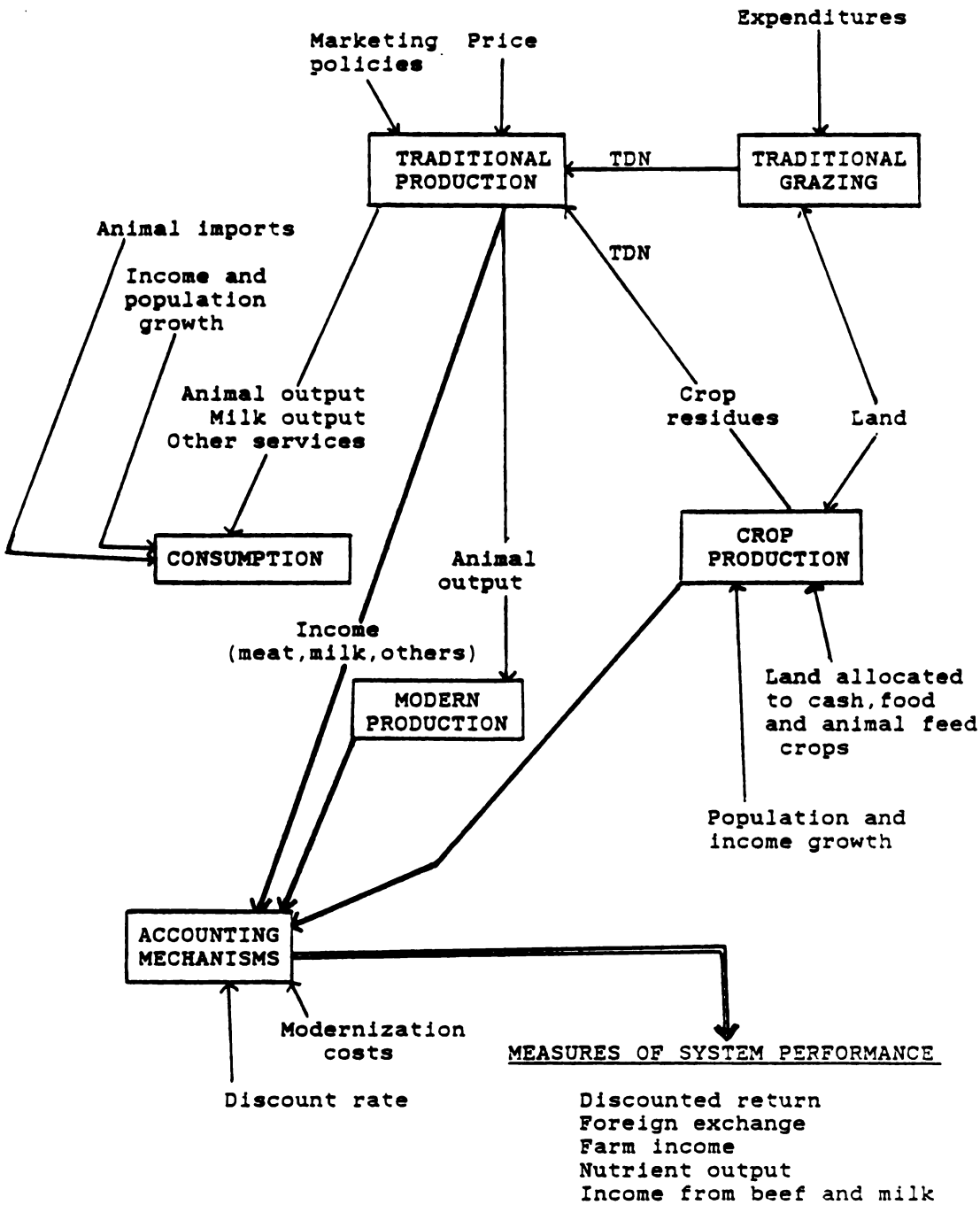


Figure 7. Functional flow diagram of cattle production (Adapted from Manetsch and al., 1971)

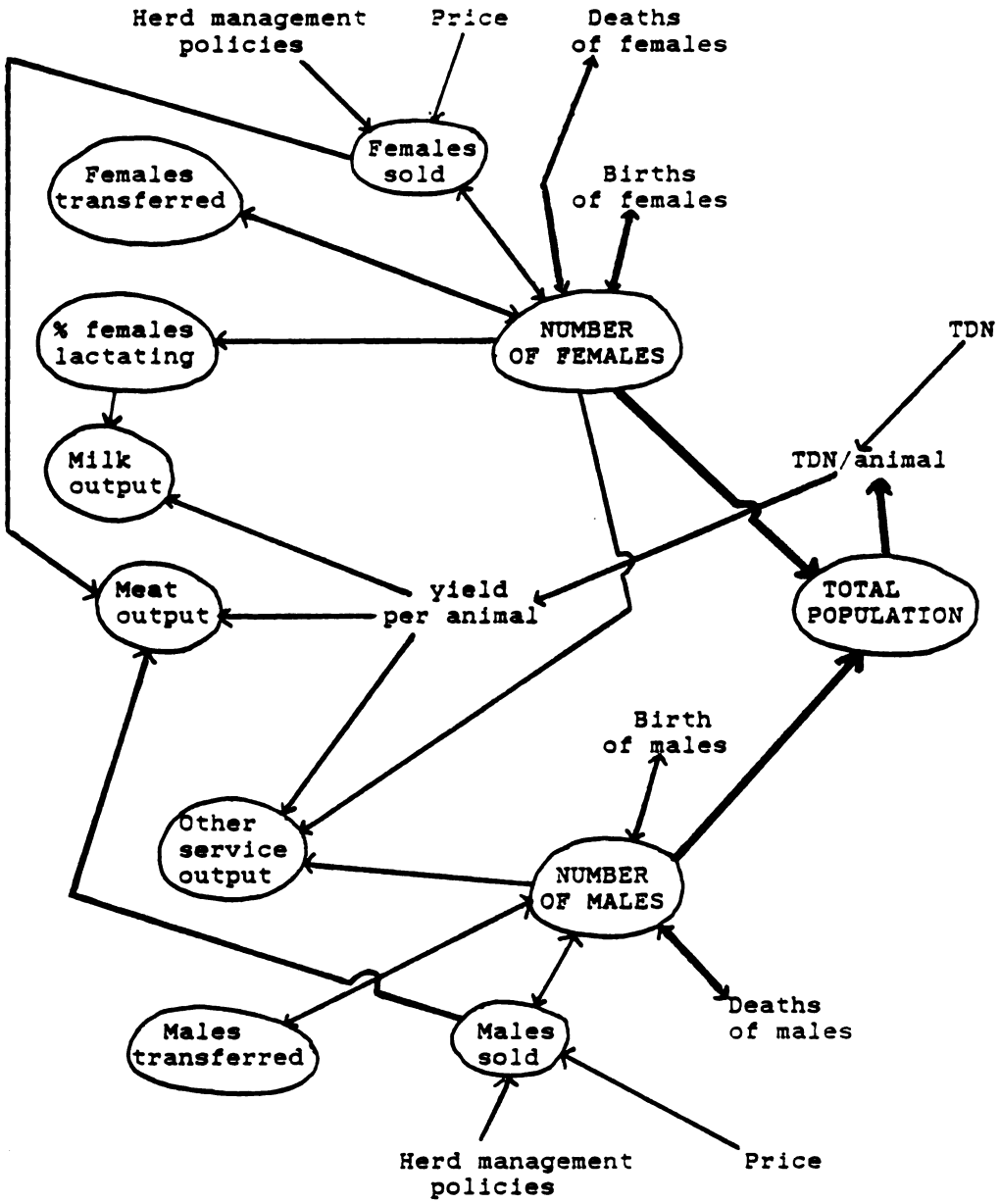


Figure 8. Causal map of cattle production (Adapted from Manetsch and al.,1971)

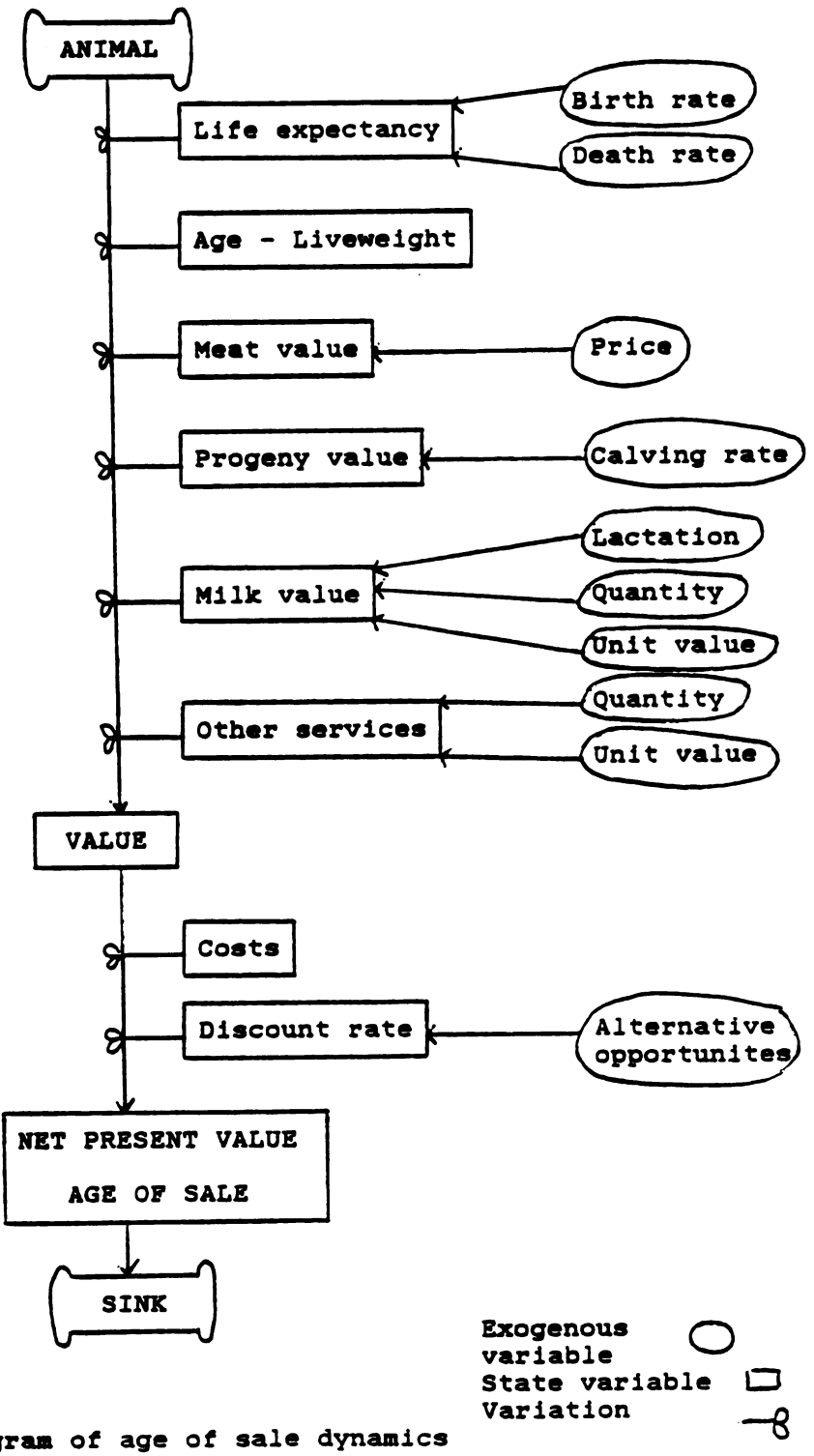


Figure 9. Diagram of age of sale dynamics

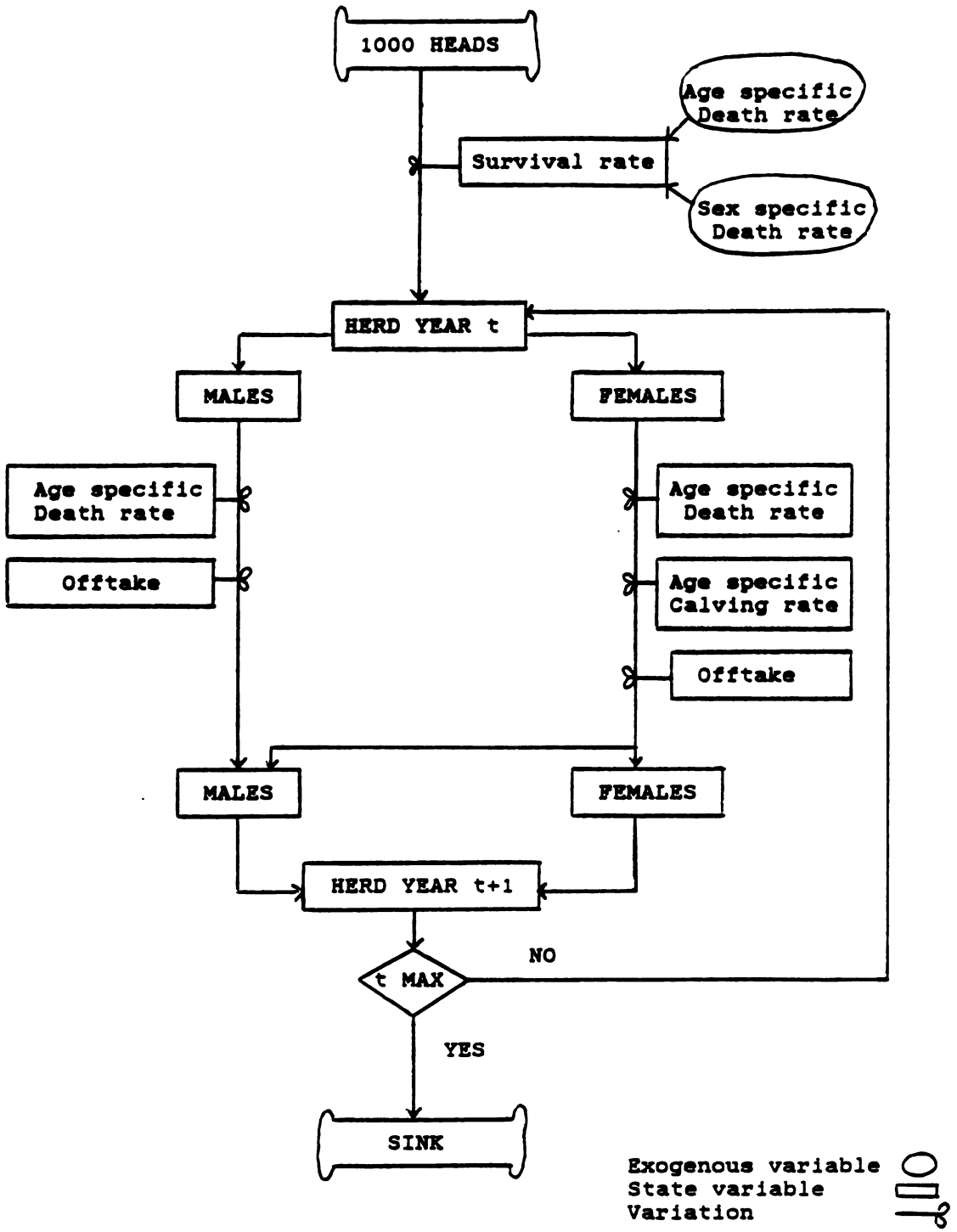


Figure 10. Diagram of herd dynamics

Footnote to Chapter V

Gompertz curve computation p. 86

$W_t = W_0 \exp.[b(1 - \exp.-mt)]$

W_t = weight at age t
W_0 = birth weight
W_A = adult weight or asymptotic mean weight

exp. = base of natural logarithm
IP = age at the inflection of the curve
$= \ln(b).m^{-1}$
(when dW_t/dt is maximum)
$b = \ln (W_A / W_0)$

m = rate of maturation; refers to growth rate relative to mature weight and is the rate of decline in the growth rate.

Let exp.-m = r

$W_t = W_0 \exp.b(1 - r^t)$

CHAPTER VI

RESULTS OF THE SIMULATION AND SENSITIVITY ANALYSIS

Optimal Age of Sale and Herd Structure

Base Analysis Results

Tables 12 and 13 present the year step results for both males and females based on the data in Chapter V. Figure 11 shows the graphical evolution of the net expected present values (EPV). The maximum EPV determines the optimum age of sale for a rational decision maker at :

- 4 years for a male
- 12 years for a female

The final herd equilibrium structure is after 25 years of simulation on the hypothetical population is the following:

- Males : 34% ; Females : 66%
- Male calves : 10% ; Female calves : 10%
- Young Males (1 to 4 years) : 24%
- Young females (1 to 4 years): 24%
- Adult females (up to 4 years): 32%

These results are relative percentages from the numbers generated and presented in the computer output in Appendix C.

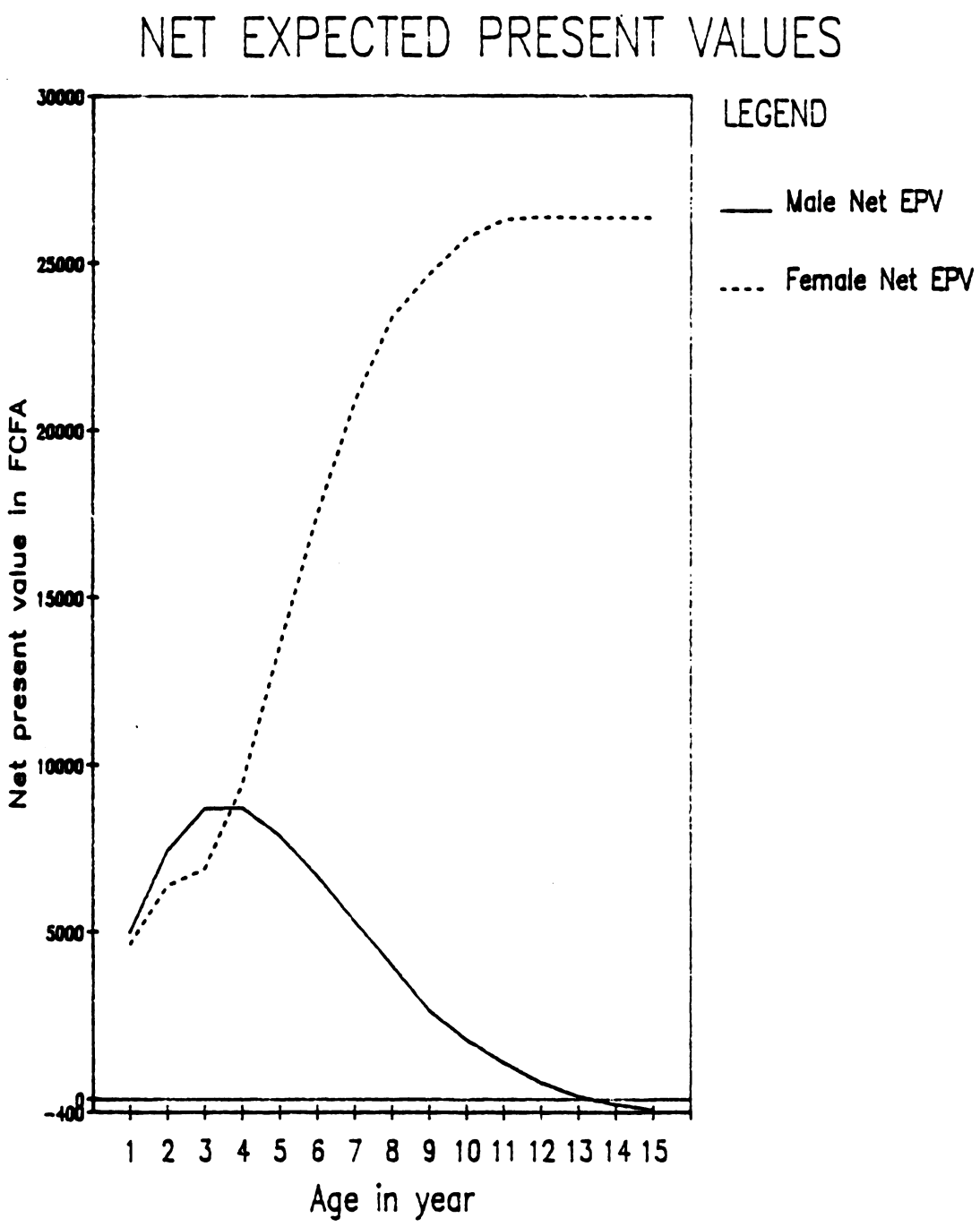


Figure 11. Net Expected Present Values

Table 13 . WEIGHTS AND EPV OF A MALE
(Base analysis results from 1 to 15 years)

Age (year)	Weight[a] (KG)	Meat Value (current)	Survival rate(%)	Life[b] expectancy(%)	NET EPV[c] (FCFA)
1	63	9384	.65	.65	4994
2	129	19327	.90	.59	7432
3	196	29387	.95	.56	8702
4	250	37473	.97	.54	8725
5	288	43146	.97	.52	7875
6	312	46822	.97	.51	6671
7	327	49096	.95	.48	5308
8	336	50465	.93	.45	4006
9	342	47858	.91	.41	2641
10	345	48303	.89	.37	1769
11	347	48563	.87	.32	1082
12	348	45235	.85	.27	475
13	349	41831	.83	.22	60
14	349	41875	.81	.18	-177
15	349	41900	.79	.14	-342

[a]. weights generated with a Gomperz curve
[b]. cumulative product of survival rates used to adjust costs and returns for mortality
[c]. Net EPV = PV at birth when animal sold at age i minus costs adjusted for time and mortality

NB: - Discount factor is 20%
- Current costs = 375 FCFA after year 1
- Epv = Expected returns minus costs

- Expected returns = current meat value*life expectancy *discount factor
- Costs = Current costs*life expectancy*discount factor

TABLE 14. WEIGHTS AND EPV OF A FEMALE
(Base analysis results from 1 to 15 years)

Year (Age)	Weight (KG)	EPV Components				
		Meat[a]	Milk[b]	Male[c] progeny	Female[d] progeny	NET[e] EPV
1	58	4641	0	0	0	4641
2	111	6545	0	0	0	6398
3	157	7172	0	0	0	6911
4	188	6826	2271	317	342	9403
5	207	5965	5878	820	1270	13509
6	217	4982	9220	1287	2586	17604
7	223	3980	11819	1650	3945	20868
8	226	3073	13798	1926	5176	23404
9	228	2153	15062	2103	5947	24679
10	229	1575	15983	2231	6591	25777
11	230	1124	16529	2307	6956	26299
12	230	727	16834	2350	7109	26394
13	230	456	16989	2372	7161	26346
14	230	303	17092	2386	7205	26350
15	230	196	17158	2385	7242	26342

[a].PV in FCFA of meat when cow slaughtered at age i

[b].PV of milk produced = Quantity*value*discount factor *probability of lactation
Probability of lactation = calving rate at age i *.5
0.5 represents the probability for a female of age i to have a normal lactation considering the high mortality rates from 0 to 2 years and the various post-partum problems that can occur

[c]. - PV of male progeny = sum of the maximum EPV of a male*cumulative probability of a male birth *discount factor to discount back to birth of the cow.
- Cumulative probability of a male birth = female life expectancy*calving rate at age i *sex ratio of .5 .

[d]. - PV of female progeny = sum of female calves present values over the reproductive life of the cow weighted by their corresponding mortality, calving rates, prices and discount factors.
- Sum of female calves PV = Total expected present value of a cow at birth - PV of meat, milk and male progeny.

[e]. - Net EPV = PV at birth - Costs discounted and adjusted for mortality.

Validation

According to Dent and Blackie (1979), the adequacy of a model should be seen in relation to its purpose and not from an absolute reference to the controversial notion of truth. Thus, the validation of a model should be based on an assessment of its prescribed use and a comparison of its performance either against recorded data with statistical testing or a subjective determination of what the output should be, given a broad understanding of the type of system represented by the model.

As shown in Chapter V, this work is entirely based on secondary information. Therefore, the validation is based solely on subjective assessments grounded in a critical appraisal of the secondary information reviewed. It is assumed that such information provides us with average values and realistic trends.

Among the data available, as much as possible has been drawn from the on-farm data collected by ISRA in a study of about 1000 head of cattle, grouped in 13 herds in the area of the Kolda research station. The conditions of the data collection and the lack of systematic statistical analysis require from us cautiousness in their use (Gueye, Ly and Diallo, 1981). Nevertheless, the data are considered to be valid in terms of a general description of the structure and composition of the herds.

The validation of the model is presented in two parts each related to one of the model's components.

Age of Sale Component of the Model

For the validation of the age of sale component, little data are available on the specific ages of cattle at their time of sale in the traditional livestock production systems in West Africa. In the literature reviewed, Shapiro (1979) and Ariza-Nino and Shapiro (1984) give a range of values that are the same than those produced with our model.

In its 1978-1980 study of 500 cases at the Kolda slaughterhouse, ISRA (1981) showed that 76% of the females slaughtered were above 8 years. Among them, 22% were from 8 to 10 years old, 18% from 10 to 12 years old and 36% above 12 years. The comparable data for males are 80% of males above 4 years. Among them, 50% were above 6 years. 60% were also castrates.

The data for the females are representative of management decisions leading to a high age of sale whose range is similar to the output of our model. In the case of the males, the data are quite different, with a higher age than that obtained with our model.

The position of Kolda in the marketing channel explains such results for the males. In effect, Kolda is not a terminal market for live animals. Therefore, young animals coming from the local herds are directed instead toward Ziguinchor, Tambacounda and even Dakar (SOMIVAC, 1982). In addition, there is an increasing use of animal

traction in Upper and Middle Casamance (Landais, 1984) and consequently, a relatively important supply of castrates and old males replaced after service. Thus, the ages of males slaughtered at Kolda are not representative of the age when cattle owners in the area destock usually. More accuracy could be reached with age data from the collection markets or from the arrivals at the markets supplied by the region of Kolda.

Finally, the validation of the age of sale component of the model is directly related with that of the herd structure component. Relatively more accurate data are available on the herd structure. Thus, since the age of sale as a management decision has direct effect on the herd structure, the validation of the herd structure component contributes to the validation of the age of sale component.

Herd Structure Component of the Model

The time path of the animal's use and the transaction strategy of the livestock owner determine the time path of the total herd structure and composition, but the reproduction and mortality parameters are also decisive variables. Therefore, the validation of the herd structure component verifies the reliability of the age output but also allows to check the validity of the assumptions made to describe the production system and some biological parameters, in particular, the age and sex

specific parameters.

Tables 15,16 and 17 present the relative values derived from the output, on the one hand, and the secondary information available on the herds in the area under investigation on the other hand.

The sex composition and age distribution computed from the model output are very close to the comparative data present in the literature. However, a significant discrepancy appears for the production parameters. The results of the model are lower. Further research is needed in this domain since we did not find in the literature current levels for those parameters. In fact, the studies found refer to predrought 1970 conditions (SEDES, 1975) and "normal times"(Shapiro, 1979). The description of the Senegalese livestock subsector in Chapter II shows, however, that the trends have changed since 1970 with more perturbations and a generally lower productivity. Thus, it is very probable that the offtake suffers from conservative attitudes of the herders. Furthermore, the growth of the herds remains low as the rebuilding processes have been constrained by the successive contractions in numbers in a decade of unfavorable ecological and climatic conditions.

Besides the comparisons of the model output with data from the real world, the model is also judged in the following sensitivity analysis.

Table 15. HERD STRUCTURE : SEX COMPOSITION
(Model output in year 25 and comparative data)

Sex	Model output (%)	ISRA (%)	SEDES (%)
Males	34	32	30
Females	66	68	70
Total	100	100	100

SOURCE : ISRA (1980) ; SEDES (1975)

Table 16. HERD STRUCTURE : AGE COMPOSITION
(Model output in year 25 and comparative data)

Age groups	Model output (%)	ISRA (%)	SEDES (%)
Male calves	10	12	12
Female calves	10	13	12
Males (up to 1 year)	24	19	18
Females (1 to 3 years)	24	15	16
Females (4 to 10 years)	27	34	}42
Females (above 10 years)	5	7	}

SOURCE : ISRA (1980) ; SEDES (1975)

Table 17. PRODUCTION PARAMETERS
(Model output in year 25 and comparative data)

Parameters	Model output (%)	SEDES (%)	Shapiro (%)
Offtake	8	11.5	11 - 13
Growth	1.3	1.5	2 - 3
Productivity	9.3	13	13 - 16

SOURCE : SEDES (1975) ; Shapiro (1979)

Sensitivity Analysis

The sensitivity analysis is a systematic evaluation of how the optimal solutions change with changes in the input data. It permits us to check the internal coherence of the model and to determine the effects of technical and economic parameter changes, especially those that are crucial to the model. In addition, the sensitivity analysis allows an evaluation of investment returns and parameter improvements by comparing the resulting net EPV with the base analysis considered as a 'without project intervention' situation.

In the following section, parameters are studied according to two categories : technical parameters and economic parameters.

The technical parameters are the mortality and calving rates, the birth and adult weights, the age at the inflection of the growth curve, the quantity of milk produced and the probability of lactation. Various interventions can change their levels. Research in animal health, nutrition and reproduction can lower the mortality rate and heighten the calving rate. Genetic selection can also influence the growth pattern and the lactation characteristics of the breed, although with a longer time frame.

The economic parameters are the prices of live animals and milk and the costs of maintenance and production set by the markets or fixed by the government.

The discount factor is studied in this category. The animals' EPV are always adjusted for mortality and other costs.

Internal Consistency of the Model

In this part, different levels of relative values are generated from the base analysis input and output data. Then they are compared with the initial values. Such an approach allows us to verify the internal logic of our model by checking the results with what may be expected theoretically in terms of directions of changes. In addition, this leads also to a better understanding of the decision-making process, the herd structure and the herd growth pattern, with the capital theory acting as the supporting economic framework.

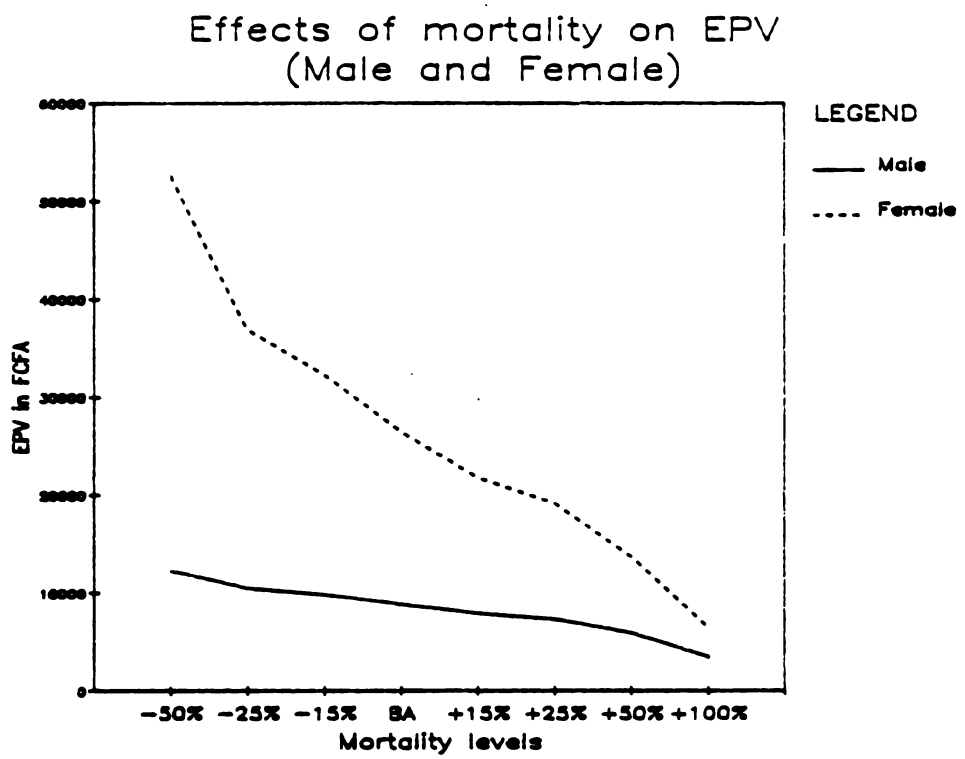
It is, however, necessary to indicate that the analysis is made in terms of relative changes from the base analysis even though that leads to some absolute values that are unrealistic for the area of study. Nevertheless, a comparison of each relative change with respect to the base analysis helps in a better understanding of the relationships and a determination of the parameters with the greatest impact on the dependent variables.

Mortality Rate Changes. Table 18 and Figure 12 present the results from relative changes in the mortality rate for each age class and sex. As the mortality rate decreases for each age class and sex, the maximum EPV and optimal age of sale increase, as predicted theoretically. The important result is, however, that higher relative changes occur with the female because there are cumulative effects of the mortality rates in the own age class of the cow and those of all its offspring.

Calving rate changes. Table 19 and Figure 13 present the results of the relative changes in calving rates. The maximum EPV and the optimal age of sale change in the same direction as the age specific calving rates. Furthermore, very rapid relative increases in EPV occur at high calving rates since more offspring enter in the valuation of the cow.

Identical trends would happen if the quantity of milk produced and the probability of lactation were varied.

Price and Cost Level Changes. Table 20 and Figure 14 present the results of the relative changes in the levels of liveweight prices. Prices, EPV and age move in the same direction. It is also very interesting to observe that the relative changes of male EPV are proportional to the price changes and the age remains at 4 years. Such a trend suggests that liveweight prices are



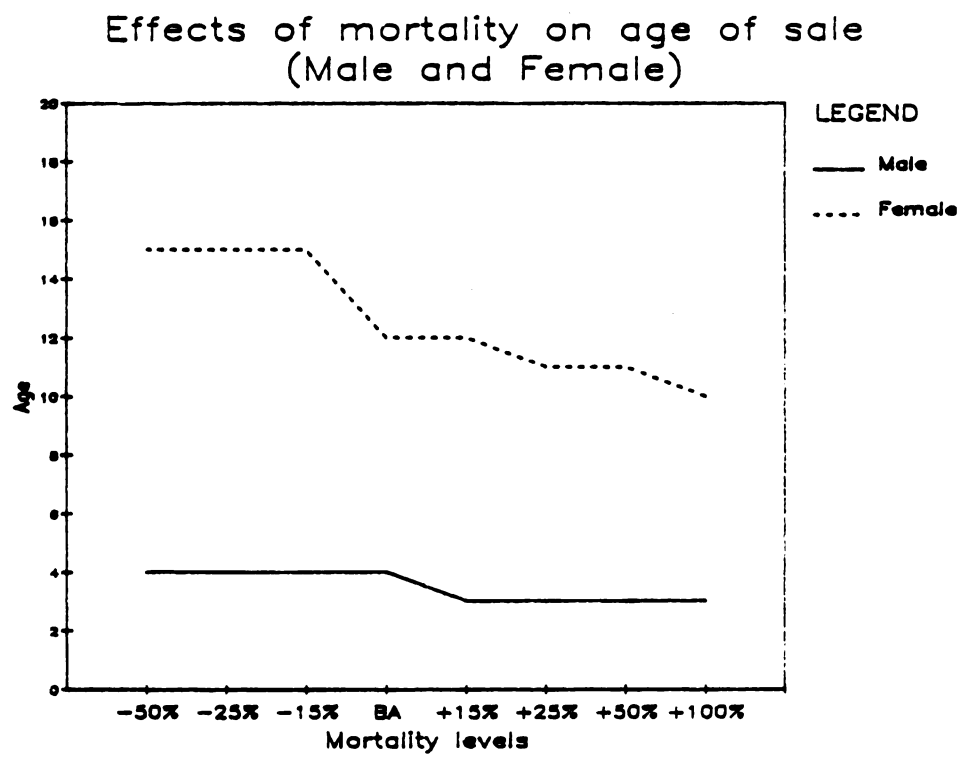
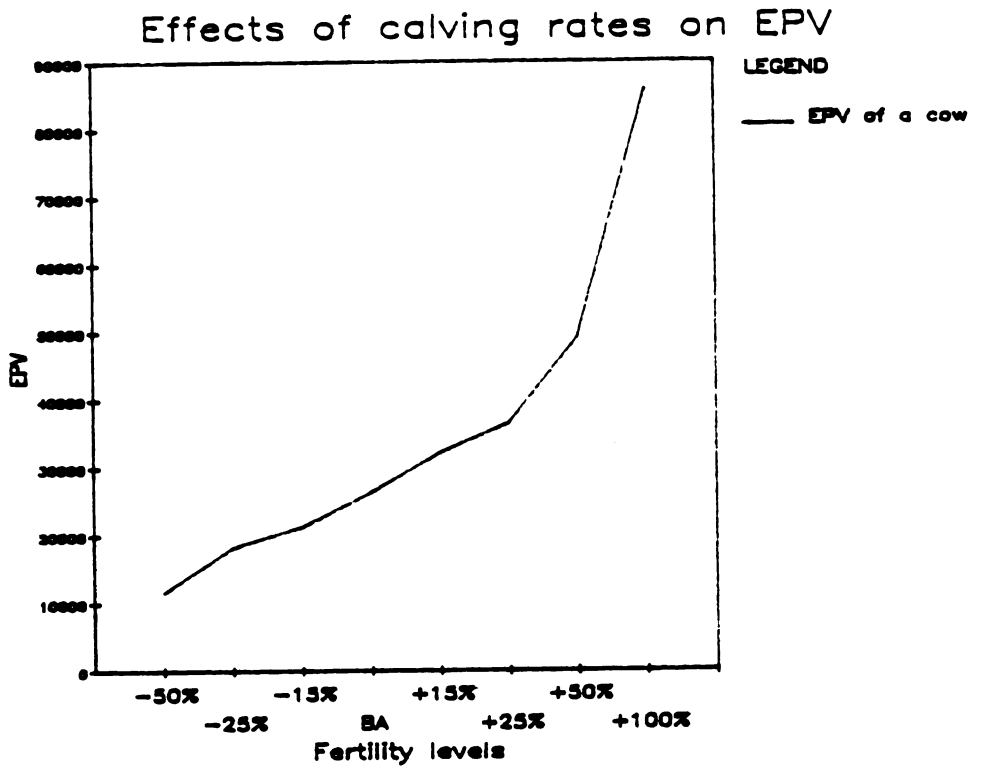


Figure 12. Effects of Mortality Rates



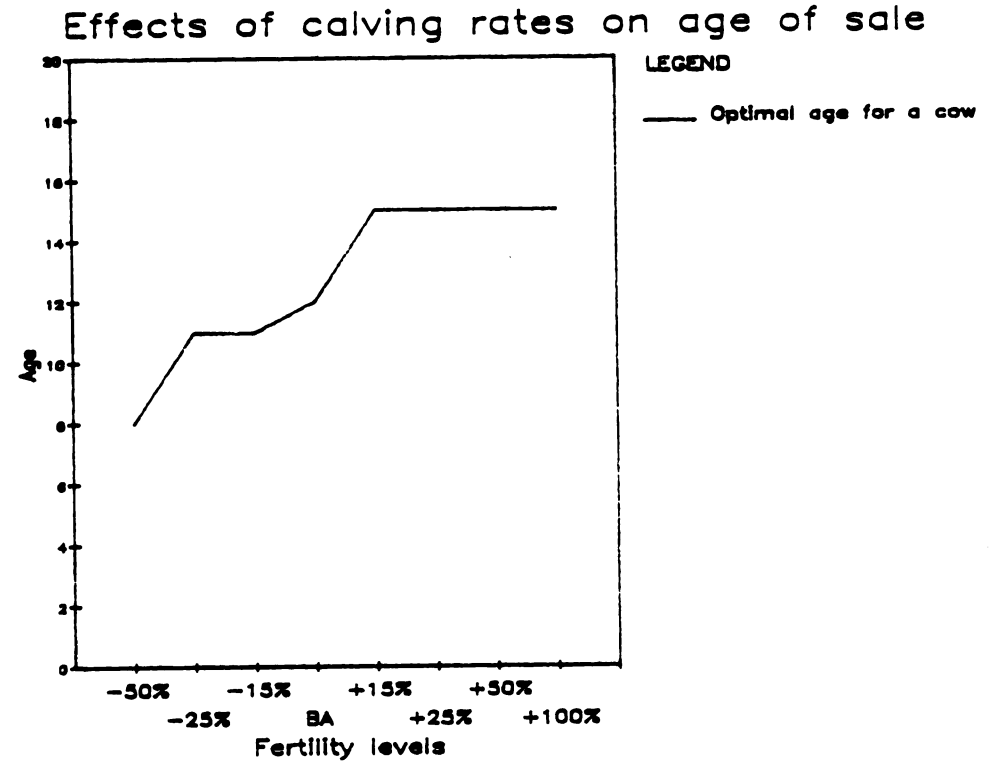
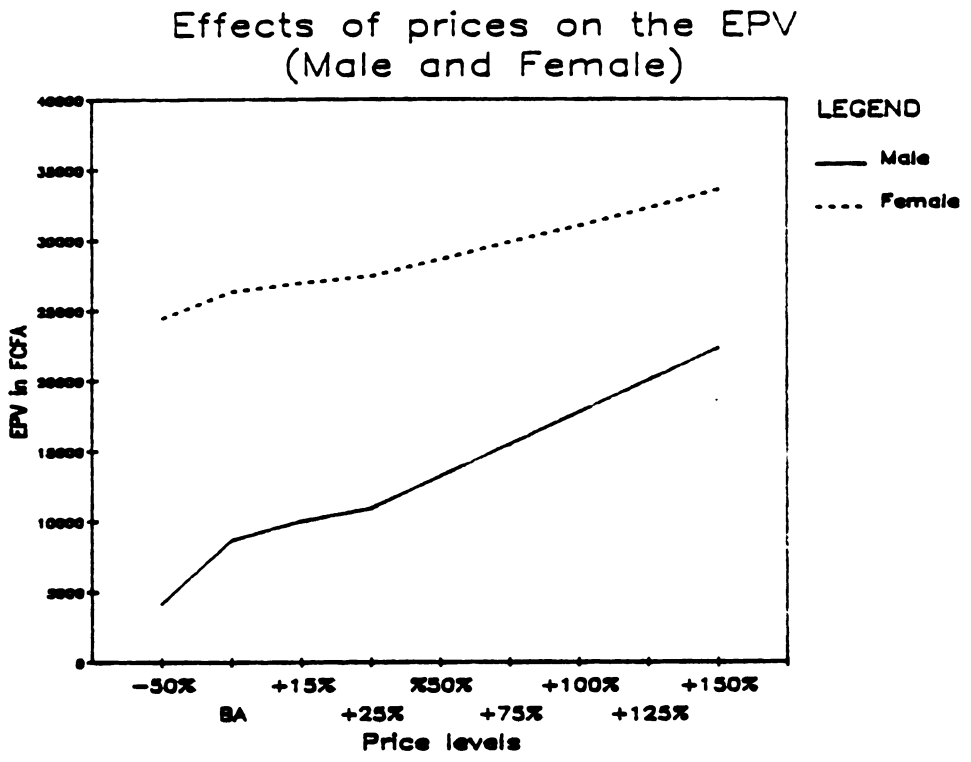


Figure 13. Effects of Calving Rates



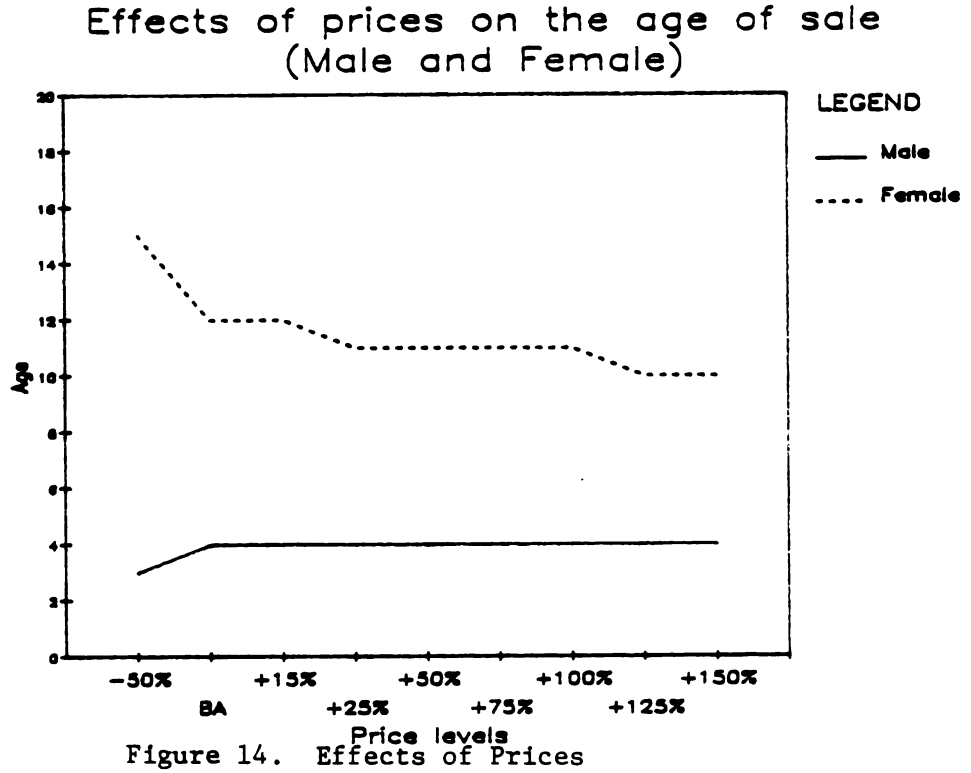


Figure 14. Effects of Prices

Table 18. EFFECTS OF MORTALITY
(Relative changes in optimal age of sale and maximum EPV)
(Males and Females)

Mortality[a] levels	Male			Female		
	Age (year)	EPV (FCFA)	Relative change	Age (year)	EPV (FCFA)	Relative change
-50%	4	12192	+40%	15	52449	+99%
-25%	4	10392	+19%	15	36873	+39%
-15%	4	9709	+11%	15	32193	+22%
0%[b]	4	8725	0%	12	26394	0%
+15%	3	7802	-11%	12	21707	-18%
+25%	3	7223	-17%	11	19062	-27%
+50%	3	5845	-33%	11	13663	-48%
+100%	3	3379	-61%	10	6429	-75%

[a]. Mortality rates for the base analysis are in Table 9.
[b]. Base analysis level from which the relative changes are computed.

Table 19. EFFECTS OF CALVING RATES
(Relative changes in optimal age of sale and maximum EPV)

Calving rate levels[a]	Age(year)	EPV(FCFA)	Change
-50%	8	11662	-56%
-25%	11	18256	-31%
-15%	11	21309	-19%
0%[b]	12	26394	0%
+15%	15	32213	+18%
+25%	15	36537	+38%
+50%	15	49111	+86%

[a]. Calving rates for the base analysis are in Table 10.
[b]. Base analysis level from which the relative changes are computed.

not the major determinant in the optimal age of sale for the males, given the data used.

In the case of the females, the relative changes in EPV are much lower than the price level changes, and the optimal age has an opposite trend with respect to prices. This suggests that, as the meat value increases, the producer might consider more sale options of younger cows, although their EPV is less sensitive to liveweight prices. This can lead to important policy considerations with respect to the role of prices on the nature of the herd (cow-calf or fattening).

Tables 21 and 22 show percentages that result from comparisons of relative values with the original level of cost and price of milk. From them, the effects of wrong assumptions on those two parameters can be checked.

The movements of costs are in the opposite direction of those for the EPV, as expected. But, with the structure of costs used, it appears that they are so low that, after adjustment for time and mortality, they have a minor effect on age of sale and EPV.

As was true for the liveweight prices, the milk price also varies in the same direction as the EPV. Changes in the EPV are roughly proportional to changes in the milk price. In addition, the higher the milk price gets, the later is the cow culled.

Table 20. EFFECTS OF LIVEWEIGHT PRICES
(Relative changes of optimal age of sale and maximum EPV)

Price[a] levels	Male			Female		
	Age (year)	EPV (FCFA)	Relative change	Age (year)	EPV (FCFA)	Relative change
-50%	3	4220	-52%	15	24502	-7%
0%[b]	4	8725	0%	12	26394	0%
+15%	4	10086	+16%	12	27045	+2%
+25%	4	10994	+26%	11	27497	+4%
+50%	4	13263	+52%	11	28695	+9%
+75%	4	15532	+78%	11	29893	+13%
+100%	4	17801	+104%	11	31091	+18%
+150%	4	22340	+156%	10	33629	+27%

[a]. Liveweight prices are presented in Table 11.
[b]. Base analysis results from which the relative values are computed.

Table 21. EFFECTS OF COSTS
(Relative changes of optimal age of sale and maximum EPV)

Cost level level[a]	Male			Female		
	Age (year)	EPV (FCFA)	Relative change	Age (year)	EPV (FCFA)	Relative change
-100%[b]	4	9077	+4%	12	27380	+4%
0%[c]	4	8725	0%	12	26394	0%
+50%	3	8571	-2%	12	25909	-2%
+100%	3	8440	-3%	12	25432	-4%

[a]. Initial costs are set at 375 FCFA (Chapter V)
[b]. Costs are equalised to zero to see the results of such an assumption
[c]. Base analysis

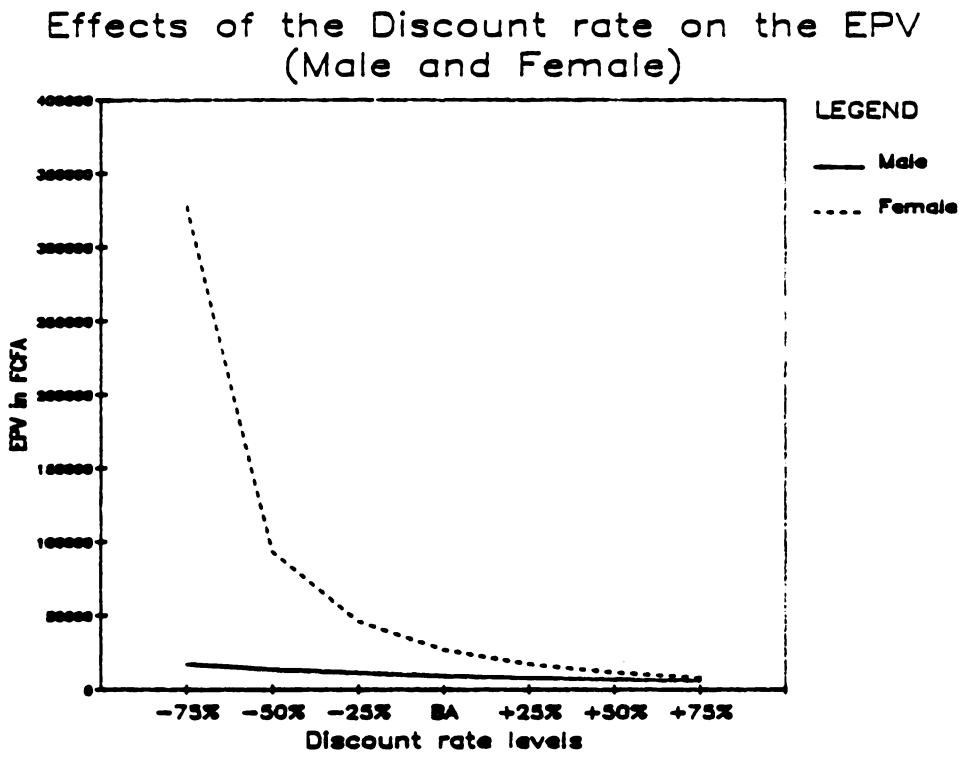
Table 22. EFFECTS OF MILK PRICE
(Relative change of optimal age of sale and maximum EPV)

Price per litre absolute	relative	Age (year)	EPV (FCFA)	Relative change
50 FCFA	-60%	10	12892	-51%
100 FCFA	-20%	11	21805	-17%
125 FCFA[a]	0%	12	26394	0%
150 FCFA	+20%	15	31072	+18%
200 FCFA	+60%	15	40533	+54%

[a].Base analysis price

Rate of interest changes. In the data section, the assumption of .20 was made for the discount rate. With the study of the effects of different levels of discount rate, it is possible to check for biases introduced by over- or underestimation of the discount rate. Table 23 and Figure 15 show the results with different discount rates.

A noticeable sensitivity is found for the model output with respect to changes in the discount rate. In fact, the discounting is fundamental in the capital theory framework where cattle are considered as capital goods. This is particularly true for the females since their offspring themselves also produce capital goods.



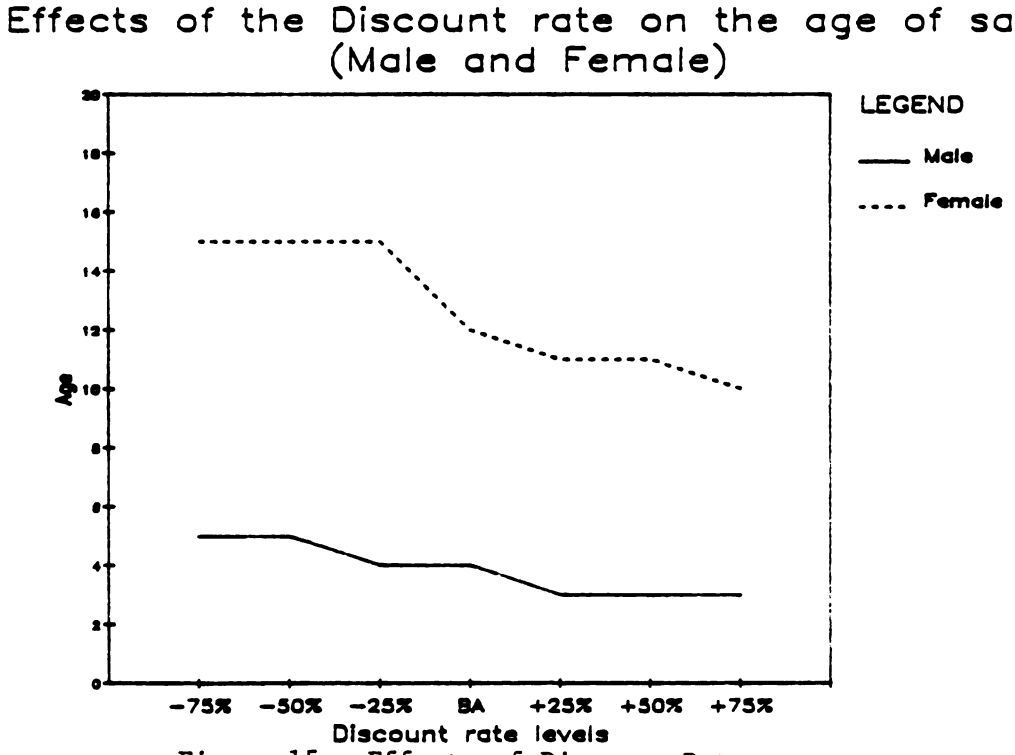


Figure 15. Effects of Discount Rate

Table 23. EFFECTS OF THE DISCOUNT RATE
(Relative changes of optimal age of sale and maximum EPV)
(Males and Females)

Discount rate[a] level		Male			Female		
Abs	Rel	Age (year)	EPV (FCFA)	Relative change	Age (year)	EPV (FCFA)	Relative change
10%	-50%	5	13096	+50%	15	93343	+254%
20%	0%[b]	4	8725	0%	12	26394	0%
30%	+50%	3	6435	-26%	11	11205	-58%

[a]. absolute value and relative value
[b]. base analysis

The study of the internal consistency of the model provides us with indications on the directions of changes and the relative effects of various parameters when compared with the base analysis. It is, however, necessary to evaluate some changes under more practical circumstances and simulate more realistic situations with the available information on prices and costs.

Evaluation of Livestock Development Interventions

It is crucial to appraise the impact of investments that can affect the technical parameters and of changes in the economic parameters. The determination of how these investments and changes affect profitability enable us to identify livestock development interventions that can lead livestock producers to make decisions that are consistent with the policy goals set by policy makers.

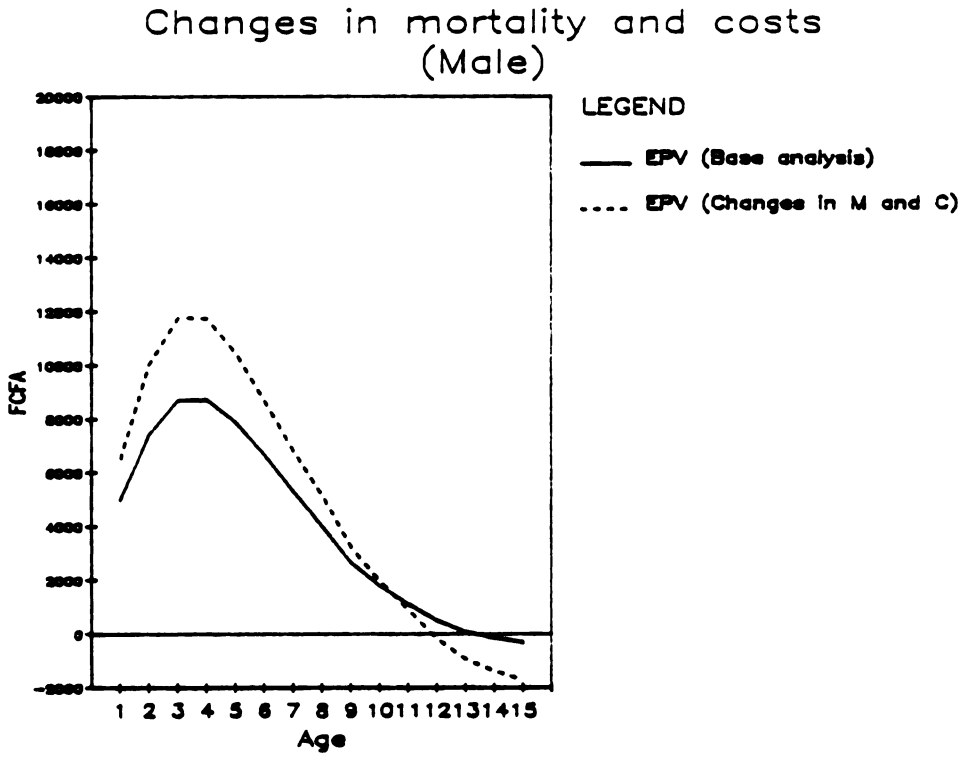
In this study, the data do not permit us to procede with a systematic cost-benefit analysis, i.e, to compare, over time and with respect to known circumstances, the costs of investments and policy changes with their associated returns. Such an analysis would require more precise data, especially for the productivity parameters in the herd and their relation with each age and sex category, the costs without and with the new production conditions and the new production or input-output coefficients.

Therefore, in terms of an operational use of the model in the conditions of the Ndama production system of Upper Casamance, the following evaluation is limited to a comparison with the base analysis of the relative changes in net expected present values generated by changes in selected economic and technical parameters compared. This provides us with lower- and upper-bound estimates about the results of major livestock development actions.

Changes in Mortality and Costs. One of the primary development actions is to reduce the mortality rates by providing better health care and an easier access to veterinary inputs and services. The overall mortality rate of 12% can be reduced by 50% with a systematic intervention on the calves which currently have a mortality rate around 35%. Such a goal would require an annual cost evaluated at 1000 FCFA per animal. This cost is considered as an average cost for a normal preventive and curative maintenance. In addition, the maximum cost that a livestock owner could incur in reducing herd mortality and still break even is calculated. The procedure used to determine the maximum affordable costs involves finding the difference between the Net EPVs in the base analysis and after the change in mortality, and then expressing this difference as an annual benefit. This is done by dividing the difference between the net EPVs by the present worth of an annuity factor corresponding to the number of years equal to the optimal age of sale after the change and a discount rate of 20%.

The new age-specific mortality rates used are from 1 to 15 years, respectively : .15, .04, .03, 5*.02, .03, 0.05, .07, .09, .07, .09, 3*.10. They are represented in Figure 3.

The results are in Table 24. Their graphical representation is in Figure 16.



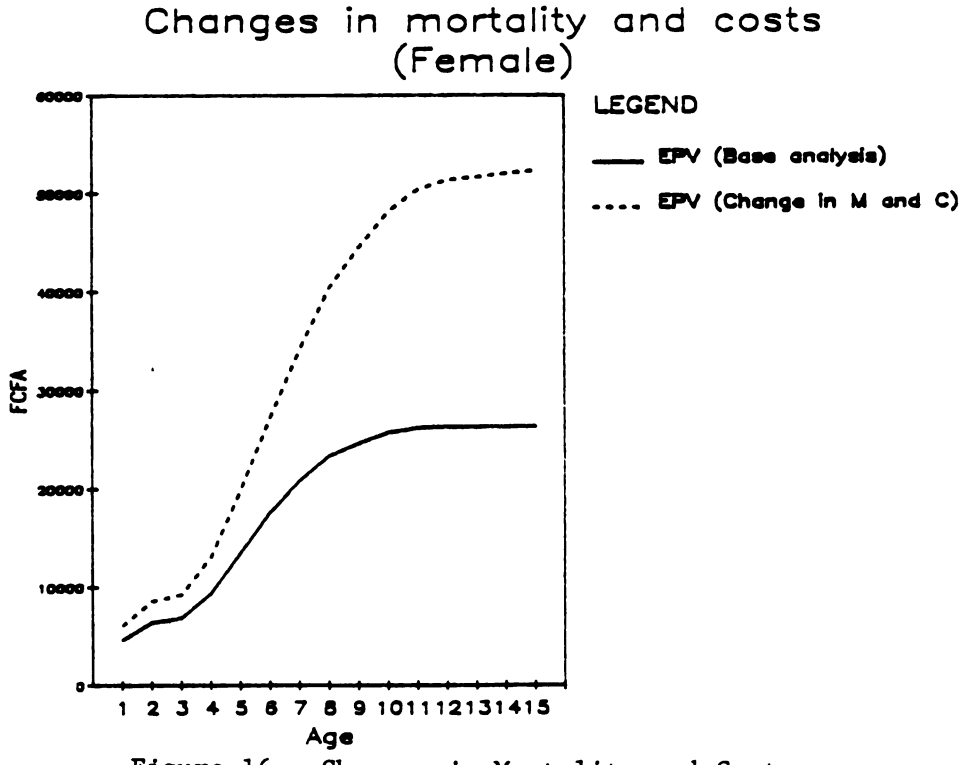


Figure 16. Changes in Mortality and Costs

Table 24. CHANGES IN MORTALITY AND COSTS
(Male and female)

Results[a]	Male	Female
Optimal age of sale	3	15
Base analysis age	4	12
Maximum EPV[b]	11784	52368
Relative change in EPV	+35%	+98%
Maximum affordable costs[c]	1452	5562

[a]. Age in year and EPV in FCFA
[b]. After changes in costs and mortality rates
[c]. Maximum current costs in FCFA that a livestock owner could afford to pay for this reduction in mortality and still break even.

There is a significant increase in net EPV for both sexes, with almost a doubling of the net EPV of females. Such results suggest that a provision of 1000 FCFA per animal for health expenditures is profitable if the overall mortality rate is decreased by 50% and ceteris paribus. For the age of sale, there is an increase for the female as expected but for the male the optimal age decreases relative to the base analysis. Such a result should not be considered as an inconsistency in the model since the net EPV in year 3 (11784 FCFA) is very close to that in year 4 (11731 FCFA). Therefore, it can be assumed that there is a same optimal age of sale for the male.

Changes in Calving Rates and costs. The calving rate is also a critical technical parameter. Its improvement is at the core of development efforts in the livestock subsector. Such an improvement requires, however, substantial investments in animal health, feed for the cows and equipment for good calving conditions.

The cost structure presented by SODESP in its interventions in the Sylvopastoral region can be used as good estimates of costs in an extensive production system with some actions for its development. However, an adjustment is made when analyzing costs in southern Senegal, where costs related to emergency feedstuffs are not likely to be faced.

For the sensitivity analysis, we use the following annual cost structure:

Groundnut cake 75 FCFA/KG * 75KG	.....	5625 FCFA
Minerals and vitamins 250 FCFA/KG * 10KG	.....	2500 FCFA
Veterinary care	.....	375 FCFA
Equipment	.....	1000 FCFA
TOTAL (per animal and per year)	.....	9500 FCFA

First, 9500 FCFA are used to follow the SODESP estimations of complement feed needed by a productive cow. Then, the figure is lowered to 3500 FCFA by reducing the minerals and vitamins by half and the groundnut cake from 75 KG to 30 KG. This is done to obtain much lower estimates for the feed needed to complement the natural

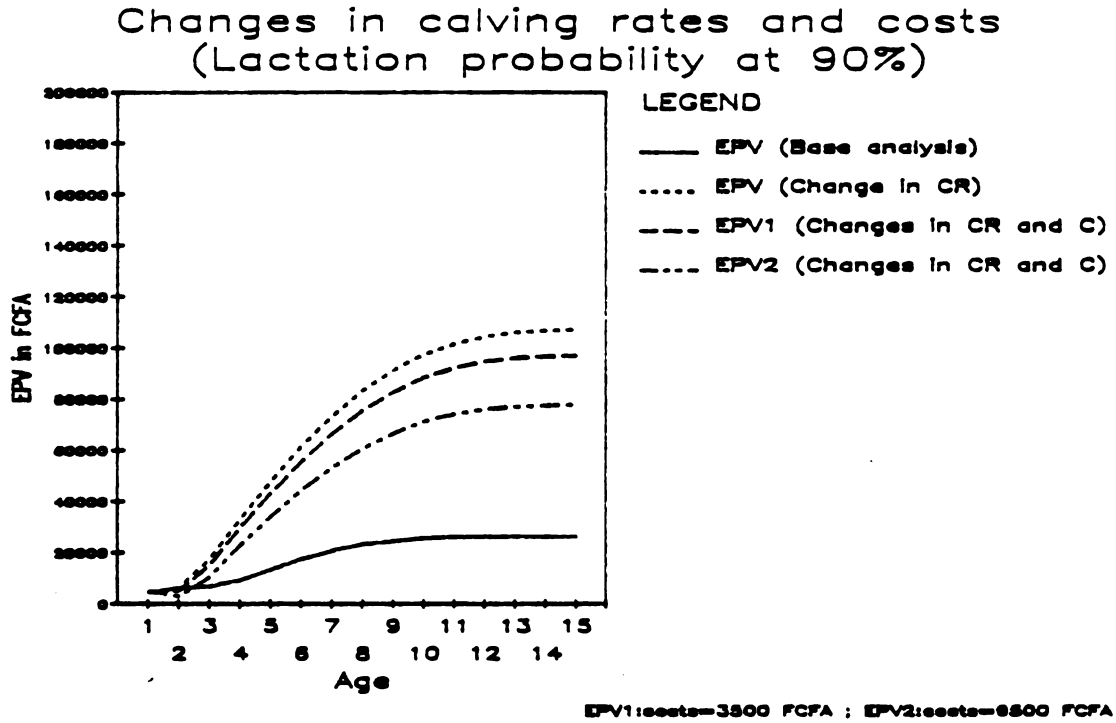
pastures.

Better health and adequate nutrition lead to an immediate improvement in the 'luxury function' that is the reproductive capacity of the cows. In the simulation run, the overall calving rate is increased from 50% to 70%.

The new age-specific calving rates from 4 to 15 years:.50, 7*.80, .70, .60, .50, .40. They are represented in Figure 4.

The analysis is made for two probabilities of lactation (50% and 90%) so that, indirectly,a decrease in calf mortality be introduced. Following the procedure explained earlier, the maximum current break-even costs for each interventions are also calculated.

The results are presented in Table 25. Their graphical representation is in Figure 17. In each case, there is an important relative increase in the net EPV of the cow,with a quasi explosive change when the probability of lactation is at 90%. The maximum affordable costs are also very high and suggest that expensive investments for changes in calving rates could be profitable. Also, the results suggest that substantial returns are possible when the calving rate is improved only by 20%, even with high costs. Important gains can also be expected when, at the same time, the mortality of calves is reduced. All results are, however, ceteris paribus.



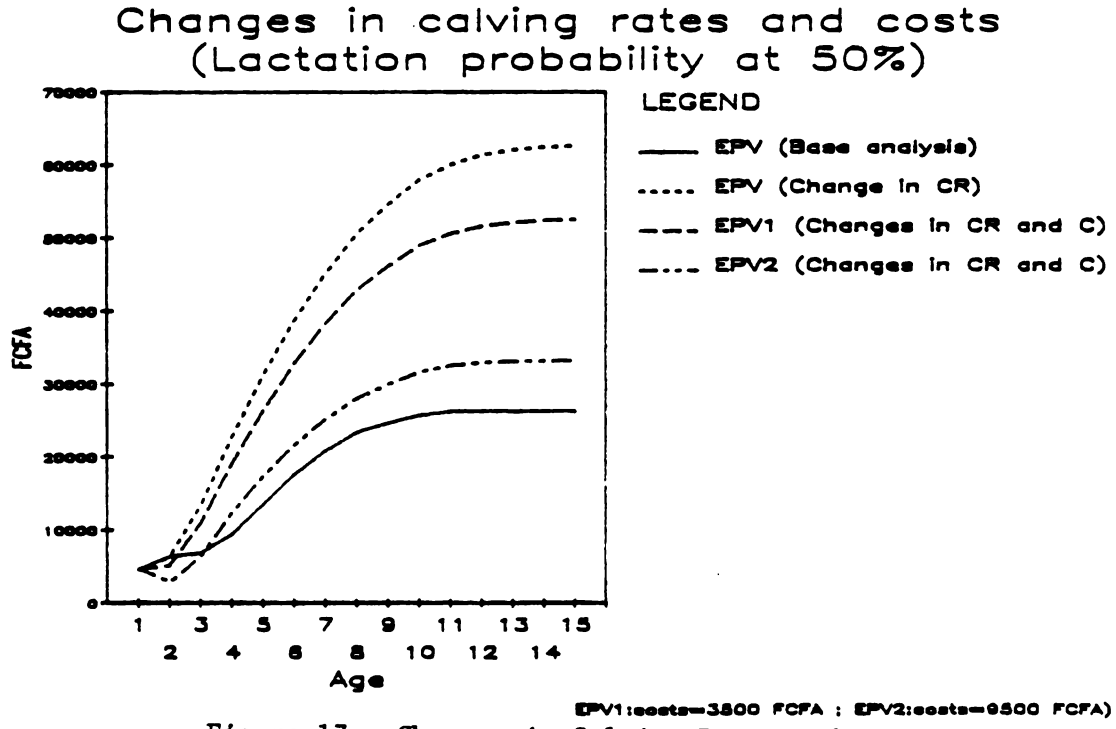


Figure 17. Changes in Calving Rates and Costs

Changes in Price and Cost Structures. Among the economic parameters, prices are considered as decisive in the determination of farmer decision-making. The following analysis is based on the price and cost structures used by SODESP for the cow-calf herds in the Sylvopastoral region.

This allows us to examine the likely effects of a development agency aiming at a reorganization of the structure of the herd in the area of study, according to the stratification framework.

For such a framework, males should be sold around one year and directed to growing-out areas. Also, females should be culled when their productivity goes down, around 10 years. These goals are expected to be realised thanks a differential pricing of animals, according to age and sex.

The prices used for this section are:

-263 FCFA/KG liveweight for one-year-old male calves. This price is the average price for the four different categories of calves set by SODESP:

-200 FCFA/KG liveweight for two-year-old steers;

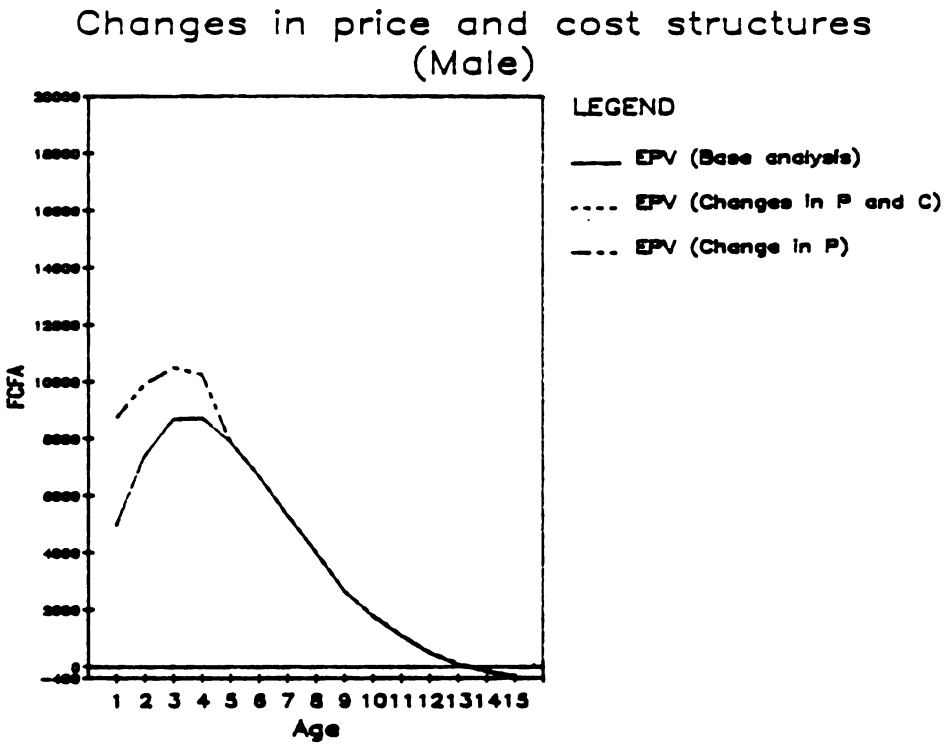
-180 FCFA/KG liveweight for three-year-old steers;

-175 FCFA/KG liveweight for four-year-old bulls; and,

-125 FCFA/KG liveweight for cows culled after 10 years.

For the categories other than those noted above, the estimated market prices listed in Table 11 are used.

The results are presented in Table 26 and graphically in Figure 18.



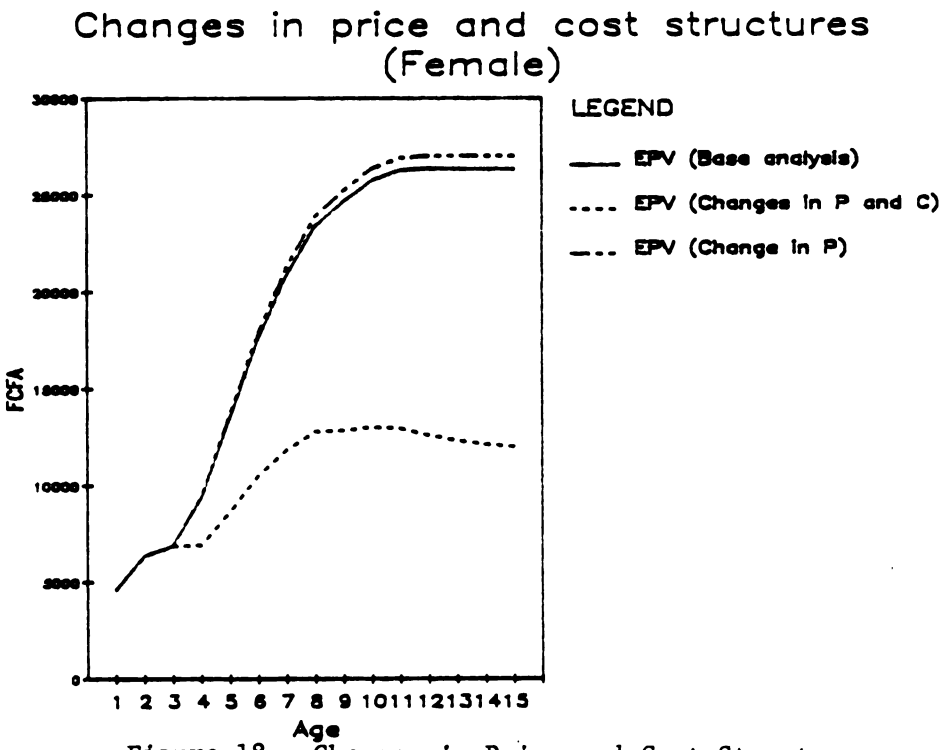


Figure 18. Changes in Price and Cost Structures

Table 25. CHANGES IN CALVING RATES AND COSTS

Results[a]	50% lactation			90% lactation		
	cost1	cost2	cost3	cost1	cost2	cost3
Optimal age	15	15	14	15	15	15
Maximum EPV[b]	62683	52607	33311	107275	97199	77854
Relative change in EPV	+137%	+99%	+26%	+306%	+268%	+195%
Maximum affordable current costs[c]	7762	5607	1500	22383	15147	11007

[a] Age in year and EPV in FCFA
[b] After change in calving rates
[c] Maximum affordable costs in FCFA

N.B :- cost1 in Base analysis= 375 FCFA; cost2 = 3500 FCFA; cost3 = 9500 FCFA
- Cost changes only for females
- Calving rate runs are made from 4 to 15 years with no change for the age at first gestation

Table 26. CHANGES IN PRICE AND COST STRUCTURES (Male and Female)

Results[a]	Male	Female	
	cost1	cost1	cost2
Optimal age	3	12	10
Maximum EPV[b]	10494	27046	13041
Relative change in EPV	+20%	+2%	-50%

[a] Age in year and EPV in FCFA
[b] After changes

N.B: cost1 in base analysis = 375 FCFA; cost2 = 9500 FCFA

In the case of the male, the price differential is not sufficient to reduce the optimal age of sale to one year. In contrast, for the old cows, the price offered leads to an optimal age at 10 years. However, this happens to lower herders' returns since the base analysis EPV is greater. Therefore, an increase in price alone, with the given cost structure and ceteris paribus, would not be profitable for the herders.

In conclusion,the results of the sensitivity analysis in its two parts suggest important research implications that are examined in the following chapter.

CHAPTER VII

RESEARCH IMPLICATIONS AND SUMMARY

Introduction

The microeconomics of livestock owners' behavior suggests important research needs. The results provided by the sensitivity analysis indicate particular relationships among technical and economic parameters that have different effects on the optimal age of sale and the net expected present values of both males and females.

Further research is needed using more reliable data to verify the directions of changes and relative results indicated by our initial analysis. Moreover, the study is limited to cattle production because not enough data are available for the other types of livestock. There is a great need to complete the analysis by extending it to small ruminants, especially goats, which are considered as having the greatest potential in small mixed farming systems. Therefore, it is crucial to get more specific information on the different uses, costs and returns from livestock in mixed enterprises with crops. This will allow a better representation of the production context and trade-offs for an optimal allocation of resources.

In addition, the trends in the Senegalese livestock

subsector, as described in Chapter II, create an urgency for sound policy actions. The role of the Senegalese research institutions is fundamental in guiding the policy process. With regard to such a situation, it is important to allocate research resources in a productive and efficient way. By providing a framework that includes economic and technical parameters, the capital theory approach contributes to a better understanding of the development needs in the livestock subsector and of the data needed to help formulate sound livestock policy.

In the following section, the Senegalese research context is described, and then the problems that might be faced in the research process are examined. In addition, a synopsis of research priorities according to the farming system research methodology is presented. Finally, a summary of the study is provided.

The Senegalese Research Context

Reviewing technology development and adoption rates in various developing countries, Eklund (1983) concludes that the adoption of new technology in peasant agriculture remains lower than expected due to biases in the conduct of research and technology prescriptions by the national research systems. Furthermore, in many instances, insufficiencies in the conduct of research have played a greater role than external and economic factors such as price structures or lack of efficient agricultural

support services.

In particular, socioeconomic research is plagued with problems related to data availability and reliability (Hardaker, 1979). To solve these problems, greater emphasis is placed on on-farm adaptative research and the farming systems research methodology (FSR) (Eicher and Baker, 1982; Byerlee and al., 1982; Eklund, 1983).

In Senegal, since 1982, there has been a general reorganization and reorientation of the research activities in ISRA, with the application of the FSR methodology to the complex array of the Casamance agricultural production systems. However, despite the multidisciplinary approach of FSR, the livestock component of the farming systems studied has not been investigated, except ox-cultivation aspects and inventories of productive animals.

Also, the Bureau d'Analyses Macroeconomiques of ISRA (BAME) has pointed out the lack of studies on livestock production and the need to find a basis for an overall program by doing preliminary diagnostic studies of the organization, functioning and performance of the livestock marketing sectors and the incentive systems faced by livestock producers. This is particularly crucial currently because,as shown in Chapter II,research-based policy recommendations are needed to implement the Nouvelle Politique Agricole with respect to the livestock subsector (ISRA, 1984).

By mid-1985, a new FSR team will be created to study the production systems in Upper Casamance and Senegal Oriental. The focus of its work will be the pastoral systems and the livestock component of the farming systems that are predominant in those areas (Landais, 1984).

FSR and Livestock Production Systems

Despite its holistic philosophy, a major limitation of the FSR approach is its chief focus on cropping systems (Deans, 1981; FSSP, 1984; Bernsten and al., 1983; Bernsten, 1982). Also, in Senegal, after a long history of on-station and commodity research, there is a great need to encompass the Unites experimentales' conceptual approach for an integrated on-farm research that recognizes the true importance of livestock production in the farming systems.

According to Eicher and Baker (1982), in 1982 socioeconomic research on livestock production in Africa was at the same point where research on the economics of crop production was 20 years ago. Namely, many assertions were being made but they were backed by few facts. This is particularly true with research on the behavior of livestock holders.

"The causes for [such] oversight are numerous and subject to conjecture " say Mc Dowell and Hildebrand (1980, p.58). In terms of policy choices, they are

reflected in the overall emphasis on cash- and food-crop production to the detriment of livestock production. Also, more technical problems have been related to the nature of research on animals.

Particular attention is placed, in the next part of the paper, on the constraints related to on-farm research on animals and the means of tackling them for greater efficiency.

Specific Problems in Research on Animal Production

Animal-related research has higher costs than other forms of research. In addition, its economic benefits are slow to be realized due to reproduction and physiology constraints. Heady and Bhide (1983) show the difficulties in estimating livestock production functions in the context of the US livestock industries and the numerous questions remaining for the model specifications, algebraic forms and appropriate statistical procedures.

With the existence of dynamic processes, including continuous flows of inputs and outputs, there are high autocorrelation risks under the classical experimental designs. Furthermore, for crop research, there is a single or finite harvest time and all selections are made by the researchers, whereas, in animal research, it is the animal rather than the reseacher that controls the decisive variables of feed inputs (Heady and Bhide,1983).

In the context of small mixed systems or pastoral

systems, identical problems arise with added complexity (Fitzhugh, 1982; Bernsten, 1982; De Boer, 1983; Behnke, 1982). The considerable variations among small farms, herds and physiological status of animals; the lack of experimental control on inputs and outputs under farm conditions; and the very long time frame, with its high risk of experimental breakdown create usually unbalanced and non-orthogonal data sets. Such data sets must, then, be treated with generalized least-squares analyses (Fitzhugh, 1982). Very high coefficients of variation are usually obtained despite the efforts to standardize (De Boer, 1983).

One other major problem, which is found in cropping systems also, is the farmer's interference due to his/her own priorities and perception of the benefits from the experiment. In addition, because of the social role of cattle, there is often an "emotional relationship" that is another source of biases in the treatments.

> "Experience from on-farm cropping research provides some basis for resolving these research problems. However, much more experience is needed with the animal component [of mixed production systems]. While we can theorize as to what types of data or experimental data or analysis are appropriate, the best answers will come from experience."
> (Fitzhugh, 1982, p.16)

Thus, for greater realism, this study concludes with a synthesis and synopsis of the research steps and priority data that have been defined in the literature as necessary for successful research on livestock production

systems. In practice, the scheme will be applied differently in different areas, according to the research resources available and capabilities of the researchers.

Synopsis of Research on Livestock Production

The FSR basic framework used for cropping systems is generally accepted, even though its history is brief and little empirical evidence exists to show that it has been as successful as expected.

Under the name of pastoral systems research or livestock systems research, ILCA is trying, in various African locations, the FSR approach (De Haan, 1983; Bernsten et al.,1983). The objective is to develop methodologies, for specific ecological zones, that would guide and assist national research capabilities.

Table 27 is a synthetic summary of the stages in a livestock systems research project, inspired by the general FSR philosophy. In addition, an attempt is made to present an extensive list of data necessary for understanding a livestock production system in the context of the capital theory framework.

Among the data, those describing the social and economic roles of women have been often overlooked and need to be highlighted (Safilios-Rothschild, 1983; Broch-Due et al., 1981). This is important because policies,

Table 27. STAGES IN LIVESTOCK PRODUCTION RESEARCH

STAGES	OBJECTS OF OBSERVATION	COMPLEMENTARY MEANS OF OBSERVATION
1. Descriptive Stage		
	Stratification of the target system	Secondary information
	Natural, livestock and human resources - Ecological situation - Biomass species and composition - Water, vegetal, feed availability - Herd size and structure, sex and species ratios, stocking rate, productivity and trends - Population parameters, cultural background	Soil survey (pedological map) Land system survey (remote sensing) (low altitude aerial surveys) On-farm surveys Herd inventories Progeny history Laboratory analyses (nutrient values, disease diagnostic)
	Non livestock production (on and off farms)	
	Livestock production - Enterprise goals and economic uses - Physical and/or financial returns and/or costs - Grazing systems - Pasture-arable land interaction within production units and at aggregate level - Health status and management - Watering management - Crop residue uses - Herd size and demand for labor and other inputs - Livestock transactions Market Social relations - Home consumption - Livestock-related household income and expenditures	

Table 27 cont'd.

STAGES	OBJECTS OF OBSERVATION	COMPLEMENTARY MEANS OF OBSERVATION
	Institutional environment - Social organization of labor - Typology of herd owners and gradient of wealth - Distribution of rights to animals and products in the unit of production and consumption -Marketing and terms of trade for products in circulation	
2. Diagnostic Stage	Constraints in the production system Priority research requirements Constraints to investigate	
3. Design Stage (Researcher-Managed and Executed)		On-station experimentation (forage, artificial pastures) Body of knowledge (Health,nutrition management)
4. Testing Stage a. Researcher-Managed and Farmer-Executed b. Farmer-Managed and Executed	Identification and acceptability of improvements Producer management of improvements	Quantitative models of output relationships and decision making-process Experimental designs Statistical analysis

Table 27 cont' d.

STAGES	OBJECTS OF OBSERVATION	COMPLEMENTARY MEANS OF OBSERVATION
		and inferences (Randomized block designs, split-plot designs)
5. Extension Stage		
	Evaluation of technical and socioeconomic impacts of improvements	Multilocational trials planned jointly by research and extension, executed by extension and analysed by research and extension

SOURCE : De Haan (1983); Grandin (1983); Eklund (1983); Fitzhugh (1983); De Leeuw and Milligan (1983); Milligan and De Leeuw (1983).

projects and even ecological disasters have different effects on the two sexes due to the sexual differential in access, control and ownership of productive resources. Therefore, certain conceptual adjustments are necessary with respect to labor input analysis,economic opportunities or trade-offs and their resulting effects on income and status, management of the herd, and veterinary medicine.

Summary

The description of the Senegalese livestock subsector shows that its development is hindered by numerous constraints. In particular, insufficiencies in the government policies have been noted. Thus, the study suggests a possible global perspective on the issues that need to be considered in implementing successful livestock development program. Such a perspective is completed by a review of the competing frameworks of analysis of the Sub-Saharan livestock production systems. Among them, the 'production rationales' framework is retained as a synthetic approach that could be the basis for a structured research program and policy recommendations.

Then, an analytical model, based on capital theory, is developed to address some technical and economic issues faced by the livestock owners in the Ndama cattle production system of south Senegal. The model is used to investigate the livestock owners' decisions on the ages of sale for their cattle (male and female) and to examine the impact of different management practices on the optimal ages of sale and the herd demography.

The results suggest that the decisions farmers currently make on ages of sale for Ndama males and females and the subsequent herd management are close to that of the optimizing livestock producers represented in the

model. Furthermore, technical parameters, such as calving and mortality rates, have more important effects on the farmers' decisions than economic parameters such as liveweight prices and costs.

Finally, the modeling exercise provides suggestions on research data priorities that could contribute to the development of policy recommendations for the Institut Senegalais de Recherches Agricoles (ISRA). In particular, these suggestions would help ISRA consolidate its efforts to follow the farming system research methodology in the study of the livestock component of farming systems in Senegal.

APPENDIX A

APPENDIX A

ANIMAL STATISTICS

1 -Livestock population : 1947 - 1984 , Senegal

Year	Cattle (1,000 heads)	Sheep and goats (1,000 heads)	Pigs (1,000 heads)
1947-52	720	1,253	35
1960-65	1,760	1,790	40
1966	2,425	2,375	85
1967	2,477	2,448	88
1968	2,527	2,521	90
1969	2,600	2,597	93
1970	2,615	2,700	97
1971	2,674	2,804	93
1972	2,508	2,698	154
1973	2,200	2,500	180
1974	2,318	2,533	190
1975	2,380	2,619	196
1976	2,440	2,660	160
1977	2,514	2,811	170
1978	2,533	2,821	184
1979	2,500	2,920	136
1980*	2,238	3,170	150
1981*	2,361	NA	NA
1982*	2,329	NA	NA
1983*	2,220	NA	NA

NA : Not available

SOURCE : FAO Production Yearbooks (1965 - 1980)
IBRD (1974)
Societe Africaine d'Edition (1983)
* DSPA (1984)

2 - Meat production (indigeneous)*: 1960 - 1982, Senegal

Year	Beef (1,000 MT)	Mutton-goat (1,000 MT)	Pigmeat (1,000 MT)
1960-65	21	6	2
1966	29	NA	NA
1967	33	8	3
1968	35	8	3
1969	36	9	4

Table cont'd

1970	36	8	4
1971	30	10	3
1972	27	5	8
1973	25	4	6
1974	26	5	5
1975	33	8	6
1976	34	8	7
1977	35	8	7
1978	39	10	7
1979	39	9	8
1980	29	8	5
1981	33	9	5
1982	35	9	6

* Production of meat from indigenous animals plus meat equivallent expoted live minus meat equivalent imported live.

NA : Not Available

SOURCE : FAO Production Yearbooks 1965 - 1982

3 -Milk production and imports of milk : 1960 - 1982, Senegal

Year	Milk animals (1,000 heads)	Yield (KG/year)	Production (1,000 MT)	Imports* (1,000 MT)
1960-65	531	370	107	NA
1966	700	NA	NA	NA
1967	770	NA	118	NA
1968	820	NA	115	NA
1969	830	NA	113	NA
1970	860	NA	110	15.853
1971	313	NA	116	16.722
1972	314	300	94	14.170
1973	275	300	79	8.853
1974	283	320	66	8.013
1975	260	370	91	8.503
1976	270	350	97	8.410
1977	270	360	95	17.058
1978	271	350	95	14.564
1979	271	350	95	17.058
1980	250	350	95	14.564
1981	225	360	81	NA
1982	230	370	85	NA

SOURCE : FAO Production Year Books 1965 - 1982
Societe Africaine d'Edition (1983)

APPENDIX B

APPENDIX B

MATHEMATICS OF THE CAPITAL THEORY

1. Discrete stream of values

$$R_1 = R_0 + R_0\, r$$

$$R_1 = R_0\, (1 + r)$$

$$R_n = R_0\, (1 + r)^n$$

PV = Present Value of the discrete stream

$$PV_0 = R_0$$

$$PV_n = R_t\, (1 + r)^{-t}$$

2. Continuous stream of values

$$R_n = R_0\, (1 + r/f)^{fn}$$

$$R_n = R_0\, [(1 + r/f)^{f/r}]^{rn} \qquad (\text{NB} : r/r = 1)$$

$$R_n = R_0\, [\, A\,]^{rn}$$

If f goes to infinity, the system is countinuous and A goes to 2.7183 or e. If f smaller than infinity, the system is discrete.

$$R_n = R_0\, e^{rn}$$

$$R_0 = R_n \,/\, e^{rn} = R_n\, e^{-rn}$$

$$PV_0 = R_0$$

$$PV_n = R(t)\, e^{-rt}\, dt$$

3. Computation of the decision rule

Given Pr(a) and Pr is profit, a function of age, its maximum is reached if and only if the following conditions are satisfied ,at the same time:

- the first-order condition, id est, the first derivative of Pr with respect to age a is equal to 0 ; and
- the second-order condition, id est, the second derivative of Pr with repect to age a is negative.

APPENDIX C

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   PROGRAM MODELOT     74/175  OPT=1 ROUND=A/S/M/D  05      FTN 5.1+587          04/05/85  12.46.59        PAGE     1
DO=LONG/OT.ARG=COMMON/FIXED.CS=USER/FIXED.DB=TB/SB/SL/EX/ID/PMD/ST.PL=50000
FTNS

      C                                                                         150
                  PROGRAM MODELOT(INPUT,OUTPUT,TAPE 5=INPUT,TAPE 6=OUTPUT)      160
      C                                                                         170
      C           THIS PROGRAM SIMULATES PASTORAL HERD MANAGEMENT DECISIONS      180
      C                    IN A TRADITIONAL AFRICAN SYSTEM                      190
      C                                                                         210
      C                                                                         220
            REAL YM(15),YS(15),YW(15),YP(15),YV(15),D(15)                       230
            REAL XM(15),XS(15),XF(15),XW(15),XP(15),XV(15)                      240
            REAL X(15),Y(15),YC(15),XC(15),CCX(15)                              250
            REAL OFF(25),TOT,ERD(25),GRO(25)                                    260
            DATA X,Y /30*0.0/                                                   270
            DATA XM / .35, .10, .05,3*.03, .05, .07, .09, .11, .13, .15, .17, .19, .21/  280
            DATA XF / 3*0.0, .30, .60,3*.70,2*.60, .50, .40,3*.30/              290
            DATA XP /8*150.0,3*140.0,130.0,3*120.0/                             300
            DATA SPVYX,SPVXS,SPVMK,PVXOMX,MAXIX /4*0.0,0.0/                     310
            DATA GX0,GXB,GXR /17.00,2.605,.528/                                 320
            DATA XLACT,XPMILK /500.0,125.0/                                     330
            DATA YM / .35, .10, .05,3*.03, .05, .07, .09, .11, .13, .15, .17, .19, .21/  340
            DATA G0,GB,GR/18.00,2.966,.580/                                     350
            DATA YP /8*150.0,3*140.0,130.0,3*120.0/                             360
            DATA PVYOMX,MAXIY /0.0,0.0/                                         370
            DATA R01 / .20/                                                     380
            DATA YC,XC,CCX /0.0,14*375.0,0.0,0.0,14*475.0,15*0.0/               390
      C*****************************************************************      400
      C                      OPTIMAL AGE OF SALE                           C    410
      C                      VARIABLE DIRECTORY                            C    420
      C*****************************************************************      430
      C     STEER=Y                  COW=X     NAME                             440
      C                                                                         450
      C     Y                        X         NUMBER                           460
      C     YM                       XM        MORTALITY RATE(AGE SPECIFIC)     470
      C     YS                       XS        SURVIVAL RATE (AGE SPECIFIC)     480
      C     YW                       XW        LIVEWEIGHT(KG)                   490
      C     YP                       XP        PRICE OF BEEF(FCFA/KG)           500
      C     YV                       XV        MEAT VALUE IN CURRENT FCFA       510
      C     YC                       XC        COST OF RAISING                  520
      C                              XF        FERTILITY RATE(AGE SPECIFIC)     530
      C                              CCA(I)    CURRENT COST OF A COW            540
      C                              CCX(J)    CUMULATIVE COST OF A COW         550
      C     CCYO                               COST OF A STEER                  560
      C                                        (ADJUSTED FOR SURVIVAL AND TIME) 570
      C     D                                  DISCOUNT FACTOR                  580
      C     R01                                INTEREST RATE                    590
      C                              XLACT     LACTATION YIELD(500L/YEAR)       600
      C                              XPMILK    PRICE OF MILK(125 FCFA/L)        610
      C     G0,GB,GR          GX0,GXB,GXR      VALUES FOR GOMPERTZ CURVES       620
      C     MAXIY                    MAXIX     OPTIMUM AGE OF SALE              630
      C     PVYR                     PVXR      PV AT BIRTH WHEN ANIMAL SOLD IN YEAR I  640
      C     PVYO                     PVXO      NET PV AT BIRTH WHEN ANIMAL SOLD AT I   650
      C     PVYOMX                   PVXOMX    MAX PROFIT FROM SALE             660
      C                              SPVYX     CUMULATIVE PROBABILITY OF HAVING A MALE  670
      C                                         OR FEMALE PROGENY                680
      C                              SPVYO     CUMULATIVE PV MALE PROGENY       690
      C                              SPVXS     PV BEEF FROM A COW SLAUGHTERED AT I  700
      C                                        (ADJUSTED FOR SURVIVAL AND TIME) 710
      C                              SPVMK     PV OF MILK FROM A COW SLAUGHTERED AT I  720
      C                                                                         730
      C*****************************************************************      740
      C                                                                         750
            READ (5,6)FACTOR                                                    760
      6     FORMAT (F15.0)                                                      770
      C        THE FACTOR IS USED IN THE  SENSITIVITY ANALYSIS                  780
      C     DO 5 I=1,15                                                         790
      C     PARAMETER(I)=PARAMETER(I)*FACTOR                                    791
      C5     CONTINUE                                                           811
            WRITE (6,1)                                                         820
      1     FORMAT('1')                                                         830
      C                                                                         840
      C*****************************************************************      850
      C                  AGE OF SALE  FOR A STEER                         C    860
      C*****************************************************************      870
      C                                                                         880
            WRITE(6,2)                                                          890
      2     FORMAT('0',40X,'AGE OF SALE FOR A STEER')                           900
```

```
      C                                                                      910
      C                                                                      920
      C             LIFE EXPECTANCY (CUMULATIVE PRODUCT OF SURVIVAL RATES)   930
                    YS(1)=1.0-YM(1)                                          940
                       DO 10 J=2,15                                          950
                          I=J-1                                              960
   10                     YS(J)=YS(I)*(1.0-YM(J))                           970
      C                                                                      980
      C             LIVE WEIGHTS (GROWTH EQUATION OF THE GOMPERTZ TYPE)      990
      C                          YW(I)=18*EXP(2.966(1-.580**I))              1000
                       DO 20 I=1,15                                          1010
                          YW(I)=GO*2.7183**(GB*(1.0-GR**I))                  1020
      C                                                                      1030
      C             VALUE OF A STEER AND DISCOUNT FACTOR                     1040
                          YV(I)=YW(I)*YP(I)                                  1050
   20                     D(I)=1.0/2.7183**(ROI*I)                          1060
      C                                                                      1070
      C             INITIALISATION OF CCYO                                   1080
                          CCYO=0.0                                           1090
      C                                                                      1100
      C             COMPUTATION OF PVYO                                      1110
                    WRITE(6,25)                                              1120
   25               FORMAT('0',19X,'I',6X,'PVYR',6X,'CCYO',6X,'PVYO',5X,'YW(I)'  1130
     *                 ,5X,'YV(I)',5X,'YS(I)',6X,'D(I)',5X,'YM(I)')          1140
                    WRITE(6,33)                                              1150
   33               FORMAT('0')                                              1160
      C                                                                      1170
                       DO 30 I=1,15                                          1180
                          CCYO=CCYO+YC(I)*YS(I)*D(I)                         1190
                          PVYR=YV(I)*YS(I)*D(I)                              1200
                          PVYO=PVYR-CCYO                                     1210
      C                                                                      1220
      C             DECISION RULE . THE SLAUGHTER AGE IS THE AGE WHERE THE   1230
      C                             DISCOUNTED EXPECTED VALUE IS THE HIGHER  1240
      C                              PROFIT MAXIMIZING CRITERION             1250
      C                                                                      1260
                          IF(PVYO.LE.PVYOMA) GO TO 30                        1270
                            PVYOMA=PVYO                                      1280
                            MAXIY=I                                          1290
      C                                                                      1300
      C             PRINT RESULTS FOR A STEER                                1310
      C                                                                      1320
   30                  WRITE(6,31)I,PVYR,CCYO,PVYO,YW(I),YV(I),YS(I),D(I),YM(I)  1330
   31                  FORMAT(1X,I5,1X,I5,6F10.0,3F10.3)                     1340
      C                                                                      1350
      C                PRINT OPTIMAL VALUES                                  1360
                    WRITE(6,33)                                              1370
                    WRITE(6,33)                                              1380
                    WRITE(6,32)MAXIY,PVYOMA                                  1390
   32               FORMAT(3X,'MAX TOTAL PV OF A STEER AT',I3,2X,'IS',2X,F10.0  1400
     *,2X,'FCFA')                                                            1410
      C                                                                      1420
                    WRITE(6,33)                                              1430
                    WRITE(6,33)                                              1440
                    WRITE(6,33)                                              1450
                    WRITE(6,33)                                              1460
      C                                                                      1470
      C*********************************************************************C  1480
      C                AGE OF SALE FOR A COW                                C  1490
      C*********************************************************************C  1500
      C                                                                      1510
                    WRITE(6,34)                                              1520
   34               FORMAT(41X,'AGE OF SALE FOR A COW')                      1530
      C                LIFE EXPECTANCY                                       1540
                       XS(1)=1.0-XM(1)                                       1550
                       DO 40 J=2,15                                          1560
                       I=J-1                                                 1570
   40                  XS(J)=XS(I)*(1.0-XM(J))                               1580
      C                                                                      1590
      C                LIVE WEIGHTS                                          1600
                       DO 50 I=1,15                                          1610
                       XW(I)=GXO*2.7183**(GXB*(1.0-GXR**I))                  1620
      C                                                                      1630
      C                BEEF VALUE OF A COW                                   1640
   50                  XV(I)=XW(I)*XP(I)                                     1650
      C                                                                      1660
      C                CURRENT COST FOR KEEPING A COW                        1670
```

```
153                CCX(I)*AC(I)*AS(I)*D(I)                                      1680
154          C     CUMULATIVE CURRENT COST FOR KEEPING A COW                    1690
155                DO 55 J=2,15                                                 1700
156                I=J-1                                                        1710
157          55    CCX(J)=CCX(I)+AC(J)*AS(J)*D(J)                               1720
158          C                                                                  1730
159          C     VALUES OF PROGENY                                            1740
160          C     REPRODUCTION STARTS AT YEAR 4                                1750
161          C                                                                  1760
162          C     PRINTINTG TITLE FOR MEAT RESULTS, COMPUTED IN MEAT LOOP      1770
163          C                                                                  1780
164                WRITE(6,58)                                                  1790
165          58    FORMAT('0',9X,'I',6X,'PVAR',4X,'CCX(I)',6X,'PVAO',5X,'SPVXS',1800
166               *      5X,'SPVYO',5X,'SPVMK',5X,'SPVYX',5X,'AS(I)',5X,'XV(I)',1810
167               *      5X,'XW(I)',5X,'XM(I)',5X,'XF(I)')                     1820
168                WRITE(6,33)                                                  1830
169                DO 60 I=1,15                                                 1840
170          C           SUM OF PROBABILITY OF MALE OR FEMALE PROGENY          1850
171                      SPVYX=SPVYX+XS(I)*XF(I)+.50*D(I)                     1860
172          C           PROBABILITY OF OCCURENCE OF A MALE CALF=.5*XF(I)      1870
173          C                                                                1880
174          C           PV BEEF VALUE OF A COW IF SLAUGHTERED                1890
175                      SPVXS=XS(I)*D(I)*XV(I)                               1900
176          C                                                                1910
177          C           PV OF MILK PRODUCED                                  1920
178                      SPVMK=SPVMK+XS(I)*XF(I)*.50*D(I)*ALACT*XPMILK        1930
179          C           CUMULATIVE PROBABILITY OF A LACTATION=.60*XF(I)      1940
180          C                                                                1950
181          C           CUMULATIVE PV OF MALE PROGENY                        1960
182                      SPVYO=SPVYX*PVYOMX                                   1970
183          C                                                                1980
184          C           PV AT BIRTH OF MILK,MALE PROGENY AND MEAT            1990
185                      PVAR=SPVYO+SPVMK+SPVXS                               2000
186          C                                                                2010
187          C           PV OF A COW AT BIRTH INCLUDING THE VALUE OF ITS FEMALE2020
188          C                                                     PROGENY    2030
189                      PVAO=(PVAR-CCX(I))/(1.0+SPVYX)                       2040
190          C                                                                2050
191          C           PV AT BIRTH                                          2060
192                      PVAR=PVAO+CCX(I)                                     2070
193          C                                                                2080
194          C           DECISION RULE                                        2090
195                      IF (PVXO.LE.PVXOMX) GO TO 60                         2100
196                         PVXOMX=PVXO                                       2110
197                         MAXIX=I                                           2120
198          C                                                                2130
199          C     PRINT RESULTS                                              2140
200          C                                                                2150
201          60    WRITE(6,61)I,PVAR,CCX(I),PVAO,SPVXS,SPVYO,SPVMK,SPVYX,AS(I),XV(I)2160
202               *,XW(I),XM(I),XF(I)                                          2170
203          61    FORMAT(6X,I5,6F10.0,2F10.3,2F10.0,2F10.3)                  2180
204          C                                                                2190
205                WRITE(6,33)                                                2200
206          C                                                                2210
207                      WRITE(6,62)MAXIX,PVXOMX                              2220
208          C                                                                2230
209                WRITE(6,33)                                                2240
210          C                                                                2250
211          62    FORMAT(3X,'MAX TOTAL PV OF A COW AT',I3,2X,'IS',2X,F10.0,1X2260
212               *,'FCFA')                                                    2270
213                      WRITE(6,33)                                          2280
214                      WRITE(6,33)                                          2290
215          C                                                                2300
216          C.....................................................C           2310
217          C                        HERD DYNAMICS                C           2320
218          C                                                     C           2330
219          C     THIS PART OF THE PROGRAM GENERATES A HYPOTHETICAL HERD      C2340
220          C   STRUCTURE FOR 1000 ANIMALS(MALES AND FEMALES)SOLD ON          C2350
221          C   SLAUGHTERED AT OPTIMAL AGE CALCULATED ABOVE                   C2360
222          C                                                                 C2370
223          C.....................................................C           2380
224          C                                                     C           2390
225          C                     VARIABLE DIRECTORY              C           2400
226          C                                                     C           2410
227          C          SSY,SSX-CUMULATIVE SURVIVAL RATE FOR EACH SEX          C2420
228          C          XS(I)=SSX*SSY-PROBABILITY OF SURVIVAL FOR X AT AGE I   C2430
229          C          XO-FEMALE CALVES NEWBORN                               C2440
```

```
C            YO-MALE CALVES NEWBORN                                          C
C            XSOLD-COW SOLD AT OPTIMUM AGE                                   C
C            YSOLD-STEER SOLD AT OPTIMUM AGE                                 C
C            X(I)= # OF COWS                                                 C
C            Y(I)= # OF STEERS                                               C
C            KYEAR-YEAR SIMULATED                                            C
C            TOTNO(I)-CUMULATIVE TOTAL AT I YEAR                             C
C            IOTHERO(K)-TOTAL HERD IN YEAR K                                 C
C            OFF(K)-OFFTAKE IN YEAR K                                        C
C            GTOT-GROWTH RATE IN YEAR K                                      C
C            PROD-PRODUCTIVITY IN YEAR K                                     C
C                                                                            C
C*****************************************************************C
      WRITE(6,35)
35    FORMAT('1',20X,'HERD DYNAMICS')
      WRITE(6,33)
      WRITE(6,33)
C
C*****************************************************************C
C     GENERATION OF AN HYPOTHETICAL HERD DISTRIBUTION WITH THE    C
C     CUMULATIVE SURVIVAL RATE ON 1000 ANIMALS                    C
C*****************************************************************C
C
          SSY=0.0
          DO 120 I=1,MAXIY
120       SSY=SSY+YS(I)
          SSX=0.0
          DO 130 I=1,MAXIX
130       SSX=SSX+XS(I)
          DO 140 I=1,MAXIY
140       Y(I)=1000*YS(I)/(SSY+SSX)
          DO 150 I=1,MAXIX
150       X(I)=1000*XS(I)/(SSY+SSX)
C
C*****************************************************************C
C                    DYNAMICS IN THE HERD                         C
C*****************************************************************C
C
C     INITIALISATION BY YEAR,NEWBORNS AND PARAMETERS
          KYEAR=0
          XO=0.0
          YO=0.0
C
C
          WRITE (6,41)
41        FORMAT(1X,'YEAR',1X,'NEWBORNS',' - - - - - - - - - -
     *- - - CLASS  1  TO  15 - - - - - - - - - - - - - - - OFFTAKE')
          WRITE (6,71)KYEAR,XO,(X(J),J=1,15)
          WRITE (6,72)KYEAR,YO,(Y(J),J=1,15)
C
C         REPETITION FOR 25 YEARS
          DO 110 K=1,25
                KYEAR=KYEAR+1
C                  NUMBER OF CALVES
                   CALVES=0.0
                   DO 80 I=4,15
80                 CALVES=CALVES+AF(I)*X(I)
C               OFFTAKE AT OPTIMAL AGE (MALES AND FEMALES)
                XSOLD=X(MAXIX)
                X(MAXIX)=0.0
                YSOLD=Y(MAXIY)
                Y(MAXIY)=0.0
C                  TRANSFER FROM CLASS I TO CLASS I+1
C                     (CLASS 2 TO 15)
                   DO 90 K1=1,14
                   J=16-K1
                   I=J-1
                   Y(J)=Y(I)*(1.0-YM(J))
90                 X(J)=X(I)*(1.0-XM(J))
C               SEX RATIO APPLIED ON CALVES
                XO=CALVES/2
                YO=CALVES/2
C               TRANSFER FROM NEWBORNS(CLASS 1)TO CLASS 2(1 YEAR)
                X(1)=XO*(1.0-AM(1))
                Y(1)=YO*(1.0-YM(1))
C
C           COMPUTATION OF OFFTAKE
```

```
                      TOTHD=XD+YD                                                3220
                        DO 1000 I=1,15                                           3230
                           TOTHD=TOTHD+X(I)+Y(I)                                 3240
1000                    CONTINUE                                                 3250
                        OFF(K)=(XSOLD+YSOLD)/TOTHD                               3260
                        TOTHERD(K)=TOTHD                                         3270
C                                                                                3280
C                            PRINT RESULTS                                       3290
                            WRITE(6,71) KYEAR,XD,(X(J),J=1,15),XSOLD,OFF(K)      3300
71                          FORMAT('0',1X,13,1F5.0,4X,15F5.0,2A,1F5.0,1X         3310
     *,'XSOLD',2X,'OFF=',1F5.4)                                                  3320
                            WRITE(6,72) KYEAR,YD,(Y(J),J=1,15),YSOLD             3330
72                          FORMAT(2X,I3,1F5.0,4X,15F5.0,2A,1F5.0,1X,'YSOLD')    3340
C                                                                                3350
110                     CONTINUE                                                 3360
C                                                                                3370
C                                                                                3380
C                       COMPUTATION OF GROWTH RATE AND PRODUCTIVITY              3390
                            WRITE(6,73)                                          3400
73                          FORMAT('1')                                          3410
                            WRITE(6,74)                                          3420
74                          FORMAT(16X,'YEAR',7X,'TOTHERD',6X,'OFF',6X           3430
     *,'GTOT',6X,'PROD')                                                         3440
                            GTOT=0.0                                             3450
                            PROD=0.0                                             3460
                            LYEAR=0                                              3470
                        DO 2000 K=1,24                                           3480
                            LYEAR=LYEAR+1                                        3490
                            GTOT=(TOTHERD(K+1)-TOTHERD(K))/TOTHERD(K)            3500
                            PROD=GTOT+OFF(K)                                     3510
                            GRO(K)=GTOT                                          3520
                            WRITE(6,33)                                          3530
                            WRITE(6,75)LYEAR,TOTHERD(K),OFF(K),GTOT,PROD         3540
75                          FORMAT(20X,I3,5X,1F7.0,5X,1F5.4,5X,1F5.4,5X          3550
     *,1F5.4)                                                                    3560
                                                                                 3570
2000                    CONTINUE                                                 3580
                                                                                 3590
                                                                                 3600
C                       COMPUTATION OF AVERAGE HERD GROWTH EVERY 4 YEARS         3610
                        WRITE (6,76)                                             3620
76                      FORMAT('0',10X,'AVERAGE GROWTH OF HERD(4 YEARS)')        3630
                          GRO(K)=0.0                                             3640
                          DO 300 K1=0,5                                          3650
                             TOGRO=0.0                                           3660
                              DO 400 K2=1,4                                      3670
                                 TOGRO=TOGRO+GRO(4*K1+K2)                        3680
400                           CONTINUE                                           3690
                                 AVGR=TOGRO/4                                    3700
                                 WRITE (6,77)AVGR                                3710
77                               FORMAT(20X,1F5.3)                               3720
300                              CONTINUE                                        3730
          STOP                                                                   3740
          END                                                                    3750
```

AGE OF SALE FOR A STEER

I	PVYR	CCYO	PVYO	YW(I)	YV(I)	YS(I)	D(I)	YM(I)
1	4994.	0	4994.	63	9384	650	819	350
2	7579.	147.	7432.	129.	19327.	585	670	100
3	8963.	261.	8702.	196.	29387.	556	549	050
4	9077.	352.	8725.	250	37473.	539	449	030
5	8300.	424.	7875.	288	43146.	523	368	030
6	7153.	482.	6671.	312.	46822.	507	301	030
7	5834.	526.	5308.	327.	49096.	482	241	050
8	4566.	560.	4006.	336.	50465.	448	202	070
9	3226.	585.	2641.	342.	47858.	408	165	090
10	2373.	604.	1769.	345.	48303.	363	135.	110.
11	1699.	617.	1082.	347.	48563.	316.	111.	130.
12	1101.	626.	475.	348.	45235.	268.	091.	150.
13	692.	632.	60.	349.	41831.	223.	074.	170.
14	459.	636.	-177.	349.	41875.	180.	061.	190.
15	297.	639.	342.	349.	41900.	143.	050.	210.

MAX TOTAL PV OF A STEER AT 4 IS 8725 FCFA

AGE OF SALE FOR A COW

I	PVXR	CCX(I)	PVXO	SPVXS	SPVYO	SPVMK	SPVYX	XS(I)	XV(I)	XM(I)	XM(I)	XF(I)
1	4641.	0.	4641.	4641.	0	0	000	650	8720.	58	350	000
2	6545.	147.	6398.	6545.	0	0.	000	585	16691.	111	100	000
3	7172.	261.	6911.	7172.	0	0.	000	556	23515.	157	050	000
4	9756.	352.	9403.	6826.	317	2271.	036	539	28181.	188	030	300
5	13933.	424.	13509.	5965.	820	5878.	094	523	31002.	207	030	600
6	18085.	482.	17604.	4982.	1287.	9220.	148	507	32612.	217	030	700
7	21394.	526.	20868.	3980.	1650.	11819.	189	482	33492.	223	050	700
8	23964.	560.	23404.	3073.	1926.	13798.	221	448	33967.	226	070	700
9	25265.	585.	24679.	2153.	2103.	15062.	241	408	31938.	228	090	600
10	26380.	604.	25777.	1575.	2231.	15983.	256.	363.	32064.	229.	110.	600.
11	26916.	617.	26299.	1124.	2307.	16529.	264.	316.	32130.	230.	130.	500.
12	27020.	626.	26394.	727.	2350.	16834.	269.	268.	29868.	230.	150.	400.
13	26978.	632.	26346.	456.	2372.	16989.	272.	223.	27586.	230.	170.	300.
14	26986.	636.	26350.	303.	2386.	17092.	273.	180.	27595.	230.	190.	300.
15	26981.	639.	26342.	196.	2395.	17158.	275.	143.	27599.	230.	210.	300.

MAX TOTAL PV OF A COW AT 12 IS 26394 FCFA

HERD DYNAMICS

YEAR	NEWBORNS	CLASS 1	10	15										OFFTAKE		
0	0	82	73	70	68	66	64	60	56	51	46	40	34	0	0	0			
0	0	82	73	70	68	0	0	0	0	0	0	0	0	0	0	0			
1	139	90	73	70	68	66	64	60	56	51	46	40	34	0	0	0	34	ASOLD	OFF= 0782
1	139	90	73	70	68	0	0	0	0	0	0	0	0	0	0	0	68	YSOLD	
2	139	90	81	70	68	66	64	60	56	51	46	40	34	0	0	0	34	ASOLD	OFF= 0773
2	139	90	81	70	68	0	0	0	0	0	0	0	0	0	0	0	68	YSOLD	
3	139	90	81	77	68	66	64	60	56	51	46	40	34	0	0	0	34	ASOLD	OFF= 0765
3	139	90	81	77	68	0	0	0	0	0	0	0	0	0	0	0	68	YSOLD	
4	139	90	81	77	75	66	64	60	56	51	46	40	34	0	0	0	34	ASOLD	OFF= 0757
4	139	90	81	77	75	0	0	0	0	0	0	0	0	0	0	0	68	YSOLD	
5	140	91	81	77	75	72	64	60	56	51	46	40	34	0	0	0	34	ASOLD	OFF= 0803
5	140	91	81	77	75	0	0	0	0	0	0	0	0	0	0	0	75	YSOLD	
6	142	92	82	77	75	72	70	60	56	51	46	40	34	0	0	0	34	ASOLD	OFF= 0795
6	142	92	82	77	75	0	0	0	0	0	0	0	0	0	0	0	75	YSOLD	
7	144	94	83	78	75	72	70	67	56	51	46	40	34	0	0	0	34	ASOLD	OFF= 0785
7	144	94	83	78	75	0	0	0	0	0	0	0	0	0	0	0	75	YSOLD	
8	146	95	84	79	75	72	70	67	62	51	46	40	34	0	0	0	34	ASOLD	OFF= 0774
8	146	95	84	79	75	0	0	0	0	0	0	0	0	0	0	0	75	YSOLD	
9	148	96	86	80	76	73	70	67	62	56	46	40	34	0	0	0	34	ASOLD	OFF= 0767
9	148	96	86	80	76	0	0	0	0	0	0	0	0	0	0	0	75	YSOLD	
10	150	98	87	81	78	74	71	67	62	56	50	40	34	0	0	0	34	ASOLD	OFF= 0764
10	150	98	87	81	78	0	0	0	0	0	0	0	0	0	0	0	76	YSOLD	
11	152	99	88	82	79	75	72	67	62	56	50	44	34	0	0	0	34	ASOLD	OFF= 0761
11	152	99	88	82	79	0	0	0	0	0	0	0	0	0	0	0	78	YSOLD	
12	155	100	89	84	80	76	73	68	63	56	50	44	37	0	0	0	34	ASOLD	OFF= 0758
12	155	100	89	84	80	0	0	0	0	0	0	0	0	0	0	0	79	YSOLD	
13	157	102	90	85	81	78	74	69	63	57	50	44	37	0	0	0	37	ASOLD	OFF= 0780
13	157	102	90	85	81	0	0	0	0	0	0	0	0	0	0	0	80	YSOLD	
14	158	103	92	86	82	79	75	70	65	58	51	44	37	0	0	0	37	ASOLD	OFF= 0777
14	158	103	92	86	82	0	0	0	0	0	0	0	0	0	0	0	81	YSOLD	
15	160	104	93	87	83	80	76	71	66	59	51	44	37	0	0	0	37	ASOLD	OFF= 0775
15	160	104	93	87	83	0	0	0	0	0	0	0	0	0	0	0	82	YSOLD	
16	162	106	94	88	84	81	77	72	66	60	52	45	37	0	0	0	37	ASOLD	OFF= 0772
16	162	106	94	88	84	0	0	0	0	0	0	0	0	0	0	0	83	YSOLD	
17	165	107	95	89	85	82	78	73	67	60	53	45	38	0	0	0	37	ASOLD	OFF= 0771
17	165	107	95	89	85	0	0	0	0	0	0	0	0	0	0	0	84	YSOLD	
18	167	109	96	90	86	83	79	74	68	61	54	46	39	0	0	0	38	ASOLD	OFF= 0770
18	167	109	96	90	86	0	0	0	0	0	0	0	0	0	0	0	85	YSOLD	
19	169	110	98	92	88	84	80	75	69	62	55	47	39	0	0	0	38	ASOLD	OFF= 0770
19	169	110	98	92	88	0	0	0	0	0	0	0	0	0	0	0	86	YSOLD	
20	172	112	99	93	89	85	81	76	70	63	55	47	40	0	0	0	39	ASOLD	OFF= 0770
20	172	112	99	93	89	0	0	0	0	0	0	0	0	0	0	0	88	YSOLD	
21	174	113	100	94	90	86	82	77	71	64	56	48	40	0	0	0	40	ASOLD	OFF= 0771
21	174	113	100	94	90	0	0	0	0	0	0	0	0	0	0	0	89	YSOLD	
22	176	115	102	95	91	87	84	78	72	65	57	49	41	0	0	0	40	ASOLD	OFF= 0771
22	176	115	102	95	91	0	0	0	0	0	0	0	0	0	0	0	90	YSOLD	
23	179	116	103	97	93	89	85	79	73	65	57	49	41	0	0	0	41	ASOLD	OFF= 0772
23	179	116	103	97	93	0	0	0	0	0	0	0	0	0	0	0	91	YSOLD	
24	181	118	104	98	94	90	86	81	74	66	58	50	42	0	0	0	41	ASOLD	OFF= 0772
24	181	118	104	98	94	0	0	0	0	0	0	0	0	0	0	0	93	YSOLD	

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25 183.     119 106  99.  95.  91.  87  82  75  67.  59  51  43.  0  0.  0    42. XSOLD  OFF= 0772
25 183.     119. 106. 99. 95.  0.   0   0.  0   0    0   0   0.   0  0.  0.   94  YSOLD
```

YEAR	TOTHERD	OFF	GTOT	PROD
1	1294	.0782	.0119	.0901
2	1309.	.0773	.0111	.0885
3	1324	.0765	.0107	.0872
4	1338.	.0757	.0077	.0834
5	1348.	.0803	.0109	.0912
6	1363.	.0795	.0129	.0924
7	1381.	.0785	.0140	.0925
8	1400.	.0774	.0145	.0919
9	1420	.0767	.0143	.0909
10	1441	.0764	.0146	.0909
11	1462.	.0761	.0146	.0907
12	1483.	.0758	.0126	.0885
13	1502.	.0780	.0122	.0902
14	1520.	.0777	.0127	.0905
15	1539	.0775	.0133	.0908
16	1560.	.0772	.0136	.0908
17	1581.	.0771	.0137	.0908
18	1603	.0770	.0136	.0906
19	1624.	.0770	.0135	.0904
20	1646.	.0770	.0133	.0904
21	1668.	.0771	.0133	.0904
22	1690.	.0771	.0133	.0904
23	1713.	.0772	.0133	.0905
24	1736.	.0772	.0133	.0905

AVERAGE GROWTH OF HERD(4 YEARS)

.010
.013
.014
.013
.014

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