AN ABSTRACT OF THE THESIS OF

Mohamadou M. Sissokho for the degree of Master of Science in
Rangeland Resources presented on March 30, 1998.
Title: Cattle Herd Dynamics and Performance Under Village Husbandry in the Kolda Region (Southern Senegal).

Abstract approved: ______________________________
Douglas E. Johnson

Parameters of herd dynamics and production performances were analyzed from data collected using a long-term survey of village cattle herds in the agro-pastoral production system of Kolda (Southern Senegal) conducted from 1987 to 1995. Monthly distribution of births averaged over the study period shows that peak conceptions occurred during the months of October and February (73% of total conceptions). This period corresponded also to that of maximum body weight of cows. Cow reproductive performance was poor, as heifers produced their first calves at a relatively late age (1703 days; C.V.= 13.1%) and tended to calve on alternate years. Average estimate of intervals between successive calving was 690 days (C.V.= 32%) and was significantly reduced by the dam's age and experience (i.e. parity number) and by a reduction of the length of the suckling/milk extraction period which resulted from calf loss.

Average weights (± s.e.)of calves at birth, 6 and 12 month old were respectively 16.8 kg (± 0.4), 49.3 kg (± 0.9) and 78.9 kg (± 2.2). Cumulative growth rate of calves (± s.e.) was 0.18 kg d^{-1} (± 0.05) from birth to 12 months old, but males grew 40-g d^{-1} faster than did females. Postpartum live weight of cows was higher during the post-rainy season

(October through January) and lower during the late-dry and early-wet seasons (March through June). Calving in the early wet season (May-June-July) resulted in significant weight gain for cows at a rate (± s.e.) of 0.16 kg d^{-1} (± 0.05), while cows significantly lost 0.14 kg d^{-1} (± 0.04) of weight when they gave birth during the early dry season period (November-December-January). Milk extraction of lactating cows for human consumption tended to decrease on average with advancing stages of lactation, and was higher during the wet season and lower during the dry season period.

Average herd size was 89 head (C.V=62%) with extremes of 25 and 212. Herd composition of cattle averaged for all years and seasons during the study period shows a maximum of breeding females in the herd (35% of all animals) and a high ratio (1/3.5) of males to females adults. Herd composition reflected the multiple use orientation of animals in the production system.

Sale was an important avenue for animal disposal, accounting for 41% of all exits recorded in the studied herds during the monitoring program. Average age (± s.e.) of animals at sale was 7.4 years (± 0.14), but males were sold at younger age (5.4 ± 0.2 years) than females (9.4 ± 0.2 years). Males were also more likely to be chosen for sale than females at all ages from birth to 8 years old, indicating a preference of herd owners to keep female animals in the herd for as long as they were able to breed. This was reflected by the presence of old cows aged 20 years or more in the herds and their offer for sale. Average proportion (± s.e.) of the total number of animals in the herds that were sold each year approximated 6.9% (± 0.5).

Approximately 4.0%, 5.5% and 9.8% of all calves born during the study years died before the ages 1, 6 and 12 months respectively, and mortality rates in the interval from birth to 24 months old tended to decrease as animals get older. Approximately 5.3 % (± s.e.= 0.05) of all animals kept in the herds died each year, but annual mortality rates were variable from one year to the next and from herd to herd.

Production performances were low when compared to on-station results and highly variable across season.

Cattle Herd Dynamics and Performance Under Village Husbandry in the Kolda Region (Southern Senegal)

by

Mohamadou M. Sissokho

A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Presented March 30, 1998
Commencement June 1998

Master of Science thesis of Mohamadou M. Sissokho presented on March 30, 1998

APPROVED:

____

Major Professor, representing Rangeland Resources

____

Head of Department of Rangeland Resources

____

Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Redacted for privacy

____

Mohamadou M. Sissokho, Author

ACKNOWLEDGMENTS

I am indebted and grateful to all persons who had supported and helped me through all the steps that led to the completion of this work.

Thanks to my parents and to my family who have sacrificed much to insure me the opportunity to pursue this degree.

My sincere thanks to my major Professor Dr. Douglas Johnson and to my other committee members: Dr. Mike Borman and Dr. David Thomas for the quality of your instruction and for your constant support and guidance through this thesis.

My gratitude is extended to the staff and the professors in the Department of Rangeland. Thanks for sharing your knowledge about rangelands.

To the graduate students and especially to John Beebe, thanks for your friendships and for your constant support during some rather difficult moments I have experienced.

My sincere thanks goes also to the researchers and technicians at the "Centre de Recherches Zootechniques de Kolda", who contributed to make this research program work. Dr. Abdou Fall and Dr. Adama Faye have coordinated this program for years before I took over. Malang Bayo and Abdoul Aziz Diallo were the key persons of this project who have supervised the fieldwork.

Special thanks also to the herd owners, who willingly accepted to collaborate in this program for so many years.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TEXT FIGURES

LIST OF TEXT TABLES

LIST OF APPENDICES

LIST OF APPENDIX FIGURES

LIST OF APPENDIX TABLES

Cattle Herd Dynamics and Performances Under Village Husbandry
in the Kolda Region(Southern Senegal)

CHAPTER 1

INTRODUCTION

1.1. Presentation of Senegal

Located in the southwestern part of Africa, Senegal is a country with a tropical climate. It covers a surface area of approximately 197,190 square kilometers and has a human population estimated at 8.5 million. Approximately 75% of this population live in rural areas, and agriculture represents an important sector of the economy, accounting for 20% of the Gross domestic Product (GDP). Livestock share of the GDP is estimated at 22%. Recent estimates of ruminant livestock numbers are 2.8 million cattle, 4.6 million sheep and 3.2 million goats (ISRA, 1995).

Relief is generally flat and most of the country lies below 100 meters. There exists a marked variability in rainfall (yearly amount, duration of the rainy season) across the country, with a single rainy season. Mean annual rainfall ranges from 200-350 mm in the arid northern part, to 400 - 900 mm in the center, and 1000-1400 mm in the southern humid portion, with a single rainy season of 3, 4 and 5 months duration respectively. Rainfall variation and its influence on crop and livestock productions are among the main criteria used to stratify the country into 5 agro-climatic zones.

Cattle breeds vary depending on geographic locations. The north and west are dominated by the Zebu Gobra breed type (*Bos indicus*) characterized by its relatively large frame size and its sensitivity to trypanosomiasis disease. The southern humid zone is populated by the Ndama breed type (*Bos taurus*) which is characterized by its smaller frame size and its tolerance to trypanosomiasis disease. In the central and northeastern zones a natural crossbreed of Zebu Gobra and Ndama called Djakore, which has an intermediate frame size, is the mainstay.

Main livestock production systems encountered are:

- Transhumant pastoral range livestock production system, found in the northern arid part, is characterized by a marginal contribution of cropping activities and frequent long distance migrations of herds due to low and irregular precipitation, and/or insecure conditions for watering livestock.

- Transhumant agro-pastoral production system, found in the half central part of the country is characterized by seasonal migration of herds primarily caused by an expansion of cultivated lands at the expense of native pastures and fallow lands.

- Agro-pastoral, sedentary production system, found in the south, is characterized by no herd migration and by a certain degree of integration between crop and livestock activities.

-Semi-intensive production system, found around big cities is characterized by the utilization of high yielding exotic breeds for milk and meat production.

1.2. Relevance of System Approach to Livestock Production

Research on livestock production systems under farm conditions has become more popular over the last three decades in sub-Saharan Africa. Shift from on-station to on-farm research has been, in most situations, the result of a limited success of many livestock development projects, and of a very limited acceptance of "improved" technologies generated at research stations using the classical top-down approach Hildebrand and Russell (1996).

The livestock population in many Sub saharan African countries like Senegal, is owned by small holder farmers with very limited resources, and managed under traditional settings. Traditional livestock production systems can be very complex with a rationale that is not always easily understood by scientists. Livestock play very important roles in these societies, not only biological and economic, but also social and cultural. Animals are functionally integrated into traditional Senegalese farming systems and are closely adapted to the ecological environment. Most cattle breeds raised by smallholder farmers and their production systems have evolved over centuries using a selection process which focuses on multipurpose functions and the animal's ability to cope with environmental stresses.

Major cattle production constraints in south Senegal seem to be associated with management, husbandry, diseases, and the seasonality of feed supply (quality and quantity). Better understanding of the rationale of existing systems is a prerequisite to improvement. Therefore, information on livestock performances, current diseases, and feed availability are needed if improvements are to be made under prevailing conditions. However in many countries like Senegal, baseline data of this type are lacking. Production levels achieved under farm conditions are not known and farmers' goals are poorly understood. New technologies must incorporate farmers' goals and perceptions of production constraints and evaluation to be successful. Low-cost technological packages based on improving existing systems seem to be most appropriate for improving the welfare of small holder farmers (Cook, 1985). The farming system approach for research, development, and technology generation has been identified as more suited for studying and improving traditional production systems of developing countries (Norman, 1995). A cooperative research methodology that places more emphasis on active participation by farmers/stock growers in the process of technology development and evaluation should be superior. " Farming system research rests on two central propositions: (1) that effective research in agricultural technology starts and finishes with farmer; (2) that integration of the perceptions of biological and social scientists is an essential element in such research" (CYMMYT 1980; after Martin, 1986). The farming systems research approach was developed in large part as a response to failures of previous efforts at technology development and transfer (Hildebrand and Russell, 1996). Its goal is to improve the well-being of individual farming families by increasing the overall productivity of the farming system, based on specific constraints and potentials identified within the existing system (Norman, 1995). It seems that, to design appropriate and relevant ways of helping farmers, it is essential to understand the conditions under which they operate. Constraint identification is therefore a critical stage in the process leading to increased productivity of small-scale farmers.

1.3. Study's Background and Objectives

Since 1982, agricultural research at the Senegalese Institute of Agricultural Research (ISRA) has evolved from on-station experiments, to on-farm, multi-disciplinary research implemented through an agricultural research program funded by the World Bank and by the United States Agency For International development. Before this time, research activities by ISRA were mostly conducted on-station with very little consideration to the specific production environment for which improved technologies were designed. The consequence of such an approach was the generation of new technological packages that proved to be inefficient and inappropriate to the predominant traditional sector of livestock production. In 1982, a critical review of the impact of the agricultural research system on farmers' welfare has led ISRA to reconsider its methodological approach for research. Subsequently, research programs based on a farming systems approach were implemented to provide a holistic understanding of the social, economic and technical aspects of livestock production in different ecological zones of the country. One of the many tasks assigned to the farming systems research teams was to identify production constraints and to design alternative solutions for increased productivity. Newly implemented farming research teams were also asked to acquire baseline data needed in the design of more in-depth research experiments and agricultural development projects.

This study, which is a long-term diagnostic survey of the current livestock production sub-system in the villages surrounding the livestock research center in Kolda, was designed and conducted within the framework of a farming system research program. Its overall goals were to (1) gain a better understanding of current production systems, (2) identify major factors limiting animal/herd performances, (3) and design alternative ways of increasing system productivity. Specific objectives were:

1) To describe the functioning of the traditional cattle production sub-system and its interactions with other components of farm activities (especially the cropping system).

2) To describe the structure and dynamics (mortality, off-take) of cattle herds;

3) To estimate levels of production performances (reproductive efficiency, milk output, and growth) achieved under village conditions, and identify major sources of environmental variations.

4) To identify pertinent research priorities to design in controlled experiments, and to formulate potential management recommendations for farmers that lead to increased productivity.

CHAPTER 2

LITERATURE REVIEW

2.1. Definition and Typologies of Livestock Systems

Livestock production represents one component of the farming system. It is defined as: "a unique and reasonably stable arrangement of farming enterprises and activities of mainly crops, livestock and off-farm work that are managed by a farm household according to a well defined practice in response to the physical, biological and socio-economic conditions, and in accordance with the household's goals, preferences and resources (land, labor, capital and management)" (ILCA, 1986).

Livestock production represents therefore a sub-system of the whole farming system and refers to activities that involve the use of farm animals to produce goods and services that may be readily consumed or utilized to enhance other farm sub-systems.

Efforts have been made over the last three decades to develop a conceptual framework for farming system research studies. Most of the work has dealt with the cropping sub-system, with only a few references devoted to the study of livestock production on the farm. This gap may be explained by the relative complexity of the enterprise, as compared to other farm activities. This was clearly stated by Sidamed and Koong (1984): "livestock production is a very complex system which has interrelated components such as climate, soil, plants, and obviously animals operating with a high degree of interaction within a certain economic and social environment".

Lhoste (1993) defined livestock production sub-systems as the husbandry methods and management practices utilized by a human community (farmers/

pastoralists) to exploit the natural resources (forage, water) which are located within a defined land territory, through raising of domestic animals, in accordance with decisions motivated by their production goals, and in response to constraints imposed by the production environment.

Livestock production sub-systems have been classified based on the relative contribution of crop and livestock activities on total household family income (Wilson et al., 1983). Pastoral production systems are those systems for which the contribution of livestock and their products are more than 50% of total household income. Agro-pastoral or mixed crop/livestock identifies systems for which between 10 and 50% of rural income are derived from livestock. Crop based systems are those in which the contribution of livestock makes up less than 10% of total family household income. Other classifications of livestock subsystems may be based on the way land and resources they support are utilized, and on the degree of integration of livestock with other farming activities. Jahnke (1982) for instance distinguishes:

- Pastoral-range livestock systems, which are comprised of two components: pastoral systems and ranching. These are found in arid to semiarid zones, and are heavily dependent upon the availability of large land areas for extensive grazing. Livestock production represents the dominant, if not the sole activity, and crop production is marginal due to insecure rainfall.

- Crop- livestock production systems which are found in more humid zones and are characterized by some degree of interaction/linkage between livestock and crop production;

- Landless livestock production systems for which the importance of land for livestock production is insignificant, and which are nearly independent of ecological conditions.

Three components make up a livestock production system. These can be used to develop a conceptual framework for research studies (Lhoste, 1993). Each component is characterized by some specific attributes whose description and analysis lead to study one or more aspects of the subsystem. These components are:

- A human community characterized by its social organization, the management skills of its members, their production goals and preferences;

- An area of land territory that sustains the natural resources (plants, soil, water) which are utilized by human and by livestock to meet their specific needs. The availability and the quality of such resources depend on physical and climatic factors such as rainfall, temperature, soil, topography, and on management practices etc.

- A livestock population which converts the energy derived from the natural resources into products readily usable for human consumption (milk, meat, fiber) and provide also other inputs (draft power, fertilizer) necessary to sustain crop production and to maintain the equilibrium of the environment.

2.2. Methodologies for Livestock System Research of Small Scale Farms

2.2.1. On-station based Research and On-farm Interdisciplinary Studies

On-station research has largely remained disciplinary and commodity oriented, using the classical top down approach where the conception of research programs and the execution of research activities seldom accounted for farmers' needs. Conventional on-station component research usually concentrates on one single aspect of the agricultural system (e.g., livestock, crops) to investigate a specific biological phenomenon or physiological process of animals or plants (e.g., breeding, ration formulation to meet some specific production objective, forage crop production, fertilization, etc.). Research programs are seldom developed as a response to real problems and constraints faced by farmers for whom technological improvements are designed. Consequently, most of the results from on-station, disciplinary research do not fit into the production environment where they must be transferred. They need to be adapted to particular conditions prevailing on the terrain. A system-oriented approach to livestock production research, on the other hand, emphasizes the interrelations between system components (Sidamed and Koong, 1984). It starts with and understanding of the whole component of the production system, analyzes all constraints and potentials, identifies appropriate research priorities and tests these on real situations (i.e.,farms). This process involves an interdisciplinary approach and a transfer of most research activities from the station to the farm. The sequencing of livestock systems research identifies four activities during the research/development process (ILCA, 1990):

- The descriptive/diagnostic phase: its main objectives are (1) to describe the production system, (2) to divide farmers into homogeneous groups on the basis of socio-cultural, environmental, institutional and economic characteristics, and (3) to identify factors which limit production and determine scope for improvement.

-The design phase during which researchers focus on technologies that are compatible with the resources and objectives of producers and consistent with the system features identified during the descriptive/diagnosis phase. Priorities are given to adaptive research or adaptation of technologies already developed by commodity research.

-The testing phase whose purpose is to test solutions proposed during the design phase by on-farm trials.

- The extension phase aimed at assessing the impact of new technology in a wider scope.

A variant of farming system research has been applied on research stations by certain institutions like the International Center for Agricultural research in Dry Areas (ICARDIA). The process involves simulation of whole farm systems on research stations by copying the actual farm environment. This approach, which uses a model farm, has some drawbacks, some of which are the lack of replication of treatment and the inability to simulate the behavior and management of farmers and cannot therefore be considered as real on-farm research. On-station-based and on-farm research are not substitutes for each other, and both are needed. They focus on different things that may be complementary to each other. On the experiment station, applied research is usually undertaken in which new technologies are created, while on-farm research concentrates on adaptive research, which involves adjusting technologies to specific environmental conditions. The farming systems research team should provide the feed back information about research priorities and problems for applied research on experiment stations. On-station research also plays an important role in technological development and evaluation. There may be situations where on-station research is more relevant than on-farm research. Such conditions are: (1) when for instance, new technologies need to be developed before on-farm testing; (2) when clear understanding of complex relationships is needed, and control must be exerted on both experimental and non-experimental variables.

On-farm trials (comparative experiments) are sometime difficult to implement and their execution may be disturbed by farmers' behavior which in turn, may complicate the analysis and interpretation of statistical results (unwillingness to participate, moving animals across treatments, disposal of trial animals, loss of interest while experiments are already implemented).

2.2.2. On-farm Livestock Performance Testing as a Research Tool for Production System Analysis

Animal performances probably represent the single measurement most used to evaluate the productivity of livestock systems. The response or indicator of system productivity in livestock/range research is often based on measurement of animal performance. Livestock performance reflects the intrinsic productive capacity of animals (genotype) and their interaction with the production environment (e.g., climatic and other related variables, nutrition, and husbandry methods). Evaluation of livestock performance thus represents a key component of system analysis and evaluation. Livestock performance will, however, be of little use if the factors which affect performance are unknown or unstated. To be of practical use in systems analysis, livestock performance testing should be coupled with complementary studies on other factors such as current states of resources and their utilization, diseases, management practices, and economic conditions (ILCA, 1990). Livestock performance testing and analysis represent therefore an integrated research tool, which focuses on relationships between production performances and environment. As a research tool, livestock performance testing is concerned with the estimation of performance traits of economic importance and the identification of major sources of variability. Environmental variables refer to any factor that may affect production performances, except those from genetic sources. These may be either characteristics of the animals (e.g. age, sex, physiological status), of the natural resources which are exploited (e.g., fluctuations in feed and water supplies), of current diseases, or of the managerial ability of herd owners. Livestock performance testing has long been applied on research stations, but its adaptation in the context of on-farm research studies is relatively recent for traditional Sub-saharan livestock production. In most situations, standard methods applied on-station need to be adapted to fit contexts prevailing on the farms.

2.2.3. Methods of Data Collection for On-farm Livestock Performance Evaluation

Several criteria (number of visits made for data collection, single or multiple subject study, longitudinal or retrospective sampling, etc.) may be used to classify methods used for studying animal production in the context of livestock systems research.

2.2.3.1 Single Visit Versus Multiple Visits Surveys

Certain attributes of animal performances may be studied from data collected from a single visit. This is the case, for instance, when one wants to determine herd structure or to get rough estimates of components of overall herd productivity (e.g., mortality, offtake, fecundity). This type of survey is not, however, suitable when observations or measurements are needed over prolonged periods of time as is the case, for instance, when one wants to estimate individual growth curves of animals and multiple visits must be used instead.

2.2.3.2. Cross Sectional, Retrospective and Longitudinal Sampling

Cross sectional sampling involves collecting information by recall or direct observations on one or more variables from a single visit made at some specific point in time. Based on the way data are obtained, cross sectional studies can be further categorized into retrospective or case control studies. In case control studies, the data collected corresponds to some attributes that are observable or measurable on the sampled units at the time of visit. Retrospective sampling, on the other hand, collects historical information. Cross sectional sampling schemes for studying structure and dynamic attributes of livestock population were developed by the French Institute of Livestock Husbandry and Veterinary Medicine for Tropical Areas (IEMVT) and applied in some countries of Africa and Asia to obtain baseline data before the implementation of livestock development projects or for rapid diagnosis of production systems (Lhoste et al., 1993). Herds are selected within the target area, and within each herd, animals are inventoried and classified on the basis of species, breed type, age and sex. In addition, the past history of all breeding females is constructed by interviews of the herd owners to determine the total number of births and abortions, and the age at which such events occurred. Finally, information is collected on the fate of each birth to determine whether the offspring was still present in the herd, died, sold, slaughtered or lost for other reasons. Analysis of such data establishes herd composition and approximates various measures of herd dynamics and performances (e.g. fecundity, mortality, off-take, etc.).

In longitudinal studies, study units are followed through time for the occurrence of some events (e.g., death, calving, etc.), or for continuous monitoring of some process (e.g., reproduction, growth, milk production etc.). Herd dynamics and performance monitoring has become increasingly of interest in recent years for livestock production system research studies, not only as a tool for system description and diagnosis of constraints, but also as a method for evaluating impacts of a livestock development project. Long term monitoring of animal performances at the farm or village level is being widely utilized by the International Livestock Center for Africa (Wilson, 1983; Wilson, 1986; Agyemang et al., 1991; Little et al., 1994).

2.2.3.3. Non-Experimental Versus Experimental Studies

Non-experimental (or observational) or experimental studies are utilized in livestock system research, depending on the study's goals (diagnosis of problems, design or testing of new technology). In observational studies, no changes are introduced into the system and the research goals are primarily directed toward a better understanding of the structure and functioning of the system under prevailing conditions (description/diagnosis). The problem with non-experimental research is, in most circumstances, it may not be appropriate to draw causal inferences. Experimental research on the other hand, requires introducing some prior change (s) or treatments into the system and the main objective is to test some hypothesis about the effects of such changes.

System analysis by using mathematical modeling is another tool utilized in livestock system research (Krover and Arendonk, 1988). System analysis is a way to understand the complexity of interrelationships among components of systems and to derive estimates of their outcome (ibid.). Models are mathematical expressions, which are developed to provide a simplified view of components of a system and their interaction. They may be useful in describing the structure and function of systems, in predicting possible outcome of experimentation, and in providing information about changes in a system that may be too expensive to obtain from real manipulation.

2.2.4. Variables and Attributes Used to Describe Herd Dynamics and Performance

2.2.4.1. Demographic Attributes and Demographic Analysis of Livestock Populations

Demographic analysis is concerned with the description or prediction of some characteristics of the population such as its size, structure and change (Henry et al., 1979; Lynn et al., 1970). Size refers to the number of units in a population, structure defines the distribution of the population among its sex and age groupings, and change relates to growth or decline of the total population or of its structural units. The components of change in total population are comprised of: births, deaths, immigration and emigration. Most methods in demography are based upon the decomposition of population changes into its components to estimate some relevant parameters. This process may be schematically expressed in terms of a balancing equation:

$$N_{t+1} - N_t = \text{Births} - \text{Deaths} + \text{Immigration} - \text{Emigration},$$

N_{t+1} and N_t are the respective sizes of the population at instants t_{+1} and t. Immigration or inflow refers to other entries in the population such as purchases, gifts, etc.

Emigration or outflow refers to exits other than deaths; they represent the components of off-take (e.g., sales, slaughters, etc.).

The life cycle of a population is characterized by a series of events which contribute to modify permanently its size and structure. These attributes describe a state of transition of the population at any point in time and are thus referred as "static variables " (Landais and Sissoko, 1986). This term may however be misleading because, as we mentioned earlier, size and structure reflect dynamic processes that have taken place in the population.

2.2.4.1.1. Evaluation of Livestock Numbers

Data on livestock numbers are important and needed for many purposes including to value herd productivity, or to determine the pressure exerted by livestock (e.g., stocking density, stocking rates, etc.) on the natural resource base. Data on livestock numbers may be collected either at the household level or at the regional level by means of sample survey or census using direct or indirect methods.

Indirect methods for estimating livestock numbers may be based on either (1) available secondary data sources such as government statistical reports, extension statistics, or veterinary records, or (2) information generated from farmers' interviews during household surveys. Use of secondary data may not give accurate results for diverse reasons (Landais and Sissoko, 1986; ILCA, 1990). Though these methods may lack accuracy and precision, they are widely utilized because they are easy to use and represent in most situations the only means to get rough approximations at low costs.

Direct methods for livestock inventory involves use of aerial or ground field techniques.

-Aerial inventory is mostly suited for use in large areas with low tree canopy. The aerial survey method most commonly used in Africa is the Systematic Reconnaissance Flight method. For more details on the technique refer to ILCA (1990).

-Ground field techniques are also widely applied in complete census and involve direct counting of animals present at certain preferential sites of concentration of livestock such as watering points. One technique was proven to be successful and relatively easy to carry out in the context of the pastoral production system in the Ferlo region in Senegal (Barral et al., 1983). The method takes advantage of permanent watering points (boreholes) which are the sole facilities available for watering livestock during the dry season period. In this pastoral production system, frequency of water use by livestock during the dry season period is a function of the distance that separates village homesteads from the boreholes. A preliminary survey must be conducted to determine the different frequencies of water use by livestock. This is achieved by interviewing a sample of herders selected at a given day within the target area. This interview is followed by a direct inventory (using ground field technique) of the total number of animals driven to the watering place during one complete day. The estimation method is better explained by an example. Suppose that a preliminary survey conducted in the area has established that: 10%, 70%, and 20% of livestock present in the area is watered with frequencies of once every day, once every other day and twice every day, respectively. This information is used to stratify the livestock population present in the area into three groups, each of which is characterized by:

-The probability (pi) of an element in the stratum is counted at any given day at the watering place, with values equal to 1, 0.5, and 2 respectively for animals which use the watering facilities once every day, once every 2 days and twice every day);

- The contribution (fi) of units in that stratum to the total population, with respective values of 10%, 70% and 20%.

Suppose that an inventory carried out on a given day gives a total number C= 600 animals utilizing the borehole. This value represents a proportion (Q) of the total number of livestock present in the area (N) approximated from the available data by the following formula:

$$Q = \Sigma\,(pi * fi).$$

Applied to our illustration case, we have Q= (0.1*1)+ (0.8* 1/2)+ (0.2*2)= 90%. This means that, for any given day, the number of animals counted at the watering place (C) represent a known proportion (Q) of the total population (N) present in the area. The derivation of N follows:

$$N = C / Q.$$

Applied to data from our example, this yields N = 600/0.9 = 667 animals.

Other methods were developed which combine both direct and indirect techniques of survey/census and applied in the Ferlo region (pastoral production system in northern Senegal).

-A method based on the total volume of water extracted from the boreholes and used for human and livestock consumption was developed by Diop et al. (1991). The technique requires prior knowledge about: (1) the volume of water extracted daily from the borehole , and (2) the proportion of the total extracted water which is utilized for human consumption (which is determined from a sample survey of pastoral family household). Assuming that the total volume of water extracted daily from the borehole is entirely utilized for human and livestock need, he derives a formula for estimating the total number of TLU (Tropical livestock Unit = equivalent of 250 kg live weight of livestock) present at a given site at specific point in time which has the following form:

$$E = d*h / q*(1-a)$$

E= total number of animals (expressed in TLU) that have utilized the watering point on a given day;

d = the power of the engine used to extract water from the borehole (expressed as volume of water extracted per unit of time);

h= length of time of operation of the engine used ;

d*h = total volume of water extracted from the borehole;

q = water requirement of livestock (expressed as unit of volume / TLU).

a = proportion of total volume of water extracted and used for human consumption;

When collecting data on livestock numbers at the household, attempts may be made to distinguish between ownership and holdings. In fact in almost all situations, all animals in a herd are not entirely owned by members of the family household of the herd manager and, conversely, the household unit may split their belongings into different management units as a strategy to manage risk.

2.2.4.1.2. Age Determination of Livestock

As defined earlier, structure results from classifying the units of the population into sex and age classes. Methods for estimating age of animals are therefore needed to establish herd structure. When birth records are kept by herd owners or are available from long-term surveys, it becomes easy to know the exact age of animals in a population at any point in time. However, in traditional livestock production systems in Senegal and many countries in Sub-Saharan Africa, such information is not routinely recorded, and we must rely on other techniques for age estimations. Two techniques are generally used in livestock surveys, either individually or in combination. The first one is based on herd owners' interviews, and the other calls for examination of some of the animal's apparatus, such as its dentition or horn to get an approximation of age.

-Methods by interviews heavily rely on the respondent's memory. The choice of respondents is often crucial for obtaining accurate and reliable data. It is often desirable to have several persons answer questions in the form of group interviews. In the context of traditional livestock production systems in Senegal, presence of both herd owners, herders and of other members of the herd owner's household family is desirable to minimize errors due to memory deficiencies (Landais and Sissoko, 1986). Interview methods are simple because they do not require manipulating the animals, and they work well if only rough approximations are desired in the form of herd composition, which is a simplified structure obtained by grouping some of the ages into classes.

-Ageing by dentition is based upon some established relationships between the chronological evolution of teeth with age (number of deciduous or permanent teeth and their wear) with age. The method requires use of standards tables established from previous studies and specific to the breed and management system under study. Use of inappropriate tables established from studies of exotic breeds to establish herd structure of indigenous breeds in tropical areas has yielded misleading results. The dynamics of teeth eruption and their dynamics of wear are influenced by management system and feeding regime (Landais, 1983; ILCA, 1990).

A final note about age determination is, in most situations, accuracy and precision may be gained by tallying information from parent related subjects. This helps sometimes detect and correct for some inconsistencies.

Data on herd structure may be used in rapid survey to gain insight about producers' management objectives (e.g., production of meat, milk, draft power or multiple functions), or to obtain rough approximation of herd dynamic attributes such as annual reproduction rate, off-take and mortality rates.

2.2.4.1.2. Interspecies Composition of Livestock

The total number of animals inventoried within a given area may not be homogenous and are often comprised of diverse species, age classes and sex. Interspecies composition of livestock refers to the relative contribution of the different animal species as a proportion of the total population size. Different animal species and animals of the same species, but in different age classes tend to weigh differently. These differences result in different pressures they exert on resources (e.g., feed and water supply, nutrient requirements). It may therefore be more relevant to use a standard unit to express the interspecies composition of livestock. Tropical Livestock Unit (TLU) is the metric commonly utilized to express animal biomass in Sub-Saharan Africa. This is defined as the equivalent of 250 kg of live weight. Conversion units to express different livestock classes to TLU equivalent are available (Jahnke, 1982; ILCA, 1990).

Interspecies composition of herds or flocks may be used in system description/ diagnostics. Mixed species composition may indicate whether or not competition for feed resources is likely to exist, as different animal species tend to have different preferences. It may also be a means utilized by producers to ensure security in case of epidemic disease or drought. Not all livestock species are sensitive to the same diseases and different species may be complementary for meeting basic household needs throughout the year.

2.2.4.1.4. Cattle Reproductive Performances

Biological phenomena that determine the reproductive capacity of livestock are important to consider for the economics of livestock enterprise in traditional production systems in Senegal. In these systems, the herd represents a capital investment that must produce enough to meet the basic consumption needs of people and to generate cash through sale of excess production. Additionally, the herd capital must also be renewed from internal growth (i.e., reproduction). Such functions first bear on the capacity of female livestock to produce their first offspring in their early lifetime, the frequency and regularity at which they give birth in subsequent years, and the ability of their offspring to survive to marketable or reproductive ages. Such attributes are grouped into what we refer to as reproductive and rearing capacity of females. These attributes reflect biological aptitudes of animals and their interaction with environmental variables (climate, nutrition, management etc.). Several reproductive traits may be utilized as indicators of the breeding efficiency of livestock: age at first birth, intervals from birth to first subsequent oestrus, pregnancy rate, birth intervals, annual reproduction rate, abortion rates, etc. Most parameters presented are relatively easy to determine under specialized production systems where breeding is controlled. This is not, however, the case in most traditional systems in Senegal where there is no choice of breeding season, or systematic oestrus detection, and where all animals are kept in the same management units regardless of sex or age. Mating occurs as breeding females show oestrus and meet a sexually active male. Early abortions in most circumstances go unnoticed and reproductive efficiency is at best evaluated on basis of live births which is used to estimate parameters such as annual reproduction rate, age at first birth and birth intervals.

2.2.4.1.4.1. Age at First Calving

Age at first calving is important because it enables one to approximate the mean age at which female livestock reaches sexual maturity and start their reproductive career. Age at first calving is measured exactly by the length of time interval elapsed between the animal' s birth date and its first calving date. Assuming a fixed immutable length of gestation period, age at puberty is approximated by subtracting the average length of gestation from the estimated age at first calving. Age at puberty approximated this way tends however to be biased upward for at least two reasons:

1) Animals may show oestrus and not have a chance to be mated if they do not have the opportunity to meet a sexually active male and,

2) Not all mating will result in impregnations, and some pregnancies will not necessarily be carried until birth.

2.2.4.1.4.2. Calving Interval

Birth interval measures the length of time interval elapsed between successive births. It is the second attribute of breeding female livestock, which determines the total number of offspring a female can produce during its reproductive career. That is why its utilization as an indicator of breeding efficiency is largely justified. But this performance trait alone does not tell the whole history about the physiological process of reproduction. It takes into account only live births, ignoring foetal deaths and other reproductive problems such as abnormal oestrus behavior. Another problem in using calving interval as a measure of reproductive efficiency in traditional livestock production system is that, it tends to attribute all the variability in reproductive performances to females in the herd, ignoring the males. The reproductive performance of male animals is assumed stable. Semen quality of bulls can be variable in association with season or variations in feed regimes (Sauveroche and Wagner, 1993).

2.2.4.1.4.3. Annual Reproduction Rate or Annual Calving Rate or Fecundity

Annual reproduction rate, sometimes referred to as annual calving rate or fecundity, is a widely utilized trait for assessing reproductive efficiency. It is defined as the average number of live births per breeding females per year. Fecundity expresses the percent females in the herd that give birth during a year. Based upon earlier discussion regarding the management of breeding herds in traditional systems, it may be difficult to find a good estimator for this trait. The main problem resides in the proper identification of which animals to include in the category of breeding females (denominator of the ratio) and how to determine their numbers. There is no control exerted on mating, and animals may exit the herd before the end of the year while they are pregnant or other females may be brought into the herd at any time of the year and must be accounted for some way. In specialized production systems with controlled mating, there is usually a choice of a single breeding season, and cows may be inseminated when they show oestrus during the breeding season. Under such circumstances, one should use the number of females inseminated in the denominator of annual reproduction rate. But, in traditional system, the choice is not obvious. Landais and Sissoko (1986) argued that one way to deal with this problem for ruminants in Senegal was to use the average number of cows aged at least 4 years old evaluated at mid-year interval in the denominator of the estimator of fecundity. The choice of age four years and more was justified on the premise that a female cow, on average, produces its first calf at age five years and is therefore ready for breeding at age four years. The evaluation made at midyear interval was introduced to correct for potential bias due to inflows to and outflows from the herd of the number of breeding females during the annual production cycle.

Other criteria exist for assessing breeding efficiency of a livestock system either at the herd or individual animal level (ILCA, 1990).

Many survey techniques exist which may be used to estimate reproductive traits of livestock. These can be classified into (1) retrospective studies based on once only recall methods or (2) long-term longitudinal survey involving repeated visits.

- The most common type of retrospective study used in livestock performance surveys is the so-called progeny history method. Based on herd owner's interview and coupled with direct observations, the method involves a reconstruction by means of retrospective sampling of the reproductive career of each breeding female present in the sample herds (number of live births, abortions). The approximate ages (for the female) at which these events occurred are also recorded. Offspring, which are still present in the herd by the time of the visit, are identified and information about their sex and function in the herd recorded. If they are no longer present in the herd, the reason and age of exit from the herd are also determined. This method has been widely applied by ILCA, (1990) and by the French Institute for Livestock Husbandry and Tropical Medicine (IEMVT) as a rapid survey method to collect baseline data on livestock performance prior to the implementation of development projects or prior to long term surveys.

- In long term, longitudinal surveys, reproductive events such as live births, abortions and still births are recorded continuously from frequent visits made to sample herds. During such visits, all reproductive events that had occurred between two successive passages of enumerators are recorded by continuous recall. The accuracy of data obtained using this type of survey depends primarily on the spacing of visits. Longer spacing results in less accurate results due to potential memory deficiencies. Long term survey methods require more resources (e.g., labor, time, and cost) than do retrospective surveys, but permit collection of more reliable and more accurate data. When data are collected by retrospective sampling, fecundity or annual reproduction rate may be estimated using one of the following estimators:

1) The ratio of total calves (animals under age 12 months) to reproductive females present in the herd at a given point time, using information on herd structure: This estimator is likely to be biased for two reasons. The first reason is that permanent flows

of animals between herds result in high variability of either the number of calves or the number of breeding females present, depending on the period of the year data are collected. For instance, some live births may have died before the visit was made to the herd and will not be accounted for. Also, any circumstance, which causes the number of breeding females to vary will tend to bias the estimator of annual fecundity rate. Such problems may be avoided by using a retrospective or prospective sampling scheme which records all births which occurred and the exact length of time period each breeding female was at "risk of giving birth" during the time interval of evaluation (e.g. number of days present in the herd).

2). The estimated slope of a regression line of the number of live births on dam's age. When the breeding history of females is established from retrospective sampling, the data may be arranged in the form of a bivariate series with one representing the age of females at birth and the other the parturition or birth number of the dam. A regression equation may be fitted to the data points with the number of births treated as the response and dams' age as the explanatory variable. The slope of the regression line (assuming a linear relationship) may be used as an approximation of fecundity. In addition, age at first birth can be estimated with the mean age of cows at which the average number of calves produced is equal to unity.

3). 365 (e.g., the average number of days in the year) divided by the length of interval between successive calving, has also been as estimator of herd fecundity. For instance, if all females in the herd tend to calve each year, then the length of interval between births is 365 days, and an estimate of annual percent fecundity is 100%. When mean age between successive births is 730 days, animals give birth on average on alternate year and an estimate of annual fecundity from the length of birth interval is 50%.

2.2.4.1.5. Mortality, Offtake and Analysis of "Time to an Event Data"

Mortality of young stock was reported to be a major cause of low productivity in many livestock production systems (ILCA, 1990). Mortality rates tend also to be irregularly distributed across age. High immediately following birth, it tends to decrease for immature and adult stocks and increases thereafter as animals get older. It is thus more appropriate to estimate age-specific mortality, rather than a single value averaged across all ages.

Components of gross offtake on the other hand are represented by exits from the herd, except those which result in losses (mortality, predation, accident, etc.). These involve voluntary disposals in the form of sale, slaughter, exchange, given away, etc), and are comprised of disposals for commercial (sales, exchanges) or non-commercial purposes (transfer between herds, gifts). Unlike other demographic attributes of livestock, which are determined to a large extent by the interaction between biological aptitudes of animals and environmental variables, off-take parameters bear almost entirely on herd owners' decisions, though such decisions may be taken from response to environmental concerns. This is the case when for instance high rates of de-stocking are observed following dry years or conversely, when producers accumulate stocks during favorable years.

Analyses of demographic events such as births, deaths, sales or other form of exits from the herds are needed for evaluating the dynamics of livestock populations.

Demographic measures such as proportion (or percentages) and rates are estimated from analysis of demographic data. In demographic studies, the outcome of interest is often either (1) the length of time since a fixed designated point until an event occurs, or (2) the proportion of individuals in a population (or subgroup of a population) who have experienced an event at a specific point in time or during a specified time interval. The probability of an event may be defined as the proportion of individuals in the total population (or subgroup of a population) which have the outcome of interest at a specific point in time or during some defined time interval. Probability or percentage measures have no units of measurements since both the numerator and denominator are measured on the same metric. The rate at which an event occurs in the population or in a subgroup of the population refers to the number of units that have experienced the event of interest over a defined time interval divided by the length of the time interval during which evaluation is made. Its metric is the number of events / time interval. "Time-to an event data" has special structure which make conventional statistical methods such as least squares procedures of ANOVA or regression inappropriate in most circumstances. Analysis of time-to-event data goes by the name of survival analysis, in reference to mortality event; but this term is generalized and used even if the outcome of interest is not death, but something else. Problems encountered in the analysis of time-to-event data and appropriate methods to use are best explained by means of an example. Suppose a producer is interested in estimating the proportion of calves born from his herd who survived beyond ages 3, 6 and 12 months (or equivalently died before these ages). He wants also to know how the risk of death is related to the animals' age. He spents some time starting from an origin to record all births which occurred in his herd, the date (or age intervals) at which these occurred, as well as any other events (e.g., sales, and transfers), until he decides to analyze the data. At the time of analysis, animals in the herds were followed for various lengths of time because they were included in the survey as they were born. Also, the outcome of interest (i.e. dead or alive) will not be known for some of the animals, which were sold or transferred to different herds within the interval ages of interest. Such cases are referred to as censored, because we do not know whether or not the outcome of interest occurred during the specific time interval of interest. For illustration purposes, suppose he recorded a total of 100 births. Out of these, 5, 8, and 3 were sold and 4, 2, and 6 died in the intervals 0 to 3, 3 to 6 and 6 to 12 months respectively. Under such circumstances, how would one estimate correctly the probability of dying in each of the 3 intervals from birth to12 months old? An initial step in the analysis of "time-to-event" data is to estimate the survival function and the hazard function. When there is no censoring, the survival function is defined as the probability that an individual survives for a time (or age) greater than or equal to some time t, which is estimated by dividing the number of individuals with survival times greater than or equal to t by the total number of individuals in the sample. In our illustration, if for instance all animals were observed for at least 12 months at the time the survey was terminated, and there was no loss to follow up (e.g., sales), the proportion of animals who survived at least until the age t would be estimated by the number of subjects with survival time greater than or equal to t divided by the total number of births. This calculation would give values of 96%, 94% and 87% for ages 3, 6 and 12 months respectively. To obtain estimates of the probabilities of dying before these ages, we just take one minus the probabilities of surviving. But this calculation is not correct because it assumes that the 5, 8, and 3 animals which were sold did survive at least until 3, 6, and 12 months old, which cannot be verified. To integrate censored cases in the calculations, it is necessary to modify the estimator in order to adjust some way for the incomplete length of observation time of the sold (i.e censored) animals for which, we do not know much, except that 2 of them did survive at least until 3 months of age and 7 of them survived at least until 6 months of age. Another option would be to discard all censored observations and work with the non-censored cases, but this would bias the survival probability estimates. Appropriate methods for dealing with survival data in the presence of censoring call for correct determinations of the adjusted number of individuals at risk of experiencing the event (for probability estimates) or of the total time each subject was at risk during the time interval of interest (for rate estimation). To be included in the risk set within an interval age defined by its lower and upper bound t and t_{+1}, a subject should have lived and not be censored at least until the age t. The contribution of a subject to the total time at risk is the exact length of time of time it was observed to be at risk of experiencing the event of interest. When the exact time at which subjects died or were lost to follow up is not known, but only the interval, like in our illustration case, an unbiased estimator for the proportion (or probability) of death in any given interval (say, the i^{th} interval defined by its lower and upper bound t_i, t_{i+1}) is given by following form from the life table method:

$$q_i = d_i / n'_i$$

q_i is the probability of dying in the interval;

d_i is the number dying within the interval

n_i is the number of animals surviving and not censored at least until time t;

$n'_i = n_i - s_i /2$ is the adjusted number at risk of experiencing the event;

s_i = the number of animals sold (censored) during that same interval.

The formula shows that the adjusted number at risk during an interval is estimated by assuming that when a subject was censored during an interval, it was at risk for only half of the interval, and contributed just to half a subject). An estimator of the hazard rate of dying at the mid-point interval using the life table method calculation is:

$$h_i = d_i \; / \; w_i * (n'_i - 0.5 * d_i)$$

w_i = the length of the interval width between times t_{i+1} and t_i.

The formula for the hazard indicates also that each subject contributes just the length of time it was followed up. This is equal to the entire length interval when an animal survived and was not censored at least up to time t_{+1}, and only half of the interval length when they died or were censored.

Both non-parametric and parametric methods are used for estimating survival and hazard functions in the cases of censored observations. Non-parametric or distribution free methods make no assumption about the underlying distribution of the survival time. The best known non-parametric methods for estimating the survivorship function are the life table (Gehan, 1966) and product limit (Kaplan and Meier, 1958) methods. The survival function from the life table method is obtained first by dividing the entire interval into a series of discrete sub-intervals (t_i, t_{i+1}). Then, for each sub-interval the conditional probability of dying conditionally upon having survived and not being censored until the beginning of the sub-interval t is computed. One minus this quantity provides an estimate of the probability of surviving. The products of the conditional probabilities of surviving for all intervals up to the age of interest gives an unbiased estimate of the survival function:

$$S_i = \Pi p_j;$$

$p_j = 1 - q_i;$

For instance, in our example, the number of animals at risk of dying in the age interval from 0 to 3 months is obtained by subtracting from the total number of births half of the number of animals which exited the herd for reasons not related to death, and half of the subjects which had not yet reached 3 months old by the time the study was terminated for analysis. For the next interval (i.e. 3 to 6 months), we subtract half of the number of censored cases observed to fall in the interval 3-6 months from the total number of animals which were alive and not censored just prior to age 3 months. As mentioned, this method assume that all censoring cases occur at the mid-age interval, and each contributes just to one half of the total time at risk in the interval. Estimates of survival curves may be biased when, for instance, all censoring occur at the very beginning or end of intervals. Also, another assumption for the life table method to yield valid results is that censoring should not be informative. For instance, if all the censored animals in our illustration case were sick and in critical condition before they were sold, estimating the survival curve using this method would not be quite right. If the exact date of birth and of exit were known for each animal in the herd, it is possible to get a superior estimator of the hazard rate. This would be obtained by dividing the total number of deaths observed to fall within any interval by total time at risk contributed by all subject in that interval.

This latter term is estimated by the sum of the individual times for which animals were followed up.

The hazard formula is given by:

$$h = d / \Sigma O_i;$$

h = hazard rate;

ΣO_i = total time at risk;

O_i = sale date – birth date if the animal was sold;

O_i = death date – birth date if the animal died;

O_i = end date of the survey - birth date if animal still alive at the end of the observation period.

The Kaplan Meier estimate of the survival function is similar to the life table method, but intervals are constructed such that their limits correspond to the death times recorded for individuals in the sample data set.

When comparison of the survival experience of two or more groups is of interest, as will be the case in controlled experiments, plots of the survival curves using the same axis provide a visual assessment of the difference, if any. Formal methods for comparing survival experiences between groups, using non-parametric tests such as the log-rank and Wilcoxon tests also exist. However, these methods for comparing survival curves are limited when the number of groups involved in the comparisons increase, and we need some kind of mathematical expression to model the hazard function, which can incorporate covariates or indicator variables for group membership. Cox (Cox and Oakes, 1984) provided a mathematical model for survival analysis. Cox model is a semi-parametric model in that it does not specify any underlying distribution for the survival times. But it does assume that the ratio of the hazard of death for any two individuals does not depend on time (proportional hazard assumption).

Several parametric methods exist for estimating and comparing treatments where the outcome of interest is the length of time until some event occurs. These methods assume an underlying known distribution for the survival time. Common assumed distributions for survival times include the exponential, Weibull, log-normal, log logistic, etc. Techniques for fitting Cox and other parametric models are given in the literature (Cox and Oakes, 1984; Lawless, 1982; Collet, 1994; Kalbfleish and Prentice, 1983).

2.2.4.2. Measurement and Analysis of Live Weight Data

Live weight is probably the most common measure of animal performance in many livestock studies. Measurements of live weights include direct and indirect methods.

-Direct methods for measuring live weight of animals are based on use of weighing scales. The time of the day when animals are weighed must be chosen to minimize variations in live weight due to gut fill.

-Indirect methods of live weight measurement may be based on known relationships between live weight and some other linear measures taken on animals such as height at withers, or heart girth. In a study involving Ndama cattle kept on research station at Kolda, Fall et al. (1982) found heart girth to be the linear measurement which was most correlated with live weight.

- Indirect estimation using visual appraisal using body condition scoring systems are also used as a means of assessing the general nutritional status of livestock when adequate standards are developed. This method is particularly useful for pregnant cows for which, live weight changes may not be representative of the animal's nutritional status because of gestation effect. Condition scoring however relies on a subjective assessment of animal condition.

Depending on the study's objectives, diverse sampling methods may be used to determine live weight and live weight gain. If the aim is to establish an overall growth curve or to obtain an estimate of the mean live weight of animals in different classes, a single visit may suffice. Animals of different age and sex classes are weighed at one point in time. Since the observations will be independent, they can be used in conventional methods of analysis of variance or regression. However, in most circumstances, particularly in long-term surveys or in controlled experiments, weight of animals is often monitored over time. The objective is to model the process of growth under natural conditions or the response of animals to treatments (e.g., drug, feed supplements, etc.). One peculiarity of data obtained from such studies is that the observations on weight measurements made on the same subjects at different points in time are correlated and not independent. Data sets with such features are referred to as repeated measures and require special tools for appropriate analysis. Repeated measures data may have different structures depending on whether or not the animals whose characteristics are monitored over time are classified into two or more treatment groups. Methods used for analyzing data having repeated measures structure are presented in the biological and statistical literature where a variety of techniques have been proposed to handle the problem posed by correlated observations (Wishart, 1938; Kowalski et al., 1974; Snee, 1979; Kenward, 1987; Everitt, 1995; De With et al., 1996).

In controlled experiments, the questions of interest often call for testing some hypotheses about:

1) The effect of some treatment on the growth response of animals;

2) The functional form of the response (growth) during the course of the experiment or time effect (e.g. is the growth response of animals to the treatment constant, increasing, or decreasing with time);

3) Whether or not the effect of the treatments depends on time (hypothesis about treatment by time interaction).

Methods proposed for analyzing repeated measures data fall into one the following procedures depending on the study's objectives and questions of interest:

- Comparison of treatment effects at each individual time point using standard methods of analysis of variance procedures. For instance, the response of animals to treatment may be compared at 1, 2, 3 weeks after the treatment was applied, by individual analyses performed on the response measured at each specific time. This analytical method gives valid statistical results and is meaningful when each specific time is of interest. It is not however efficient since it requires performing as many analyses as the number of time points of interest. Also, it does not provide any way of testing whether there was a time trend in the response of subjects nor does it provide information about a possible treatment by time interaction. Also, the individual tests performed at each time point may not be independent when each time period is not of interest on its own (Everitt, 1995).

-Standard univariate analyses on selected summary measures computed from the series of repeated measurements on each animal such as the total weight change or the average daily weight gain observed during the course of the experiment. This technique has the advantage of simplicity. It enables one to apply conventional methods of analysis of variance or regression to test hypotheses about treatment effects, since the repeated observations on each subject are reduced to just one summary measure. However, it cannot address research questions related to time effect, and is therefore appropriate for use when only an estimate of overall group difference is needed. Precision for estimating treatment difference maybe improved by including baseline observations like the pre-treatment weight as a covariate in the statistical model (analysis of covariance).

- Mixed model analysis of variance: This method uses a mixed model which includes the fixed effect of treatment and the random effect of subject into the statistical model similar to the one used to analyze data generated by a split plot design. However, one fundamental difference between the repeated measures and the split plot designs is that, in the former, the repeated measures factor cannot be randomized on subjects, while subplot treatment factors in split plot designs are randomized. Therefore, the validity of the tests statistics about treatment and treatment by time interaction from such an analysis is only guaranteed under very restricted conditions regarding the variance-covariance matrix structure of the data set being analyzed. The form of the covariance matrix, which is assumed for valid test is referred to as the sphericity condition, which means that the variance for the difference between any two repeated measures taken on the same animal is the same (Huynh, 1970). When this assumption does not hold for the repeated measures, some adjustment is suggested which alters the degrees of freedom used in the

F-ratios. (Huynh, 1978). Using this method, it is possible to investigate research questions that pertain to the effects of treatment, time and time by treatment interactions.

- Repeated measures analysis of variance: When the assumption of spherical covariance matrix does not hold, an alternative is to use repeated measures analysis of variance. The technique known as profile analysis (Kowalski, 1974) allows testing of all three kinds of hypotheses in the context of an analysis of variance using a multi-variate approach. The method involves performing a series of simultaneous tests on a set of transformed variables, which represent contrasts among the repeated measures factor and their interaction with treatment. Common transformations used are the polynomial, profile (successive differences among the repeated measures), and contrast (difference between each of the repeated measures with one defined as a reference) transformations. The major drawback to using repeated measures analysis is that an individual must have complete observations on the response variable at all time points to be included in the analysis. This often reduces drastically the sample size if many observations are missing, which may result in significant loss of power to detect treatment differences. For instance, in our study, only 18 lactation records out of a total of 200 on the file were found to have complete records.

Most of the methods for analyzing repeated measures described above are straightforward to apply only under experimental conditions with uniform observation schedules, when all subjects are observed at exactly the same series of ages or time. In longitudinal non-experimental conditions, weight data arise in such a way that uniform schedules are unattainable in view of practical considerations, resource availability and efficiency. Weight is monitored over time on animals that were born at different times and the survey design usually determines a fixed schedule for herd visits to collect information. This introduces some other complications regarding appropriate and easily performed analysis methods to use.

2.2.4.3. Measurement and Analysis of Milk production

Milk production is another important criterion used to evaluate performances of livestock. Milk production is a sensible indicator of the nutritive value of the diet as changes in diet quality are quickly reflected in changes in milk yield. Milk yield is measured in the animal by using various methods including hand milking while the offspring nurses, weighing the calf before and after nursing, or machine milking after oxytocin injection.

Analysis of milk production data usually attempts:

1) To estimate total yield during a lactation cycle for individual cows, or

2) To model the variation in daily production associated with the length of time interval since parturition (stage of lactation) or season, under natural conditions or after some treatment (like feed supplements) is applied. These analyses are generally performed on reduced data sets obtained from repeated sampling made at some specific points in time defined by the survey method.

Wiggans and Grossman (1980) provide a general methodology for estimating total milk production from incomplete lactation records obtained from sample test days.

Methods for modeling milk production fall into the general framework of analyzing repeated measurements. An abundant literature dealing with lactation curve fitting is available (Wood, 1972; Goodall, 1938). But these studies deal primarily with specialized production systems with a dairy orientation, and most techniques use a non-linear model to fit lactation curves. Some linear models have been applied to lactation of dairy cows by use of polynomials or inverse polynomials (Papajcsik and Bodero, 1988). These techniques are useful in decomposing the lactation curve into interpretable features such as: total yield, peak yield and persistence. By developing such models, analysis centers mainly on describing the variation of production associated with the stage of lactation and they work well under planned systems of herd management. In the context of traditional livestock production systems, like the one prevailing in Senegal, estimating total milk production of cows is a difficult task due to the partial milking of cows for human consumption. Only that portion of the cow's milk production extracted is readily measured. It is possible to estimate the production consumed by the calf by weighing it before and after sucking, or by using conversion factors that allow estimation of the quantity of milk from the growth rate of the calf. Another difficulty under traditional system of herd management arises through temporary interruption of milk off-take which is often practiced during the hot and dry season (when production declines as a result of food shortage), and is resumed the next rainy season if the cow is still giving milk. This yields production records, which not only are measured at irregular intervals, but also have missing values at many time points, introducing further complications in the analysis.

2.2.4.4. Productivity Indices

Most livestock production systems in Sub-saharan Africa are multipurpose oriented. Animals produce meat, milk, and draft power, manure and other commodities.

Therefore, measure of their production performance should reflect these multiple functions. Also, some of the outputs derived from livestock like work and manure are difficult to measure and to value. Attempts to develop productivity indices by the International Livestock Center for Africa (Wilson, 1983; Wilson, 1986; ILCA, 1990) were in response to the need to combine the most economically important production performances into a single index, which may be used as composite indicator for the purpose of making meaningful comparisons of productivity. Productivity indices developed by researchers at ILCA integrate cow reproductive performance, viability and live weight of the cow-calf pair into a single measure (Wilson, 1983; Wilson, 1986).

2.2.4.5. Management Variables

Livestock producers have particular sets of objectives with respect to the stock they own or hold. Such objectives include production, income generation through sale of excess stock, and security, and will influence the way resources are utilized. The ability to make sound decisions in using such resources in order to meet specific objectives is referred to as the producer's managerial ability (ILCA, 1990). Components of herd management include herding, watering practices and water management strategies, and general husbandry methods (nutrition, breeding, etc.). Management is commonly cited as a key factor, which affects animal performance. Influence that management may exert on animal performance will depend on the state of resources (availability, accessibility, quality) within the production system, and comparison to assess management effect on herd productivity should be made between producers with similar resources.

CHAPTER 3

STUDY AREA AND PRODUCTION SYSTEMS DESCRIPTIONS

3.1. Physical Characteristics and Climate

The study area is located in the southern part of Senegal in the Kolda administrative region, which occupies approximately 21,011 sq. km (11%, of the land area in Senegal). The climate is classified as Sub-guinean with two distinct seasons: a rainy season from June to September and a dry season from October to May. However one may distinguish four seasons, based on average temperatures and rainfall. These are the early rainy season (May-June-July), the late rainy season (August-September-October), the early dry, or post rainy season (November-December-January), and the hot or late-dry season (February-March- April).

Mean annual rainfall in the area ranges from 900 mm in the northern part of the region to 1200 mm in the southern part, with much variability from one year to the next. Rainfall is unimodal with most precipitation falling during the months of August and September. Mean annual temperature averages 28 degrees Celsius with minimum values recorded in December - February (20 degrees Celsius) and maximum occurring in April and May (35 degrees Celsius). Relative humidity ranges from 97% in September to 21% in February.

Vegetation types are a forest in the southwest, and wooded savanna in the northeast. Major soils include the red and beige soils of the plateaus, which are used for pastures and cereal crop cultivation, and the grey or ochre soils present on sloping terrain, which are used for rain-fed rice, market gardening and orchards.

Relief is flat, rarely exceeding 40 meters. Topography is characterized by a sequence of plateaus of low elevation occupied by opened woodland forests, followed by a gentle back slope used for dry land crop cultivation and a valley which drains runoff water from upland sites. This last element of the topographical sequence supports the village homesteads, palm plantations and ends with a depression that stays flooded for the rainy season period, permitting rice cultivation.

3.2 Description of Production Systems

The traditional farming system in Kolda may be qualified as an agro-pastoral sedentary system with rotation fallow farming, and livestock rising. It is a mixed crop/livestock system, where almost all household families practice some farming activities based on rain fed cultivation of vegetables and cereal grain crops (millet, sorghum, rice, etc.) to meet basic subsistence needs, and cotton and groundnut for cash income. Approximately 90% of household units raise some livestock species (cattle, goats, sheep, horses, donkeys, and poultry) for various purposes including domestic consumption, sale to generate cash and inputs (e.g., fertilizer, draft power and transport) for use in cropping activities.

3.2.1. Pattern of Land Use

The availability of land is not yet a major constraint yet in the region. The quality of land is, however, variable across the region. Infertile soils, due to continuous periods of cultivation, without enough compensation for nutrient uptake from the soil by crops is a major constraint to agricultural production. The land tenure system also contributes to land and other natural resource degradation. A law passed in 1964 designated all land not registered prior to this date as part of the National Domain. Therefore, farmers or pastoralists only have the right of land on which they cultivate or graze their animals. But they do not have transaction rights on it, and the government can at any time redistribute any land not being used, or targeted to be utilized for national needs. The consequence of such an insecure system of land tenure is that people are hesitant to make improvements because at any time right of land use may be withdrawn.

A central aspect of the agro-pastoral system in Kolda is the spatial and temporal organization of land use. Land use pattern reflects the coexistence between crop and livestock activities. Three types of land use are identifiable within the village territory: the village homesteads, crop cultivated lands including fallow and natural pasturelands. Land areas used for dryland crop cultivation are arranged inon circles surrounding the village homesteads. A first circle of fields, which is generally contiguous with household yards, is continuously cropped with vegetables and short cycle cereals (maize). This area is regularly manured with household wastes and animal dung. Outside the first circle, there is a second one in which long cycle cereal food cultivation (sorghum, millet etc.) occurs. This area receives cattle manure, though not continuously. The last circle of cropping fields surrounding the village homesteads is reserved for cash crops (cotton and groundnut), sometimes in rotation with fallow. The local population differentiates between two types of fallow systems based on the duration of the rotation cycle: short duration fallow (with periods of rotation of 1 to 2 years) and long duration fallow (more than 3 years). Local population reports a general decreasing trend in both the proportion of total land area reserved to fallow and their duration in the rotation cycles, as a result of rapid population growth and immigration. Rice is cultivated in depressions, which are flooded by rainfall.

Native pastures occupy upland sites in the plateau zone, which delineates the boundaries between villages and the palm plantations in the valleys. Vegetation type in open forest zones of the plateau is classified as forest woodland savannah.

This classification of land between areas reserved for crop cultivation and for forest grazing zones is however very loose, and only valid during the cropping season. After harvest, the entire land area is freely utilized by livestock for grazing.

3.2.2. Livestock Species and Their Role in the Production System

Five livestock classes are found in this region: donkeys, horses, sheep, goats, and cattle. One of the salient features of the traditional livestock production system is its lack of specialization, especially for ruminant species. Animals are utilized for multiple purposes that help improve the livelihood of family households.

Non-ruminant species (donkeys and horses) are primarily utilized as a source of power in transportation and crop cultivation. The population of horses is limited in size and their introduction in this region is relatively recent. They suffer from tsetse flies, which transmit trypanosomiasis disease, to which they are very sensitive. In spite of high morbidity and mortality, local farmers keep raising horses because of their performance in transportation and in cropping operations that require high speed.

Sheep, goats and cattle are of the trypanotolerant species and contribute to family diets through production of milk and meat. They also represent a source of cash income readily convertible in emergency situations and through sale of excess milk and stock. Cattle also provide power for traction in agricultural operations such as soil tillage, and contribute to soil fertility through recycling of nutrients harvested from pasture and croplands in the form of manure.

Social importance of livestock is also worth noting. Ruminant species are involved in many ceremonial events such as weddings, etc., when they are given as gifts or slaughtered for consumption.

Two forms of livestock subsystems may be distinguished based on husbandry and management practices: extensive and semi-intensive. With the extensive subsystem, animals are herded and kept outside the homesteads, the whole year round on pasture and croplands. This form of management involves cattle herds and the small ruminant species, which are occasionally managed in mixed units. Animals under the extensive system are grazed in native pastures and cropping fields during the day, and gathered and tethered at night in crop, fallow, or forest zones depending on the particular season of the year. The second form of management system is more integrated with the farm. Animals are kept most of the time within the household yards and stall fed with crop residues and grass straw. Livestock included in this subsystem are horses and donkeys, some small ruminants, and cattle that are fattened or utilized for draft power.

Horses and donkeys are never herded; the former are usually stall fed with crop residues harvested from croplands, while the latter are grazed freely without any surveillance.

3.2.3 Feed Resources and Their Utilization by Livestock

Open grazing provides feed for cattle herds. Fodder resources are derived from natural vegetation present on forest grazing lands, fallow fields, and from field crops (crop residues left after grain harvest). Forage production on native pastures was estimated at 1150 to 2200 kg DM/hectare/year, with a period of growth limited to 158 days. Fallow fields produce from 1500 to 3600 kg DM/hectare/year (Blancfort, 1991). Crop residues from maize, sorghum, millet, and rice are principal forage sources during the post harvest season, which begins in December.

Forage resource availability and accessibility are subjected to high seasonal variations due to climatic factors, the cropping calendar, and their utilization by animals. Native vegetation from pasturelands represents the only fodder resources type, which is accessible to cattle during the rainy season. At this time the small stock and the non-ruminant species are grazed on fallow fields. As the rain ceases, resources from native pastures decline as a result of grazing and other losses. Cereal crop residues provide supplemental sources for livestock feeding starting in December with cereal fields harvested first. The small stocks (goats and sheep) are first introduced to the cropping areas where they utilize weed regrowth and leaves of cereal stubble. It is only after groundnut harvest that cattle are allowed to graze cropping fields. After resources from the cropping zones become depleted (starting in March), the entire land area is put into grazing by all species.

3.2.4 Cattle Herding and Husbandry Practices

Cattle under the extensive management system, which is the most predominant one, are kept in herds of variable sizes. Herds represent the basic units of cattle management and consist of gatherings of animals of different age classes and sex, which are collectively grazed during the day and are kraaled at night on the same site. Members of one or more household units either individually or collectively own animals, which make up a given herd. Acquisition of cattle occurs via one of the following patterns: purchase, trade, marriage, gifts, or inheritances. Herds can be partitioned into sub-herds belonging to a group of people with particular affinities. Sometimes, the owner is an individual external to the village. An important aspect of herd ownership and management is the intervention of many operators: cattle owners, herd managers, and herdsmen. All have control to a certain extent over herd management. This complexity in the ownership pattern implies some form of organization in the process of making decisions and executing tasks for herd management. Management of the herd involves several levels of hierarchy. As mentioned in previous sections, not all farmers keep cattle. Reasons are (1) first, not all of them own animals and (2) not all cattle owners manage a herd. Economics of scale dictates the gathering of small size individual herds under a common management unit. There exists a minimum size below which herd creation is not efficient. A practice widely used consists of grouping cattle owned by members of different household units into a communal herd.

Organization in terms of herd management distinguishes:

- Herd owner or herd manager: This is the person who supervises all activities related to herd management and maintenance and is therefore accountable for good or poor productivity of animals in the herd. He is often selected among the shareholders because he owns most of the animals, though this is not always a determinant criterion. Good knowledge and skills about herd management are required to accomplish this position. Responsibilities devoted to him include making important technical decisions, of either strategic or tactical nature, that lead to the maintenance of the animals in good condition. Because of this, he is named and acts as the "herd owner." He is also in charge of all costs involved in herd maintenance.

-Herdsmen are operators in charge of executing the day-to-day management of the herd such as driving animals to pastures and watering points, milking lactating cows, and providing health care to individual animals. This position does not, however, require one to own animals in the herd and is mostly accomplished by specialized persons hired by the herd owner and paid partly in cash and partly in kind from a portion of the milk extracted from lactating cows.

-Other animal owners: Though major decisions regarding herd management are given to herd owners, decisions to sale, or to slaughter animals are taken by individual owners. Other responsibilities they may have depend upon the size of their holdings. Some of them may act as "co-managers" while others may not have any management decisions, though they have animals in the herd.

3.2.5. Day-to day-Herd Management

Herd management involves feeding animals, health care, collection of animal by-products such as milk or manure, breeding, and genetic improvement, etc. Such practices represent important actions which determine overall herd productivity.

Communal grazing in native pasturelands and in crop lands after harvest represents the main system for feeding cattle herds. Grazing is free and takes place within all types of land units, with the frequency and intensity of use of each land type being variable across seasons. The availability and accessibility of agricultural land units (pastures, crop fields) and of the fodder resources they support are tied to the cropping calendar, hence season. Cattle have access to various feed resources, which are available in variable quantity and quality depending on climatic factors and other farming activities such as cropping. It is possible to divide the year between three periods based on the cropping calendar activities, each of which corresponds to different patterns of land utilization and to different contributions of feed resource types to cattle diets.

-Period 1, which extends from the first rain (May-June) until the post harvest period (November), corresponds to an intensive and exclusive utilization of forest zones by cattle herds. The need to protect growing crops from livestock damage, means that animals use forest zones exclusively. Watering during this period is twice daily and takes place from natural ponds located in the plateau. Animals are tethered at night on the ground either on fallow fields or on cleared sites within the plateau.

-Period 2 starts just after crop harvest (November) and lasts about three months. During this period, cattle herds are released into the cropping fields to graze crop residues. Cereal stubble and rice straw represent the main residues available for grazing. Groundnut hay, because of its commercial value is systematically harvested, stored in the farm yards and selectively fed to certain livestock classes such as fattened cattle and sheep, draft oxen, and horses.

-Period 3 corresponds to the late and dry season (February to April-May), when both crop residues and native vegetation from pasture lands decline as a result of heavy utilization. Most of the herds are free roaming at this time and are not followed and watched by herdsmen. Watering takes place from wells located in the palm plantation zone where the water table is about ten meters deep.

Richard and aL., (1993) reported on the utilization of the different grazing areas for pasturing cattle in one of the villages included in our study. They found that cattle spent most of their grazing time on a whole year-round basis on crop fields and forest zones, which contributed respectively to 36% and 32% of total grazing time. There was some seasonal variation in the relative contribution of the different land types to livestock feeding, where contribution was measured by the presence time in a given land unit as a proportion of total time spent feeding whole year round. Forest zones and fallow fields accounted respectively for 95% and 2% of total grazing time in period 1, while in period 2 these contributions were 84% for crop fields, 7% for forest zones and 9% for the palm grove. As the dry season advances, animals shifted their preference to the rice fields (45% of total grazing time), and the palm grove (35% of total grazing time), while the contribution of forest zones increased to12%.

Total grazing time for cattle varies from one season to the next, and is determined not only by the availability of feed resources, but also by other herd management practices such as partial milking of cows which causes delay for departure to grazing. Cows are milked once every day, in the morning before they are released for grazing, and the higher the number of milked cows in the herd, the longer it takes to complete this task, unless supplemental milkers are hired. Mean duration of grazing time was estimated between 500 to 700 minutes per day with important variations from one season to the next (Colleie, 1995). There was a tendency to release animals earlier at periods of food scarcity (late-dry season), which also corresponds to the period in which, most of herd owners stop milking cows. Walking distance was also found to be variable across seasons, with the longest travel observed during periods when fodder resources were at lowest and herds are not followed on pasture by herdsmen (Colleie, 1995). Night-time grazing is almost never practiced in any season because of the need to kraal animals on cereal crop fields for fertilization, and also of fear for animal loss due to theft or predation.

Partial milking of lactating cows for human consumption is widely practiced, due the contribution of dairy products to meeting dietary needs of household families. Cows are milked once every day during periods of feed abundance (rainy and post rainy seasons). Milk extraction usually starts within three days to one week after calving, and ends when cows dry off as a result of either normal (intervention to wean the calf, advance stage of gestation) or abnormal termination of the lactation cycle (deaths of the calf for instance). During the hot and dry season, in the absence of supplemental feed milk secretion declines as a result of nutritional deficiencies. In order to alleviate the stress caused by milking to the cow-calf pair, milk extraction for human consumption is usually withheld during that season and resumed the next rainy season when forage becomes available in higher quality, provided the dam did not dry off by this time. A peculiarity of the physiology of lactation of Ndama cows is the role of the sucking action of the calf as a stimulus for milk ejection. Milk extraction by humans is only possible after the calf has initially initiated the process of milk ejection through sucking. That is why milking is always preceded by letting the calf suck for few minutes to initiate milk let down. Then, the calf is attached to the leg's dam, which is hand milked. After this, the residual milk production is left for the calf. Partial milking of cows is reported to result in adverse effects on cows and calves' productivity. It may cause severe competition between the calf and human and slow the calf's growth rate. Extended periods of milking and sucking may also interfere with the cow's reproductive performances by delaying the postpartum return to oestrus cycles. Another adverse effect noticed in the field are the reduction in total grazing time it causes, by delaying the departure to pastures. However, partial milking of cows is necessary for improving the nutritional status of rural populations.

There are no specialized practices to control mating except for choosing bulls, which remain in the herds. Breeding is open with bulls accompanying the cows year-round. Mating may occur at any time during the year if required conditions are met. Cows are bred as they show oestrus and accept the bull. Criteria for choosing future breeders are based on some desirable phenotypic characteristics that a candidate future breeder must meet. Rapid growth rate for an individual, and high milk producing capability of its dam are usually reported by herdsmen as main criteria for selecting bulls.

Castration of males not retained for breeding is sometimes practiced, but is not systematically applied and is mostly directed toward animals that will be utilized for traction.

3.2.6. Coexistence of Livestock and Crops: Complementary or Competition?

The coexistence of livestock and crop activities as main components of the production system results in either some form of complementary or competitive utilization of land and other natural resources. This is dependent on the scale at which we look and on the structure of the farm households. Complementary is evident when relationships are considered at the individual household unit levels. It is expressed as exchanges of energy and matter for the benefit of both activities. Feeding animals with crop residues improves their nutritional status and increases productive output. Livestock in turn, by providing power, traction and manure, play an important role in enhancing crop production. Competitive relationships may however occur, and are expressed as competition for allocation of land and utilization of natural resource base. These are frequently observable at the level of the village territory. There exists no defined plan for allocating land between crop and livestock activities. Field crops can be located anywhere in space and as far as land is cultivated, it may not be utilized for grazing until grain harvest. The main problem encountered by cattle herds is the need for extensive areas for grazing. In some villages, the proportion of cultivated land has increased, leaving less and less space for grazing during the cropping season. The spatial location of field crops can be such that, cattle have impaired access to water and food. This occurs especially at the end of the rainy season when water resources from the ponds are dry and livestock need to be grazed on forest lands while being watered on wells situated in the palm grove. To avoid problems caused by livestock damage to crops, some of the cattle herds in some villages temporarily migrate to larger forest areas where they stay until the post harvest season.

CHAPTER 4

MATERIAL AND METHODS

4.1. Selection of Villages and Herds

A total of 23 herds from 10 villages were selected for study in 1987, but some of the herds were subsequently dropped from the survey. Selection of the villages and herds was primarily based on the following criteria: they were representative of prevailing environmental conditions and production systems prevailing within the target area, they were close to the research station and accessible, there was a willingness of producers to cooperate, and cost. Such a method of sampling is certainly open to criticism, if findings are to be generalized to some broader context. Although probability sampling is very important for making statistical inferences, it must be pointed out that it was neither practical, nor efficient to carry out a strict probabilistic selection of units to include in the survey. On-farm research surveys have some specificity that makes them difficult to apply strict probabilistic methods of sampling, among which is the need to obtain full cooperation of farmers in order to collect reliable and accurate data.

4.2. Field Operations

After villages and herds were selected, field operations began with an initial registration designed to collect baseline data needed to build individual records for each animal. All animals present in the selected herds were identified by means of numbered ear-tags. Individual identification of animals was a key step since individual records per animal were needed for most analyses. Physical identification of animals was followed by herd owners' interviews to determine the origin of animals in the herd, their mode of acquisition and circumstances of entry into the herds. Ages of animals were also determined based on herd owner's interview and cross-checked by using information obtained by direct examination of teeth. Data on breeding history of all adult females was also collected to determine the number of previous parturition by the time of initial registration. After the initial registration, herds were visited every week, during which all demographic events (births, deaths, other entries and exits) that had occurred between the previous and actual day visits were recorded. For birth events the new born calf was assigned an identification number and the birth date recorded to the calf's individual record as well as the dam's along with the parity number. Other events such as purchases, deaths and other exits and entries were treated the same way, such that each event was linked to the animal's identification number and the date of occurrence. This permitted us to locate each event in time (age of the animal, year and month calendar) and with respect to village and herd. Once every week, the volume of milk extracted for human use (milk offtake) was measured individually on lactating cows in a calibrated cylinder during morning milking. Once every month the weight of each animal from a sub-sample of herds was measured at fasting with an electronic scale before animals were released for grazing. A survey questionnaire was also administered to herders and herd owners to collect information on management practices.

4.3. Data Preparation

All measurements and observations made in the field were recorded on field sheets before they were transcribed on individual record cards established for each animal, and entered on microcomputer. Three databases were initially created to store raw data collected from the field: demographic events, milk extraction, and weights respectively. These files were not however ready for use in statistical analysis and preliminary data manipulations were carried out to reorganize the database, and compute additional variables of direct interest in statistical analysis.

4.4. Statistical Analyses

4.4.1. Cow Reproductive Performance

Maintenance of short and regular calving intervals is desirable for efficient reproductive performances in cattle and for the economic return to farm households. Reproductive efficiency in cows is primarily determined by two factors: the age at which they reach sexual maturity and start to be productive and the length of time interval between one calving to the next. The length of calving interval depends primarily upon the rapidity of recovery of the reproductive organs from postpartum stress, and many factors are reported to affect this, among which the sucking effect of the calf, milk extraction, nutrition, the season and the year of occurrence of the previous part, and the parity of the cow (Eduvie, 1985; Ducker et al., 1985; Wilson, 1986; Agyemang et al., 1991; Oyedipe et al., 1992; Redge et al., 1993; Tegegne et al., 1994).

Identification of factors that lead to increase efficiency of reproduction is useful for increasing herd productivity.

Cattle reproductive traits analyzed were age at first calving, calving interval and seasonal distribution of births. Age at first calving was calculated for a number of 151 primiparous cows which were born during the study period and whose exact birth date and date of first calving were known. A total of 852 intervals between successive calving were also available and quantified for 575 cows.

Age at first calving and calving interval were analyzed by analysis of variance using the General Linear Procedure (GLM) of the Statistical Analysis System (SAS) (Littell and al. 1991). The statistical model assumed for the distribution of age at first calving was:

$$AFC_{ijk} = U + S_i + Y_j + E_{ijk}$$

AFC = age at first calving observed on the k^{th} primiparous cow born during the i^{th}season and the j^{th} year;

U = overall mean common to all observations;

S_i = fixed effect i of the season of birth of the heifer categorized as: early wet (May- June-July), late wet (August-September-October), early dry (November December-January) and late dry (February-March-April);

Y_j = the fixed effect j of year of birth (1987 to 1991) of the cow;

E_{ijk} = the residual error variance.

Analysis of calving interval used the following mixed model:

$$Ci_{ijlmno} = U + V_i + H_{j(i)} + Y_l + S_m + T_n + E_{ijlmno},$$

C_{ijlmno} = length of calving interval for an individual cow;

U = overall mean;

V_i = random effect of village i;

$H_{j(i)}$ = random effect of herd j nested within village i

Y_l = fixed effect l of the year of occurrence of the previous calving of the interval;

S_m = fixed effect m of the season of occurrence of the previous parturition of the Interval;

T_n = fixed effect of the length of survival time of the calf born from the previous parturition that defines the interval and coded as: 1= less than or equal to180 days and 2= greater than 180 days;

E_{ijlmno}= random error model component.

The proper error term to use for testing the null hypothesis for village, and for computing the standard errors for treatment means or fixed effects in the statistical model were determined from the expected mean squares given by using the random statement of PROC GLM of SAS.

Seasonal pattern of births was analyzed by chi-squared test of independence from a total of 1882 births recorded from 1987 to 1995 and classified by month of occurrence. Since there were unequal number of days in different months, the number of births expected to fall in each month (under the null hypothesis) was calculated as:

$$Ei = (d_i / D)*B$$

d_i = the number of days in the month (e.g, 28.5 for February 31 for January; March May July August, October and December; and 30 for other months);

D = 365 (e.g, the average number of days in the year);

B = 1887 (the total number of births recorded during all years of the study).

4.4.2. Herd Structure and Cattle Disposal Pattern

The relative contribution of the different structural units (defined by age and sex classes) in a herd often reflects the production orientations assigned to it. Herd sizes and components of herd structure can be variable across seasons and year, to reflect management strategies or tactics followed by herd owners in terms of reproduction and off-take. Timely planned management decisions such as grouping of births or seasonal marketing are often associated with some important modification in herd sizes and herd composition.

Specific objectives aimed by analyzing data on herd size and structure and structure and disposal pattern were:

1) To identify managerial orientations assigned to cattle herds,

2) To estimate mean age of cattle at sale,

3) To estimate the survival curves of cattle for death and sale events.

Characteristics of cattle herd dynamics analyzed were: mean age of animals at exit, rates of animal death and sale, herd size and structure.

Mean age of animal exits was analyzed by least square analysis of variance methods using the GLM procedure of the Statistical Analysis System (Littell et al., 1991). Observations making up the data set in this analysis consisted of all animals that exited the surveyed herds during the entire period of the study. The statistical model used was:

$$Y_{ijk} = U + R_i + S_j + (R*S)_{ij} + E_{ijk}$$

Y_{ijk} = age at disposal for an individual animal

U = overall mean;

R_i = fixed effect i of reason of exit categorized into 4 classes: deaths, sales, slaughters, and others;

S_j = fixed effect of the sex j of the animal;

$(R*S)_{ij}$ = interaction effect between sex j and disposal reason i.

The survivorship functions for death and sale events were estimated for all animals born during all years of the survey and whose exact birth date were known, using the PROC LIFETEST of SAS (Allison, 1995) and the life table method of estimation. The time variable analyzed was the length of time since birth until the event of interest occurs, or until the animal was censored (occurrence of an event other than the one of interest, or termination of the study).

Rate of animal death and animal sale were analyzed by maximum likelihood methods using appropriate methods of survival analysis and the GENMOD procedure of SAS (Allison, 1995; Maura et al., 1995). There were many reasons (sale, death, and transfer to other herds) why animals could exit the herds, but not all animals did so by the time the data were analyzed. Observations included in the analysis consisted of all animals which were born during the period of study (1987 to 1995), whether they died, were sold, or exited for other reasons, or were still present in the herds by the closing date of the survey. The time variable in this analysis was the length of time interval since birth until the event of interest occurred (i.e. death or sale) or until the animal was censored (occurrence of an event other than the one of interest, or termination of the study before the animal "failed"). Each event type of interest (death or sales) was analyzed by Poison log-linear model to assess the dependence of the hazard rate with age and sex, assuming a constant hazard rate within each age interval. Age was categorized

into four distinct classes for each event type as follow: 0 to 6, 6 to 12, 12 to 18 and 18 to 24 months for death events; and 0 to 2, 2 to 4, 4 to 6, 6 to 8 years for sale. A preliminary restructuring of the data was necessary to allow creation of multiple records for each animal at each age interval it was at risk of experiencing the event according to Allison (1995). The time variable was reset to 0 at the beginning of each age interval and the contribution of each animal included in the risk set for each interval age calculated as follows:

O_i = Length of interval width between t_{i+1} and t_i if no event occurred until time t_i and the subject was at least t_{i+1} age old by the study was closed;

O_i = Age of the animal at exit minus its age at the beginning of the interval if exit occurred within the interval t_i, t_{i+1};

O_i= Animal's age at the closing date of study minus its age at time t_i if the study was terminated before the animal was ti+1 age old no "failure" occurred. A censoring indicator variable was created and coded 1 if the animal "failed" within the age interval , and 0 otherwise.

The statistical model assumed for the analysis was:

$$\log (n_{ij} / N_{ij}) = X'B$$

n_{ij}/ N_{ij} = hazard of the event (n_i is the number of subjects who have experienced the event of interest during the age interval i in the sex group j;

N_{ij} = total time at risk contributed by subjects in the sex group j and age interval i

X' = the incidence matrix for the explanatory variables sex and age

B = vector of regression coefficients denoting the effects of sex and age.

"Snapshots" herd composition were determined by identifying the number of animals present in each herd at 2 pre-chosen times for each of the 9 years of the study, and classifying each animal present on the basis of age and sex class. The specific times chosen to analyze herd composition were March 1st and August 1st to represent the dry and wet seasons respectively.

4.4.3. Growth Performances and Milk Extraction

The identification of managerial and environmental factors which influence milk yield and a better understanding the mechanisms by which milk off-take act on cows' reproductive performance are prerequisites for increasing overall herd productivity and farm income.

Milk production from lactating cows is reported be highly variable across seasons, to the extent that, most herd owners stop milking their cows in the late dry season. However, because of the seasonal distribution of calving, variation in milk yield associated with season of production can just be confounded with what may be attributable to stage of lactation (time since calving). Our objectives in analyzing data on milk off-take was to see how the stage of lactation interacted with season to determine the variability in milk extracted daily from lactating cows.

Growth performances of both young and old animals are also reported to be highly variable across seasons as a result of forage fluctuations, with period of abundance corresponding to higher rates of weight gains, and period of feed shortage resulting in slow growth rates.

It was helpful to see how these hypotheses hold in the context of the cattle production system in Kolda.

The original file on live weights and milk production had repeated measurements for each animal, taken at irregular time intervals of 0 to 1 month after birth for live weight and, 0 to 15 days for milk off-take.

Live weights of calves were adjusted to specific ages of: 0, 180, and 360 days since birth by linear interpolation using the growth rate estimated from the two weight measurements which best bounded the standard age at which adjustment were made. Live weight estimated at each age was then analyzed by means of univariate analysis of variance procedure of the Statistical Analysis System (Littell et al., 1991). The fixed effect linear statistical model assumed was the following:

$$Y_{ijkl} = U + S_i + G_j + P_k + E_{ijkl}$$

Y_{ijkl} = weights of calf at 0, 18 and 360 days and average daily weight changes from day 0 to day 180, and from day 180 to day 360.

U = overall mean;

Si =season of birth common to all calves born in the ith season

G_j = sex of the calf (male or female);

P_k = parity of the dam that gave birth to the calf, classified into one of three following classes: 1, 2 to 4, and 4 and more;

E_{ijkl} = random residual error variance.

Live weights of cows were averaged to obtain estimates of the first month (day 1 to day 30) and of the fourth month (day 90 to 120) postpartum weights.

The average growth rate during this time interval was calculated for each cow as follows:

$$ADG = (W1 - W4) / T$$

ADG is the average daily weight change from the first to the fourth month postpartum;

W1 and W4 represent the live weights of cows at the first and fourth months since birth respectively;

T was set equal to 90 days to represent the average length of time interval between the first and fourth month postpartum.

The first 3 months postpartum weight change of cows was analyzed by least square analysis of variance using the following statistical model:

Live weight of cows were analyzed using the following procedures:

$$ADG_{ijk} = U + S_i + P_j + E_{ijk}$$

ADG_{ijk} = Average daily weight changes from day 0 to day 90 postpartum;

U = overall mean;

S_i = fixed effect common to all cows which calved in the i^{th} season;

P_j = effect of the parity j of the dam categorized as (1^{st}; $2\text{-}3^{th}$; 4^{th} and more);

E_{ijk} = random error component of the model.

Live weights of cows were also averaged by calendar month of weight measurement for each cow within parity class and analyzed assuming the following mixed model:

$$Y_{ijkl} = U + P_i + Cow_{k(i)} + M_j + E_{ijkl}$$

Y_{ijkl} = Live weight for individual cow;

U = overall mean;

P_i = fixed effect common to all cows in the i^{th} parity group (1^{st}; 2-3^{th}; 4^{th} and more);

$Cow_{k(i)}$= random effect of cow k nested within parity class j;

M_j = effect of the calendar month j during which weight was recorded;

E_{ijkl} = random error component of the model.

A repeated measures analysis was finally conducted on cows' body weights after these were averaged by season of measurement, using the repeated option of the SAS GLM procedure (Littell et al., 1991). The between subject effect in this analysis was the cow's parity number, and the within subject effect or repeated measures factor was live weight by season of measurement. Differences between average live weight in the late wet season and that in each other seasons were used as transformations of the repeated measures to investigate seasonal variations in weight performance.

Milk off-take production records were also adjusted to times 1, 4, 7, and 10 representing the averages daily extractions of the 1^{st} (day 1 to day 30), 4^{th} (day 90 to day 120), 7^{th} (day 180 to day 210), and 10^{th} (270 to 300) months postpartum respectively. Statistical analyses performed on daily milk off-take were:

1) Univariate "mixed model" analysis of variance with a statistical model which included the effects of time postpartum and season of calving treated as fixed, and the random effect of cow nested within season of calving. The validity of this model was determined by testing the sphericity condition (Maulchy Test of Sphericity) for the covariance matrix of the repeated measures factor, and a conservative

adjustment (Huynh and Feldt epsilon) was applied to the numerator and denominator of the F ratio after the test showed inconclusive results regarding sphericity.

2) Multivariate repeated measures analysis of variance restricted to a subset of cowshaving completed records at each of the four time points considered. The within subject or repeated measure factor in this analysis was the daily milk off take at each of the four specific time points, and the between subject factor was the season of calving of cows.

Successive differences among repeated measures taken at the different four time points were used as the transformed variable for the analysis of within subject effects (time and time by season of calving interaction).

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Cow Reproductive Performance

The monthly distribution of 1887 births (animals born in complete years of the study from 1987 to 1995) is presented in Table 1, which also shows the distribution of conception (based on the assumption that females conceived 280 days prior to calving). Monthly distribution of conception was not uniformly spread through the year ($P < 0.01$). Approximately 73% of total births occurred between June and October, indicating that conceptions took place between February and June. Ratios of observed to expected number of births indicate more births than expected during June through September and a deficit from December to April.

Estimated mean age (± s.e.) at first calving was 1703 days (± 15). The frequency distribution of values for this trait indicates an unimodal pattern with a peak occurring between the ages 4 and 5 years (53% of all values). Very few animals (2.4%) had their first birth before the age of 3 years. Analysis of variance for this trait (Table 2) indicates a highly significant ($P < 0.01$) effect of the year of calving of the dam, but no significant ($P=0.2$) effect of season of birth. Least square means computed from the ANOVA indicate that females born in latter years of the study tended to have shorter age to first calving. Overall mean estimate of interval between successive calving was 690 days (CV=32%). The variance component estimates for the effects of village, and herd within village were not statistically significant ($P > 0.5$).

Table 1. Monthly Distribution of Births and of Conceptions (Period 1987-1995).

	Births			Conceptions		
Month	**Observed (O)**	**Expected (E)**	**O/E**	**Observed (O)**	**Expected (E)**	**O/E**
JAN	61 (3.2)*	160	0.38	211 (11.2)	155	1.36
FEB	39 (2.1)	147	0.27	172 (9.1)	160	1.07
MAR	46 (2.4)	160	0.29	136 (7.2)	155	0.88
APR	42 (2.2)	155	0.27	62 (3.3)	160	0.39
MAY	130 (6.9)	160	0.81	61 (3.2)	160	0.38
JUN	304 (16.1)	155	1.96	39 (2.1)	147	0.27
JUL	392 (20.8)	160	2.44	46 (2.4)	160	0.29
AUG	292 (15.5)	160	1.82	42 (2.2)	155	0.27
SEP	211 (11.2)	155	1.36	130 (6.9)	160	0.81
OCT	172 (9.1)	160	1.07	304 (16.1)	155	1.96
NOV	136 (7.2)	155	0.88	392 (20.8)	160	2.44
DEC	62 (3.3)	160	0.39	292 (15.5)	155	1.82

* Percentages are in parenthesis

Table 2. Least Square Means (± s.e.) for Age at First Calving (AFC) and Calving Interval (CI)

Factors	Levels	AFC (days)	CI (days)
Overall		1703	690
Season(1)	Early dry	1556 ± 40	563 ± 52
	Late dry	1561 ± 61	533 ± 70
	Early wet	1645 ± 29	540 ± 45
	Late wet	1600 ± 35	524 ± 44
Year**	1986		520 ± 66
	1987	1807 ± 30	614 ± 48
	1988	1737 ± 39	611 ± 56
	1989	1568 ± 42	641 ± 50
	1990	1615 ± 43	629 ± 59
	1991	1226 ± 72	568 ± 55
	1992		506 ± 63
	1993		480 ± 68
	1994		294 ± 131
Parity**	1st		616 ± 46
	2nd		566 ± 47
	3rd		548 ± 51
	4th		513 ± 56
	5th		513 ± 66
	6th and more		484 ± 79
Calf Survival/Suckling**	0 -180 days		416 ± 70
	180 days and more		664 ± 28

(1) Season of previous calving for calving interval and season of birth of the dam for age at first calving.

* Denotes significance at P<0.05; **Denotes significance at P<0.01

The cow's parity, year of previous parturition, and the survival time of suckled calf all showed statistical significance ($P < 0.05$), but season was not significant ($P > 0.05$). Least square means computed for fixed effects in the model are given on Table 2. These indicate a reduction in the length of interval between calving with parity. Also, births followed by longer periods of suckling and milk extraction resulted in longer subsequent calving interval.

The tendency of births to occur more frequently during the rainy and post rainy seasons is consistent with results reported by Fall (1987) from a study conducted in the same area and the same production system. The same general pattern was also observed in the same area but under controlled environment on research station (Fall et al 1982). This pattern was also similar with the one reported by Faye (1993), from a study conducted in the agro-climatic zone of the Senegal Peanut Basin. Under an uncontrolled mating system, it is unlikely that these results reflect any preferences by herd owners. The most plausible explanation for the seasonal pattern of births in these livestock system is the relationship between nutrition, climate, and reproduction through the effect of the former factors on the oestrus cycle (Eduvie, 1985; Eduvie and Dawuda, 1986; Topss, 1977; Robinson, 1990). Peak birth, which was observed between the months of June and September, resulted from conceptions, which took place between October and January. This corresponds to a period when nutritional status of animals is expected to be adequate following pasture growth and crop residue availability. The hot and dry season (March through May) was the most unfavorable period for conception to occur because fodder resources are low in both quality and quantity. Without supplemental feeding, body reserves are depleted, animals lose weight, and reproductive functions are probably inhibited. Food supply improves with the onset of the rainy season (starting on May) and nutrients replenish body condition, which is required for normal sexual activity. Studies by Topps (1977) and Dwinger et al. (1991) reported that in most farm animals conception appears to be a function of live weight and postpartum body changes. This probably explains the time lag between the onset of the rains (June) and the occurrence of peak conceptions (October-January). This period of peak conceptions also agrees with that of maximum cow live weight. But, other environmental factors not related to the direct effect of nutrition such as temperature and day-length may also have influenced the observed distribution of conceptions (Wilson and Sayers, 1986).

Age at first calving in this study (1703) was longer than values reported by Fall (1987) or Faye (1993) who found an estimated age of 50 months (1500 days). Estimated mean age at first parturition in our study is equivalent to an approximate age at first conception of 3.9 years or 47.7 months, which is relatively old when compared to most on-station research. For example, studies by Fall and al. (1982) in the same area but under improved management system at the Kolda Livestock research center found an average age at first conception of 30 months while Agyemang et al. (1991) reported values of 39 months in Gambia. This implies that substantial improvement can be achieved with better management. The most plausible explanation for this delayed age at first conception in our study is poor nutrition. Many research studies have reported that nutrition was an important factor which influence age at puberty in cattle breeds kept under farm conditions, since heifers will not conceive for the first time until they have reached an optimum targeted live weight (Kirkwood, 1987; Topss, 1990).

Our estimate for mean interval between calving (690 days) was above values reported by Fall (1987) and Faye (1993), but close to estimates of Rege et al. (1991), Little et al. (1994), and Wilson (1986) from on-farm studies. On a research station in Senegal, Fall et al. (1982) reported an estimate of 495 days length, which is much shorter than our results. Better on-farm husbandry and management practices should lead to significant improvement in calving interval. In addition, a birth interval of 690 days translates to an average calving percent of approximately 53 % which means that, on average, cows gave birth in alternate years in this study. The observed effect of parity indicates that the dam's age and experience influences calving interval. The general tendency for cows to show shorter interval as they age may be explained by nutrition. Primiparous cows have higher nutrient demands because they are still growing and must synthesize body tissues for growth, in addition to requirements for reproduction. This is probably why their reproductive function takes longer to recover from postpartum stress. With advancing maturity, cows have fewer requirements for growth and become somewhat more accustomed to postpartum stress, explaining their faster recovery, which resulted in shorter intervals. Our results agree with studies by Eduvie (1985) who reported increasing ovarian activity in cows with parity or age.

The effect of the length of suckling and milk extraction was another factor found to have major influence on the length of interval between calving. In partial milking systems, lactation ceases completely after the calf is lost because cows no longer have the stimulus of suckling from the calf. We therefore employed length of survival time of the calf as surrogate for the effect of suckling and milking. Much shorter calving intervals following early calf loss (416 days for age at death occurring within 180 days after birth) contrasts with the longer intervals (664 days) obtained when the calf survived past 180 days. Mechanisms by which suckling and milk extraction influence the recovery of the postpartum ovarian activities were discussed by Agyemang et al. (1991), Little et al. (1994), and Eduvie and Dawuda (1986). When early weaning eliminates the stress of lactation, nutrients normally used for milk production can be utilized for restoring body condition, thus increasing the chance for conception. Agyemang et al. (1991) however reported contradictory results in an on-farm experiment where partially milked cows showed higher reproductive performances than their non milked counterparts. Though season of occurrence of the previous birth was not statistically significant in this study, the least square means indicated a tendency for shorter calving intervals following calving in the wet season compared to those that occurred in the dry season. Again, it is likely that this trend is the consequence of nutrition with animals that calved during periods of forage abundance taking less time to return to ovarian cyclicity than animals that calved during period of nutrient deficiency. Many studies have shown that poor nutrition adversely affects ovarian activity with animals failing to conceive when body condition is poor (Robbinson, 1990; Topps, 1977; Little, 1994; Eduvie, 198; Eduvie and Dawuda, 1986). For example, experiments conducted on a farm in Gambia revealed that conception rates increased as much as 2 to 3 fold when supplements were distributed to cows during the dry season (Little, 1994).

Our study of reproductive performances of Ndama cows kept under traditional management settings in the sub-humid zone of Kolda in Senegal showed that animals calve very late and subsequently calve in alternate years. This probably results from a combination of several interrelated causes. Though it was not possible from our study to establish cause and effect relationships, strong associations found between cow reproductive performances and environmental variables suggest that poor nutrition, inadequate husbandry, and disease results in poor fertility. Mechanisms by which these factors operate in the context of the traditional livestock system in Kolda need however be investigated more closely.

The reproductive physiology of Ndama cattle is poorly understood. Measurement of reproductive performances alone is, in most cases, insufficient to identify how poor nutrition or inappropriate management reduce fertility. Extended calving intervals may result from either: long sexual postpartum ovarian inactivity, high frequency of early foetal deaths, or both. The interval between successive births may be divided into two sub-intervals, with the first one going from the previous birth to the next conception, and the second from conception to the next birth which represents the length of the gestation period. It is mainly the interval from birth to conception which represents the most influential period in determining the length of interval between calving in cows, as the gestation length tend to be less variable. Factors affecting postpartum infertility in cows were classified into uterine involution, short oestrus cycles, postpartum anoestrus, and pregnancy loss. Reviews by Short et al. (1990) report that the interval from parturition to the first next oestrus was a more serious problem than was either uterus involution or short oestrus cycles. Postpartum anoestrus is influenced by several factors including season, age or parity, presence of a bull, suckling and nutrition from which the latter two represent the major ones. The mechanisms by which such factors act on the reproductive physiology of cattle were also reviewed by Short et al. (1990). Management decisions such as the length and choice of the breeding season may also be of extreme importance. A study on reproductive physiology of Ndama cattle (Sauveroche and Wagner, 1993) reported seasonal variations on oestrus intensity, with most animals showing oestrus at mid-day during the cool season period and at night during the hot season period. Herd management practices, in the production system studied might also interfere with reproduction, as animals are tethered at this time, which prevents them from mating.

5.2. Herd Structure and Animal Disposal Pattern

The distribution of animal exits from the herds by reasons is presented in Table 3. Sales were the most single important means of disposal, accounting for 41.1% of all exits. Deaths were also an important cause for animal losses, accounting for 27.3% of total exits from the herds, while other animal losses such as accidents, thefts or predations represented only 7.3% of total exits. Animal slaughter, which accounted only for 5.1% of total exits, was a minor avenue of animal disposals. Animal exchanges, transfers and other social transactions such as: given as gifts, dowry or inheritance jointly accounted for 19.2 % of all exits.

Animal sales were as frequent for males (51 %) and females (49 %), but the sex distribution differed markedly across age classes (Appendix Table 2). Approximately 90% of all male sales occurred before an age of 9 years old, compared to only 36 % for female sales. Males were therefore more represented than females in the sample of animal sales at younger ages up to 8 years old, but less at older ages. The distribution of each sex across age classes in the sample of animal deaths (Appendix Table 2) indicates that nearly 93% and 55 % of total deaths were observed before age 4 years old for males and females respectively. Least squares estimates of mean age at disposal are presented on Table 4.

Table 3. Distribution of Animal Exits by Reason

Reasons for exits	Frequency	Percent
Deaths	422	27.3
Other losses	113	7.3
Exchanges	34	2.2
Transfers	189	12.2
Sales	636	41.1
Slaughters	79	5.1
Given	74	4.8

Table 4. Least Square Means (± s.e.) for Age at Exits by Reason and Sex

Reason for Disposal	Num ber	Sex				Overall Mean Age (Years)
		Males		Females		
		Prop. (%)	Age (Years)	Prop. (%)	Age (years)	
Sale	636	51	5.4 ±0.2	49	9.4± 0.2	7.4 ±0.1
Slaughter	79	45	4.1± 0.6	55	9.7± 0.6	6.9 ±0.4
Death	422	61	1.6± 0.3	39	5.1 ±0.2	3.4 ±0.2
Other	412	33	4.2 ±0.3	67	5.8 ±0.2	5.0 ±0.2

Mean age of cattle at disposal was significantly associated with disposal reason ($P < 0.01$) and sex ($P < 0.01$), but the relationship of mean age at exit with disposal reason also depended on sex ($P < 0.01$). Mean age of animal at sale (± s.e.) was 7.4 years (± 0.14 years), but males were on average sold at a younger age (5.4 ± 0.2 years) than females (9.4 ± 0.2 years). Average age (± s.e.) at which animals were slaughtered was 6.9 years (± 0.4), with a significant difference ($P < 0.05$) between males (4.1 ± 0.6 years) and females (9.7± 0.6 years). There was a tendency for animal sales to be more frequent during the month of September (18% of the total sales) and less frequent during the month of December (4%). Sales during the late rainy season (August September and October) accounted for 40% of total sales and were significantly ($P < 0.01$) higher then sales in any other season.

Life table estimates of the survival function for deaths events computed for all births recorded during the course of the study (Appendix Tables 5 and 6) indicate that, out of the total number of calves born, approximately 4.0%, 5.5% and 9.8% died before ages 1, 6 and 12 months respectively. Neither the sex of the calf, nor the season at which it was born showed statistical significance ($P > 0.05$) at either interval from birth to 6 months or from birth to 12 months.

Comparison of the hazard of deaths across age intervals of 6 months length from birth to age 24 months and between sex indicates that mortality varied for animals in different age classes, but there was no evidence of a difference ($P = 0.2$) between males and females.

Figure 1. Variation of Mortality Rate Across Age Class

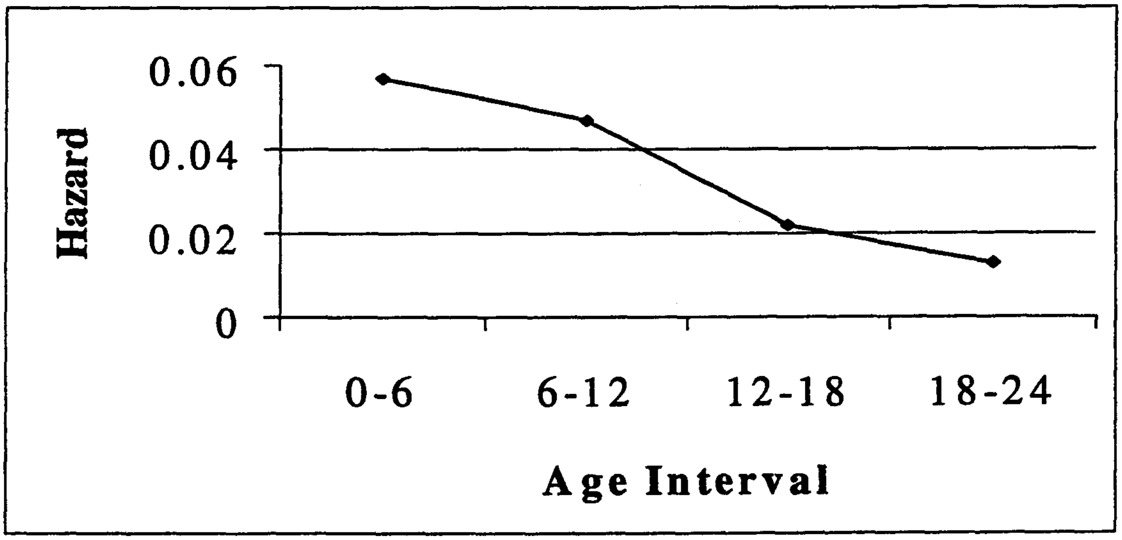
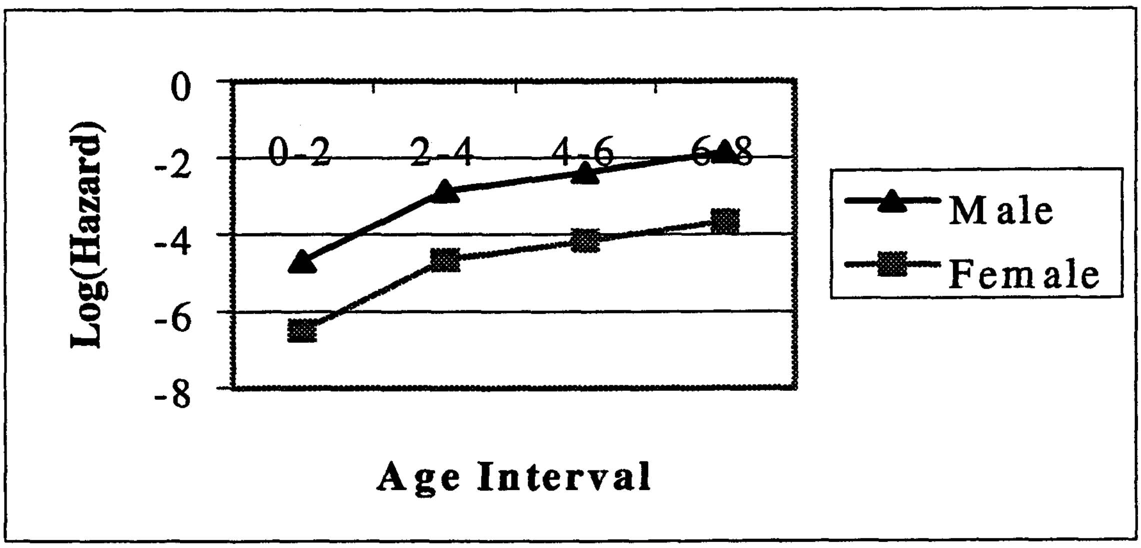


Figure 2. Variation of Sale Rate Across Age Class and Sex



Analysis of contrasts among the 4 age intervals (Appendix B.1.) and plot of the hazard of deaths on age class computed from maximum likelihood parameter estimates of the model (Figure 1) indicate that the hazard of death tended to decrease from birth to age 24 months. The survivorship function estimates for sales and slaughter events (combined in one class) obtained by the life table method (Appendix Table 6) show that only 1% and 0.5 % of all births were sold before age adult (4 years) for females and males respectively.

Maximum likelihood analysis to compare "risk"of sales between males and females and across age class from birth to age 8 years (grouped into intervals of 2 years) indicate that (1) males were about 6 times more likely to be chosen for sales than females at any age class ($P< 0.01$), and that (2) sale rates significantly ($P< 0.01$) increased with age (Figure 2 and Appendix B.2). These results were not what we would expect from examining the graph of the hazard function constructed from the life table estimates (Appendix Figure 3), which indicate higher increase of the hazard of sale for male than females.

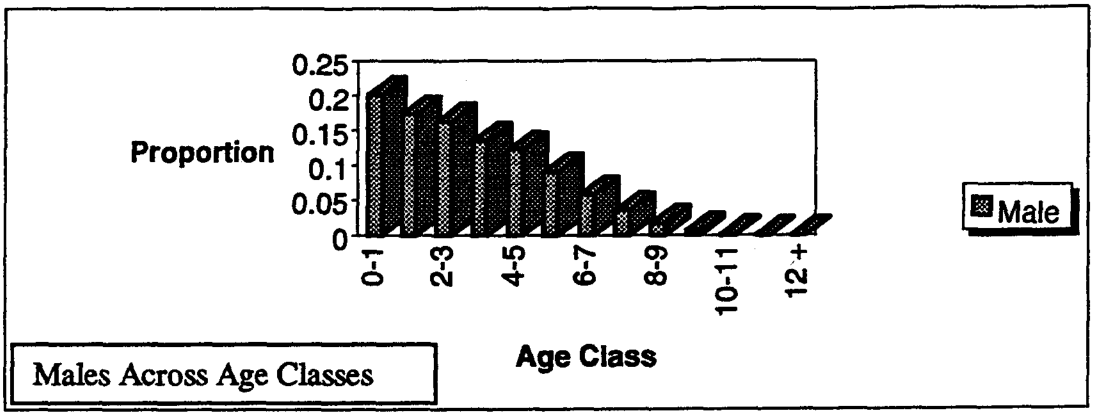
Average proportion (± s.e.) of the total herd sold each year (frequency of animals sold per year as a proportion of the total herd size) approximated 6.9% (± 0.5), but was variable across year ($P=0.02$) and herd ($P=0.09$). The frequency of deaths as a proportion of total herd size was approximately 5.3 % per year (± 0.5) and was significantly variable across herd ($P= 0.09$) and year ($P= 0.04$).

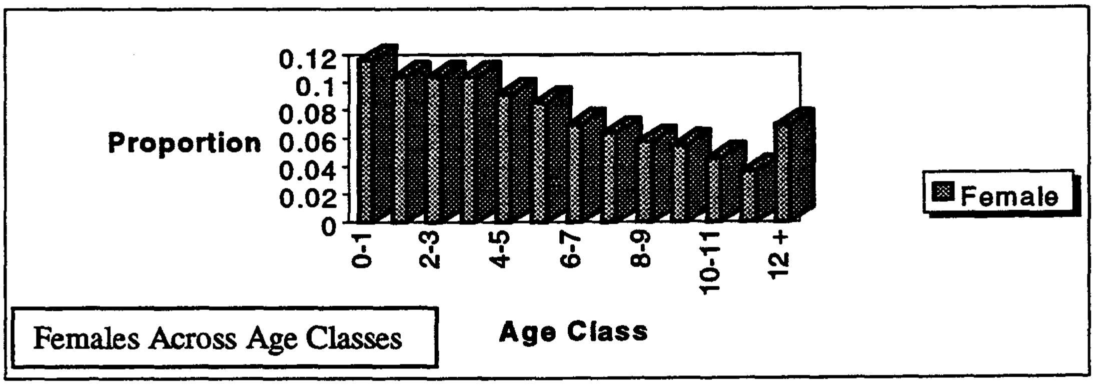
Average proportions of calves (0 to 1 year all sex confounded), young bulls (males 1 to 4 years), heifers (females 1 to 4 years), bulls (male aged 4 years old or more) and cows (females aged 3 years or more) in the study herds, were 14.4%, 15.7%, 20.8%, 10.9% and 38.2% respectively. There were on average, more females (67%) than males (33%) in the herds, but male and female frequencies in the herds were variable when comparisons were made within individual age classes. The ratios of females to males were near unity (1.1) for calves (0 to 1 year), 1.3 in the class of immature (1 to 4 year), and 3.5 in the class of adults (4 years and more). There were very few males beyond age 10 years in the herds, while females as old as 23 years were still present. Animals in the age class 10 years and more represented also only 0.04% of total males kept in the herds and 15.1% of total females (Figure 3).

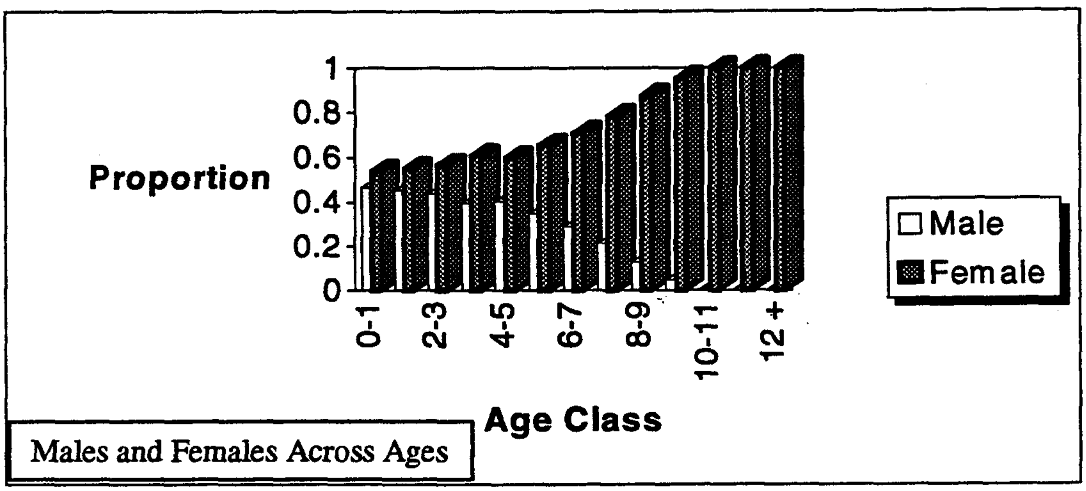
The mean (± standard deviation) and median herd size in this study were 89 (± 55) and 79 animals respectively, but the range was wide (25 to 212).

On average, the number of animals in the herds increased by a proportion of 3 % per year with, significant effect of herd (P=0.02) and year (P=0.01). Herd composition of cattle observed in this study reflects a mixed orientation for beef and milk production, with a relatively high proportion of breeding females, and also a high ratio of male to female adults. Cattle herd represents an investment, a productive capital and renewable resource for people and must produce both milk and calves. The high proportion of cows (38.5 %) in the herds reflects the option taken by producers to accomplish their multiple production goals.. Keeping a large number of breeding females in the herds represents one means to maximize calf and milk production from the herd. Low ratio of calves to adult females in the herd (0.35) reflects poor reproductive performance and/or high mortality rates at young ages. The ratio of bulls to cows (3.5 females per bull) shows an excess of males adults for the sole purpose of reproduction. But the number of males included castrated animals.

Figure 3. Herd Structure







Poor calving rates may be a plausible reason that prompts herd owners to keep more adult males above numbers necessary for breeding alone. It might be that, a sizeable proportion of adult males in the herds are not retained for breeding, but are expected to be those awaiting sale at optimum weight or period. This was also a reflection of the role of the herd as a form of capital reserve and security, which is utilized in time of need.

Sales were an important disposal avenue, when compared to other productive off-take (slaughter, trade), and slaughter were less frequent, reflecting the fact that the livestock production system was not primarily oriented toward subsistence. In this production environment, with only low opportunities for meat storage, cattle slaughter is likely to occur only under special conditions like emergencies or social events. On the other hand, small stock (sheep and goats) is preferred to cattle for slaughter for domestic consumption.

The relatively old age for cattle marketing (7.4 years) observed in this study may be explained by poor growth rates due to inadequate nutrition. Because of poor growth performance, animals are kept until they reach desirable marketable weight, which occurs at relatively old ages. It can be also expected, in this production system oriented toward milk production, and with very low inputs for animal maintenance, that most of the animals sold or slaughtered are excess males or culled cows. There were only very few sales involving young stock in the age class of 0-1 year (only 3 animals observed out of a total of 636 during a period of 8 years). This was not surprising as calves are still sucking at this age and are not weaned until after 1 year old. A higher proportion of male to female sales in the age interval before reproductive age, a reverse trend observed at older ages, and the higher average age at sale for females as compared to males were consistent with the orientation of the production system toward calf crops and milk production and reflects the strategy of herd owners to retain females in the herds for as long as they are able to breed. This was reflected by the presence of females 20 years old and more, and their offer for sale. In general, breeding females are not usually sold except for culling because of poor mothering ability (delayed age at first calving, long interval between calving, high frequency of abortions and still births).

Seasonal distribution of animal sale was consistent with the pattern of forage supply, and its influence on body condition of livestock. The higher frequency of animal sale during the late rainy season probably reflects a strategy of stockowners to defer cattle marketing until a period when body condition is high in order to maximize their cash values.

Higher mortality in the herds following birth probably results from greater sensitivity of young animals to diseases and poor nutrition. In most circumstances, it was not possible to identify a single cause of death, as factors tended to be interrelated in their effects.

5.3. Growth Performance and Milk Extraction

Average live weights at birth, 9 months, and 12 months were respectively 16.8 kg (se=0.4), 49.3 kg (se=0.9) and 78.9 kg (se=2.2). Growth rates were estimated at 0.183 kg day^{-1} (se=0.044) from the period between birth and 6 months and 0.170 kg day^{-1} (se=0.056) from 6 months to 12 months, giving an overall estimate of 0.176 kg day^{-1} (se=0.04) from birth to 360 days. Season of birth was significant ($P < 0.01$) for live weight at 180 days and for growth rates at all age intervals. Calves born during the late dry season had significantly higher growth rates between birth and 6 months and those born during the early dry season achieved better performance in the age interval from 6 to 12 months. Sex approached significance (P = 0.05) for daily weight change from 6 to 12 months, and was highly significant (P < 0.01) for growth rate in the overall interval from birth to 360 days. Males on average achieved faster growth rates than did females.

Least squares means and standard errors for cow live weights changes from the 1st to 4th month following parturition are presented in Table 5. Both parity and season of calving of the cow were highly associated (P < 0.01) with growth performances during the first three months following parturition.

Table 5. Live Weight Changes of Cows (± s.e.) During the First 3 Months Postpartum

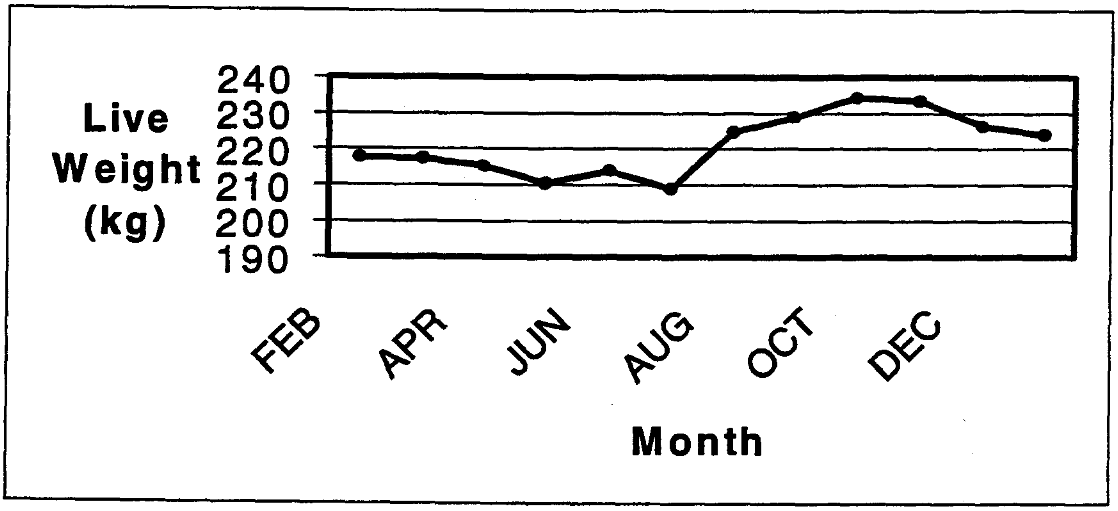
Factors	**Levels**			
Seasons **	**Early-Dry**	**Late-Dry**	**Early-Wet**	**Late-Wet**
Daily weight Changes (kg day^{-1})	0.14 ± 0.04	0.13 ± 0.11	- 0.16 ± 0.05	0.04 ± 0.04
Parity **	**1**	**2**	**3**	**4 and more**
Daily weight changes (kg day^{-1})	0.06 ± 0.06	0.07 ± 0.06	0.02 ± 0.05	0.12 ± 0.04

** Denotes statistical significance at P<0.00

The least square means indicate that primiparous cows were still growing even after their first birth, and that mature weight was not reached until the third or fourth gestation. Growth performances during the first 3 months postpartum indicate significant weight gains (0.16 ± 0.05 kg day^{-1}) for early wet season calvers, and significant weight loss (0.14 kg ± 0.04 kg day^{-1}) for early dry season calvers. Daily weight change for late dry season calvers (-0.13 ± 0.11 kg day^{-1}) and for late wet season calvers (-0.04 kg ± 0.04 kg day^{-1}) expressed as negative numbers were not statistically significant because of high standard errors of estimates. Average daily gain performed during the first three months following parturition may be used as a means for comparing growth achieved during the transition from one season to the next, and to assess the fluctuation in live weight associated with season of measurement. The response variable analyzed here was the daily weight change of cows from the first (day 1 to day 30) to the fourth (day 90 to day 120) month postpartum. This was compared among groups of cows classified on the basis of the season at which they gave birth. If for instance, cows gave birth during the early wet season (months of May, June and July), then their live weights taken in the fourth month postpartum (i.e. between day 90 to day 120 postpartum) would fall during the late wet season (months of August, September and October), which is three months after the season at which calving occurred. Therefore the weight change from the first to fourth month following parturition estimated for these cows would also correspond to a contrast between their average live weight recorded in the early wet season (first month live weight) and that recorded in the late wet season (fourth month postpartum live weight).

Comparisons indicate that: (1) the transition from the early-wet to the late-wet season was associated with an increase in live weight at a rate estimated at 0.16 grams d $^{-1}$ (se=0.05) during the first three months after birth; (2) live weight of cows during the first three months following parturition decreased at a rate of 0.14 grams d^{-1} (s.e. = 0.04), when calving occurred during the early dry season. This comparison suggests seasonal fluctuations in body weights of cows. Results of the mixed model ANOVA (which included the fixed effects of months of visit and parity, and the random effect of cow) indicated a highly significant effect (P<0.01) of month of visit and of parity, but the interaction term between the two factors was not significant (p =0.8).

Figure 4. Monthly Variation of Live Weight of Cows.



Results of the multivariate test from fitting a repeated measures ANOVA on cow body weight averaged by season of visit indicated significant effects (P<0.01) for season and parity, but the test for the interaction term was marginally significant (P= 0.04). Analysis of contrasts among the repeated measure factors indicated: (1) no evidence (P=0.8) of a difference between average live weight recorded in the late wet season and that recorded in the early dry season; (2) average live weight recorded during the late wet season was significantly higher than those recorded either during the early wet season or late dry season. Seasonal trend in body weight of cows is illustrated in Figure 4 which shows a plot of the least squares means obtained from a run of the mixed model analysis versus month of visit. Cows were heavier during the late wet season and post rainy seasons (months of August through January) and lighter during the late dry and early wet seasons (February through July) at all parity classes.

Results of the mixed model analysis of daily milk extraction which included the fixed effects of season of calving, time since calving (categorized into 4 classes representing the average production of the first, fourth, seventh and tenth month extraction respectively), an interaction term between these two factors and the random effect of cow nested within season indicated highly significant effect ($P<0.01$) for all terms, except that for season ($P=0.3$). The same analysis run by using repeated measures methods with only 18 lactations which had complete records at each of the 4 times, indicates that the sphericity condition underlying the validity of the test for the effect of season and time*season was inconclusive ($P= 0.04$). There was a significant effect ($P<0.01$) of time and time by season of calving interaction, even after adjustment of the univariate test with the Hyunh-Feldt epsilon ($\gamma= 0.9$). The multivariate version of the same test indicated also the same results.

The interaction between season of calving and time indicates the variation in off-take associated with the particular season in which milk extraction was measured. Comparisons of daily milk extraction among groups of cows (classified based on the season at which they gave birth), within the individual time at which milk off-take was adjusted provide an alternative means of assessing daily fluctuations in milk off-take associated with season of production. It is possible, at any time interval since birth to approximately locate the season at which milk extraction was measured, from knowledge of the season at which birth occurred. For instance, during the fourth month postpartum, cows in group 1 (early-wet calving season), group 2 (late wet calving season), group 3 (early dry season calving) and group 4 (late dry calving season) had their off-take production measured during the late wet, early dry, late dry and early wet seasons respectively. Correspondence between season of calving and season of measurement for any time were approximated by simply moving forward the calving season by the length of time interval at which comparison are being made.

Table 6 indicates that:

-At time 1 (first month postpartum) daily extraction was high for all cows except those who calved during the late dry season.

-At time 4 (fourth month postpartum) earlywet season calvers, who had their off-take production measured during the late wet season had the highest recorded, while early dry season calvers (production estimated in the late dry season) had the lowest. Off-take productions for late dry and for late wet season calvers which were estimated in the early wet season and early dry season, respectively, were intermediate.

-At time 7 (seventh month postpartum), late dry season calvers had the highest off-take, and late wet season calvers the lowest. Cows in these groups had their extraction measured during the late wet season and late dry season, respectively.

-At time 10, the highest mean off-take production falls in late wet season, and the lowest was observed in the early wet season.

These results indicate that milk off-take was consistently lower during the late dry season and higher during either the late wet, early wet or early dry season, depending on the stage of lactation. Also, lactation, which started during the late dry season, were characterized by a peak yield, which was reached in mid-lactation which corresponds to the onset of the rainy season. Wet season calvers, on the other hand show peak extraction during their early lactation, followed by a steady decline thereafter. Stage 1 (first month of lactation) for late dry season calvers (February-March-April) coincides with the most unfavorable period of the year in terms of forage supply. When calving occurred at this time of the year, peak yield was delayed until the next rainy season, which was 4 to 7 months later, when forage supply improved. Wet season calvers in turn, exhibited maximum production at their early stage of lactation, probably because of the effect of improved nutrition.

The peak off take for early dry season calvers appeared to be the highest, probably because, cows in this group spent most of their gestation period during periods of food abundance (wet season).

Table 6. Daily Milk Offtake (ml) by Season of Calving and Stage of Lactation.

Season of Calving	**Time Period Postpartum**			
	1st month	**4th month**	**7th month**	**10th month**
Early Dry	1003 ±175 (Early Dry)*	393 ±166 (Late Dry)*	445 ± 109 (Early Wet)*	813 ± 115 (Late Wet)*
Early Wet	992 ± 107 (Early Wet)*	905 ± 101 (Late Wet)*	434± 67 (Early Dry)*	309± 71 (Late Dry)*
Late Dry	376 ± 151 (Late Dry)*	707 ±143 (Early Wet)*	711± 94 (Late Wet)*	311 ±100 (Early Dry)*
Late Wet	873 ± 175 (Late Wet)*	612 ± 166 (Early Dry)*	215 ± 109 (Late Dry)*	188 ±116 (Early Wet)*

* Seasons of measurement are indicated in parenthesis

Milk from lactating cows contributes to a large extent to the nutrition of farm household families, and to generate daily cash income. This explains why partial milking of cows is a widely used practice in traditional production systems. In these systems, young calves depend heavily on their dam's milk production during the first months of their life to satisfy their nutritional needs. This results sometimes in severe competition between humans and growing calves, as local cattle breeds under these environments have very limited potential for milk production. High intensity or extended periods of milk extraction are reported to result in adverse effects on overall herd productivity such as: low growth rate for young animals associated with a delay in the age to reach sexual maturity, lengthening of calving intervals (Agyemang et al., 1991; Eduvie and Dawuda, 1986). Our results are consistent with the hypothesis that extended periods of milking were associated with longer postpartum return to oestrus for cows. But, whether or not partial milking impairs the calves' and cows' growth performance could not be addressed through this study and requires the design of more controlled experiments.

Analysis of growth performances and daily milk off take indicates a marked influence of season on production output. Periods of high performance coincide with that of forage abundance. The period of maximum body weight of cows (late wet and early dry seasons) coincides with the peak of conceptions. Though we cannot rule out other possible causes for seasonal fluctuations in performances, nutrition appears to play an important role. This suggests that significant gain in production could be achieved with better feeding during period of food shortage.

CHAPTER 6

CONCLUSION

6.1. Summary

Analysis of parameters of herd dynamics and performances of Ndama cattle kept under village management system has shown that the production system is multipurpose oriented, with animals making an important contribution to meet the livelihood of families. Calf and milk production appears to be the most important output from the herds, and contribute to meet both the nutritional and monetary needs of families. But, cattle raising were not restricted to these, and animals are means of capital reserve for households, and also contribute to the enhancement of crop production. Production performances evaluated on an individual basis were low when compared to most on-station results and significant gains are possible with better management if single or limited production objectives are targeted. The most likely causes of poor performance levels were climate, and especially rainfall pattern, multiple use of animals, management practices, and diseases. Rainfall in the area is restricted to a single rainy season of 5 months when food supply is adequate, leaving an extended dry season period when forage availability diminishes and is of poor quality. Animals benefit from high nutrition plane during the rainy and post rainy seasons as a result of pasture growth and crop residues availability. But, as the dry season advances, forage availability and quality decline as a result of plant senescence, advancing lignification, and destruction of fodder resources by fire. This was reflected in both the observed trends in live weight and milk extraction. The lack of specialization of the production system is probably incompatible with high levels of performance. Management practices followed by herd owners, while they permit diversification and secure production, are generally incompatible with high levels of performances. Extended periods of milk extraction provide food and cash to livestock owners, but in turn impairs the reproductive efficiency of cows and the growth of the calves. Partial milk extraction of cows also reduces grazing time. Kraaling animals during night-time for crop field fertilization reduces grazing time for animals, and potential time of mating. This practice however helps reduce animal losses that would result from predation and thefts, and enhances crop production. Examples of this type are numerous and not restricted to these. This indicates that introducing changes into the system may interfere with producer's goals, and that caution must be exercised when attempting to improve one component of the system.

6.2. Research Perspectives

The analysis of the cattle production systems under village husbandry in the Kolda region in southern Senegal has shown that strong relationships exist between most production performances on the one hand and the environmental and management variables on the other hand. It has also allowed us to screen potential research pathways we need to focus on for more in-depth diagnosis of constraints to increased productivity.

One of the main characteristics of the production system is the seasonality associated with most performance traits (i.e, reproduction, growth performance and milk off-take). The most likely mechanism by which season affects animal performance is probably through the variations in feed supply and quality. Introduction of technology called stabling in this region by ISRA researchers (Fall and Faye, 1991) is based on selectively supplementing animals with cotton seed meal and treating them against parasites. This technique has proven successful in significantly reducing weight loss and in increasing milk extraction during the dry season period. The stabling technology would however benefit from research aimed at increasing the availability or quality of supplemental feed to use for feeding stabled animals. Better management of available resources through harvesting forage at optimal period for ensiling and chemical treatment of low quality roughage such as crop residues and grass straw with ammonia and urea should be tested on-farm. Experience shows that, in most circumstances, fodder resources for such improvement exist within the village territory, but are not well managed.

The most limiting nutrients in the diet and the periods they are most needed with respect to season and to the physiological stages of animals (prior to conception, early or late gestation) need to be investigated. The effects of pre-pubertal growth and postpartum weight changes on subsequent reproduction need more clarification.

If the effect of nutrition on animal performance is already established, whether temperature and light intensity exert direct effect on the reproduction of Ndama cattle has not yet been clearly stated and need further investigations.

In terms of herd management, it is necessary to know how the intensity and frequency of sucking and partial milk extraction affect the postpartum return to oestrus of nursing cows, and whether providing supplemental feed helps alleviate such stress. Non-control of breeding, which allows year-round mating must also be contrasted with the choice of a defined breeding season to meet specific objectives such as coordinating herd management with the growth cycle of forage resources.

The efficiency of specialized versus the current traditional system oriented toward multiple production objectives is also another domain on which research needs to focus. An assessment of the response of the whole production system to an attempt to specialize production objectives must include measures of both biological and economic efficiencies.

BIBLIOGRAPHY

Agyemang, K., R. H. Dwinger, and A. S. Grieve. 1991a. Milk Production Characteristics and of Productivity of Ndama Cattle under village management in the Gambia. *Journal Dairy Sciences,* 74:1599-1608.

Agyemang, K., R. H. Dwinger, A. S. Grieve and D. A. Little. 1991b. Studies on the Effects of Milking on Calf Growth and Viability and on Cow Reproductive Performances inTraditionally managed Ndama herds. *Animal Production,* 53:11-18.

Agyemang, K., Little D. A., Bah M. L. and Dwinger R. H. 1991c. Effects of Postpartum Body Weight changes on subsequent Reproductive Performances of Ndama cattle maintained under Traditional Husbandry Systems. *Animal Reproduction Sciences,* 26:51-59.

Allen, B. O. 1983. A Guide to the Analysis of Growth Curve Data with Special Reference to SAS. *Computers and Biomedical Research,* 16: 101-115.

Allison, P.D. 1995. Survival Analysis using SAS System: a Practical Guide. SAS Institute, Cary, NC.

Barral, H., G. BOUDET , and B. BENNEFICE, 1983. Systemes de Production d'Elevage au Senegal dans la region du Ferlo. Synthese de fin d'etude une equipe pluridisciplinaire. ISRA/ ORANA/ GERDAT/ OCCGE/ ORSTOM. Dakar, Senegal.

Blancfort, V. 1991. Contribution a l'Etude d'un Bilan fourrager pour trois Terroirs Agro-pastoraux de Casamance (Senegal). Programme A.B.T. , I.S.R.A/ I.E.M.V.T. Vol.1

Brown, G.H. and J. B. Donnely. 1988. A Note on Comparing Growth rates of Animals between groups. *Biometrics,* 44:985-993 .

C.I.P.E.A. 1983. Recherche sur les Systemes Pastoraux. International Livestock Center for Africa, Bulletin 16, Addis Abeba , Ethiopie.

Cobby, J. M. and Y. L .P. Le Du. 1978. On Fitting Curves to Lactation data. *Animal Production,* 26:127-133.

Colleie, F. 1995. Contribution a l'Etude des Pratiques de Conduite de Troupeaux auPaturage sur Terroirs Agro-pastoraux en Casamance (Senegal). Relations avec l'Alimentation et les Performances. Diplome d'Etudes Superieures Specialisees Productions Animales en Regions Chaudes. I.S.R.A. / I.E.M.V.T.

Cook, R. H. 1985. Criteria for evaluation of livestock on-farm trial. Proceedings Research Methodology for On Farm Livestock Trials, IDRC, Ottawa, Canada.

Cox, D. R. 1972. Regression models and life tables. *Journal Royal of Statistical* Association *B.*, 34:187- 202.

Delacharlerie, P. F. 1994. Contribution a l'Etude de l'Alimentation des Bovins sur Parcours naturels en Casamance (Senegal): Composition botanique des Regimes, Roles des Ligneux, premiere Approche de la Disponibilite Fourragere Ligneuse. Memoire D.E.S.S.P.A. en region chaude, I.S.R.A. / A.B.T., Dakar, Senegal.

De With, C. et al. 1984. Methods for Comparing groups of Growth Curves when Pattern of observation times vary among subjects. *Growth,* 48:187-191.

Diop, A.T. and M. Diene. 1991. Determination de la Charge Animale de l'Aire d'Influence d'un Forage a partir de la Quantite d'Eau exhauree. In: *Proceedings of the Fourth International Rangeland* Congress, Montpellier, France, 824-825.

Dwinger, R. H., K. Agyemang, W. F. Snow, P. Rawlings, P. Leperre, and M.Bah.1994. Productivity of Trypanotolerant Cattle kept under Traditional Management conditions in the Gambia. *Veterinary Quaterly*, 16: 81-6.

Eduvie, L. O. 1985. Factors Affecting Postpartum Activity and Uterine involution in Zebu cattle indigenous to Nigeria. *Animal Reproduction Science*, 8:123-128.

Eduvie, L. O. and P. M. Dawuda 1986. Effects of Suckling on Reproductive Activities of Bunadji cows during the Postpartum period. *Journal of agricultural Science Cambridge*, 107: 235-238.

Elandt-Johnson, R. C. and Johnson, N. L. 1980. Survival Models and Data Analysis, Duxbury, New York.

Everitt, B. S. 1995. Analysis of Repeated Measures: a Practical Review with Examples. *American Statistician*, 44:113-135.

Fall, A., M. Diop, J. Sandford, Y. J. Wissocq, J. Durkin, and J. C. M. Trail 1982. Evaluation of the Productivity of Djallonke sheep and Ndama cattle at the Centre de Recherches Zootechnique, Kolda, Senegal. ILCA Research Report 3, Addis Abeba, Ethiopia.

Fall, A. 1987. Les systemes d'elevage en Haute Casamance: Caraterisation, Performances et Contraintes. Menoire de titularisation I.S.R.A./ DRSPA, Senegal, Dakar.

Fall, A. and A. Faye. 1992. Les Etables Fumieres en Zone d'Elevage du Betail Trypanotolerant au Sud du Senegal. Centre de Recherche Zootechnique de Kolda, Senegal.

Faye, A. 1993. Situation et Perspectives de l'Elevage Bovin dans les Systemes Agro-pastoraux denses de la zone Soudano-Sahelienne. These de Doctorat en Sciences Agronomiques, ISRA/ ENSAT-M, CIRAD-EMVT, Montpellier, France.

Gehan, E. A. 1969. Estimating Survival Function from the Life Table. *Journal of Chronic Disease*, 21:629-44.

Goodall, E. A. 1986. An analysis of Seasonality of Milk Production. *Animal Production*, 36:69-72.

Henry, L. 1976. Population: Analysis and Model. Academic Press, New York.

Hildebrand, P. and J.T. Russel. 1996. Adaptability Analysis, a Method for Design, Analysis and Interpretation of on-farm research extension. Iowa University Press, Ames, Iowa.

Huynh, H. 1970. Conditions under which Mean square errors for Repeated Measure Design have an exact F distribution. *Journal American Statistical Association*, 65: 1582-1589.

Huynh, H and Feldt, L. S. 1976. Estimates of the Box Correction for Degrees of Freedom for Sample data in Randomized Block and Split plot Design. *Journal of Educational Statistics*, 1:69-82.

Huynh. H. 1978. Some Approximate Tests for Repeated Measures Design. Psychometrika, 43:61-176

ILCA, 1986. (Ed). Modeling extensive livestock Production system. Proceedings of LCA / ARO / CABO workshop, ARO, Bet Dagan, Israel.

ILCA, 1990. Livestock System Research Manual. I LCA working paper 1, Vol. 1. International Livestock Center For Africa, Addis Abeba, Ethiopia.

ISRA, 1995. Identification des Objectifs et Operations de recherche. Plan strategique de La Recherche Agricole. Caraterisation des Systemes de Production de la Zone agro- ecologique Senegal Oriental/Haute Casamance: Elements d'Analyse des Potentialites et Contraintes au Developement Agricole.Recherche Agricole 1996-2006.

Jahnke, H.E. 1982. Livestock Prodution Systems and Livestock Development in Tropical Africa. ILCA, Kieler, Wissenschaft , Kiel.

Joan, S.A. 1984. The Evolution of a donor Assistance Strategy for Livestock Programs in Subsaharan Africa. In:Simpson , J.R. and P. Evangelou (Ed.). Livestok development in Subsaharan Africa: constraints, prospects, policy. Westview Replica Press, Boulder, CO.

Kalbfleish, J. D. and Prentice, R. L. 1980. The Statistical Analysis of Failure Time Data, Wiley, New York.

Kirlwood, R. N. 1987. . Reproductive Energetics in Mammals. In Loudon A. I (ed.) *Proceedings of a symposium held by the Zoological Society of London*, 203-206.

Kowalski, C.J. and E.G. Kenneth. 1974. Longitudinal data analysis. Growth 38:137-169.

Krover, S. and J.A.M. Van Arendonk. 1987 (Ed). Modelling of Livestock Production Systems. Klumer Academic Publishers, Brussels, Belgium.

Kuel, R. O. 1994. Statistical Principles of Research Design and Analysis, Duxbury Press, Belmont, CA.

Landais, E. 1983. Analyse des Systemes d'Elevage Bovins Sedentaires du Nord de la Cote d'Ivoire. These Doctorat es Sciences, Universite de Paris Sud, Orsay, France.

Landais, E. and M. M. Sissoko. 1986. Bases Methodologique du Controle des Performances Animales pour l'Analyse Zotechnique et Demographique: Collecte des Donnees et Choix des Variables. Atelier sur les Methodes pour la Recherche sur les Systemes d'Elevage en Afrique Intertropicale. Collection Etudes et Syntheses de l'I.E.M.V.T , 20:433-485.

Lawless, J. F. 1982. Statistical Models and Methods for Lifetime data. Wiley Press, New York, New York.

Lee, E. T. 1992. Statistical Methods for Survival Data Analysis, Wiley, Hew York.
Lhoste, P. et al. 1993. Zootechnie des Regions Chaudes: Les Systemes d'Elevage. C.I.R.A.D. Collection manuel et precis d'elevage, Ministere de la Cooperation Francaise, France.

Lhoste, P., V. Dolle, J. Rousseau, D. Soltner, 1993. Zootechnie des regions chaudes. Les systemes d'elevage. Ministere de la Cooperation, France.

Little, D.A., G. J. Wassink and K. Agyemang 1994. Feed supplementation of lactating Ndama cows under village husbandry. *Tropical Agriculture*, 71:223-228.

Littell, R. C., G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS System for Mixed models. SAS Institute, Inc, NC.

Littell, R. C., R. J. Freund, and P. C. Spector 1991. SAS System For Linear Models. SAS Institute, Inc, NC.

Peters, K. J. and W. Thorpe. 1985. Current trends in on farm performance testing of cattle and sheep in Africa. *Troisieme Congres Mondial de Reproduction et Selection des Bovins a Viande*, INRA, Paris.

Martin, U. 1986. Modelling economic outcomes of livestock production systems. *In: Modelling extensive livestock production systems*. Proceedings of ILCA/ ARO/ CABO workshop held at ARO Bet Dagan, Israel 5-9 February 1985, ILCA, Addis Abeba, Ethiopia.

Maura, E.S., et al. 1995. Categorical data analysis using SAS System. SAS Institute, Inc. Cary,NC.

Norman, D. W. 1995. The Farming System Approach to Development and Appropriate Technology Generation. FAO farm systems management series 10, FAO, Rome.

Oyedipe, E.O., V. Buvanendran, and L. O. Eduvie. 1982. Some Factors Affecting the Reproductive Performance of white fulani Cattle. *Tropical Agriculture*, 59:231-234.

Radhakrishna, R. C. 1958. Some Statistical Methods for Comparison of Growth Curves. *Biometrics,* 14:1-17.

Redge, E. O., R. R. Faufmann and R. I. Mani. 1993. On-farm Performance of Bunadji Cattle: Herd structure and cattle disposal. *Animal Production,* 57:199-209.

Richard, D., B. Ahokpe, V. Blancfort, and B. Pouye. 1991. Utilisation des Zones Agricoles et Pastorales par les Ruminants en Zone soudanienne (Moyenne Casamance, Senegal). *Proceedings of the Fourth International Rangeland Congress*, volume 2, Montpellier, France. 754-756 .

Robbinson, J. J. 1990. Nutrition in the Reproduction of Farm Animals. *Nutrition Research Review*, 3: 253-276.

Sauveroch, B. and Wagner, H. G. 1993. Physiologie de la Reproduction des Bovins trypanotolerants. Synthese des connaissance actuelles. Projet PNUD/ FAO/ RAF/ 88/100, Banjul, Gambia.

Short, R. E., R. A. Belows, R. B. Staigmiller, J. G. Berardinelli, and E. E. Custer. 1990. Physiological Mechanisms controlling Anestrus and Fertility in Postpartum beef cattle. *Journal of Animal Sciences*, 68: 799-818.

Sidahmed , A. E. and L .J. Koong. 1984. Application of System Analysis to nomadic Livestock Production in Sudan . *In* : Simpson , J. R. and P. Evangelou (Ed.). Livestock Development in Subsaharan Africa: Constraints, Prospects, Policy. 61-76. Westview, Replica Press, Boulder, CO.

Snee, R .D. and S. K. Acuff. 1979. A Useful Method for the Analysis of Growth Studies. *Biometrics* 35: 835-848.

Spedding, C. R.W. 1987. General Aspects of Modelling and its Application in Livestock Production Systems. *In*: S. Korver and J.A.M Van Arendock 1987 (ed.). *Modelling of livestock production systems*. Klumer Academic Press Publishers, Brussels.

Stokes, M. E., C. S. Davis, G. G. Koch. 1995. Categorical Data Analysis using the SAS System SAS institute, NC, Inc.

Tegegne, A., A. Galeto, P. O. Osuji. 1994. Influence of Dietary Supplementation and Partial Suckling on Body weight and on Lactation and Reproductive Performance of primiparous Boran cows in Ethiopia. Journal of Agricultural Sciences , 23:267- 273.

Topps, J. H. 1977. Relation between reproduction and undernutrition in beef cattle. *World Review of Animal Production.*, 13:43-49.

Wiggans, G. R. and M. Grossman. 1980. Computing Lactation records from sample day Production. *Dairy Herd improvement Letter*, Vol. 56 (4), 1-5.

Wilson, R. T. 1983. Recherches sur les Systemes des Zones Arides du Mali: Resultats Preliminaires. *Rapport de Recherche CIPEA*, 48:1-23.

Wilson, R. T. 1985. Livestock Production in Central Mali: Reproductive aspects of sedentary cows. *Animal Reprodution Science* 9: 1-9.

Wilson, R. T. 1986. Livestock Production in Central Mali, long term studies on cattle and in the agropastoral system. *ILCA Research Report*, 14:43-63, Addis Abeba, Ethiopia.

Wilson, R.T. and A. R. Sayers. 1987. Livestock Production in Central Mali: effects of Climatic Variables on the period of birth and on litter size in traditionally managed goats and sheep. Agricultural and Forest Meteorology, 40: 31-36.

Wishart, J. 1938. Growth rate Determination in relation with the bacon pig and their Analysis. *Biometrics*, 30:16-28.

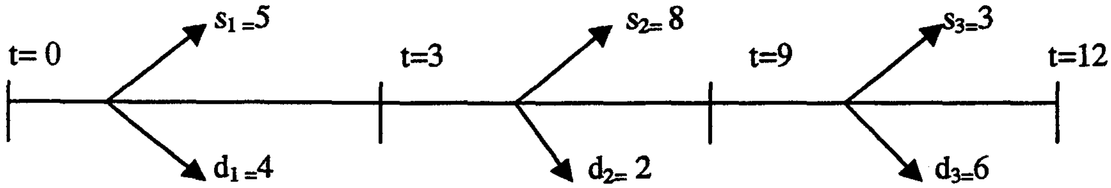
Wood, P. D. 1972. A note on Seasonal Fluctuation in Milk Production. *Animal Production*, 16:89-92.

Wood, P. D. 1967. Factors affecting the shape of the lactation curve in cattle. *Animal Production*, 11:307-31 .

APPENDICES

APPENDIX A. Selected Tables

Appendix Table 1. Life Table Method for Estimating Survival Function



t_i = limits of time intervals
s_i = number of sale between t_i and $_{ti+1}$
d_i= number of deaths between t_i and t_{i+1}

Interval [ti-ti+1)	Number alive at t_i (n_i)	Died (d_i)	Censored (s_i)	Effective number at risk (n'_i)	Cond prob. Event (q_i)	1-q_i (p_i)	Survival (S_i)
0-3	100	4	5	97.5	0.041	0.959	0.959
3-9	91	2	8	87	0.023	0.977	0.9369
9-12	81	6	3	79.5	0.0755	0.9245	0.8662

For each sub-interval defined by t_i-t_{i+1};
The effective number at risk $n'_i = n_i - si/2$;
The conditional probability of dying $qi= d_i/n'_i$
The conditional probability of surviving = n_i-d_i /n'_i = 1-q_i
The survival estimate at t_{i+1} $S_i = \Pi\, p_i$;
The hazard rate of dying at the mid-point interval t_i, t_{i+1} $h_I = d_i/w_i*(n'_i-d_i/2)$

Appendix A (Continued)

Appendix Table 2 Distribution of Animal Exits by Reason, Sex, and Age Classes

Type of exit						
Age Classes (years)	Deaths (%)			Sales (%)		
	Females	Males	Overall	Females	Males	Overall
0 to 4	54.5	92.8	69.4	12.4	29.5	21.0
4 to 8	17.1	4.8	12.4	23.6	59.9	42.0
8 to 12	18.3	2.4	12.1	34.7	10.6	22.5
12 and +	10.1	0.0	6.2	29.3	0.0	14.5

Appendix Table 3 Descriptive Statistics for Age at Sale and at Death.

Type of exit	Sex	Number Observ.	Mean (years)	St. Dev.	Median (years)	Min. (years)	Max. (years)
Death	Male	165	1.6	1.8	1.0	0.0	9.4
	Female	257	5.1	5.1	3.4	0.0	22.3
Sale	Male	322	5.4	2.2	5.2	1.3	11.3
	Female	313	9.4	4.3	9.8	0.3	23.5
Slaughter	Male	36	4.1	2.1	3.3	0.5	9.5
	Female	43	9.7	4.6	10.6	1.6	19.3

Appendix A (Continued)

Appendix Table 4 Components of Herd Dynamics During Selected Years of the Study

		Herd Size					
Year	**Number of herds**	**Mean ± st. Dev. (%)**	**Minim**	**Maxi**	**Annual Death Rate (%)± s.e**	**Annual Sale Rate (%) ± s.e**	**Annual growth rate (%) ± s.e**
1988	18	77.1± 40.7	23	153	4.5 ± 1.2	5.2 ± 1.3	7.1 ± 3.6
1989	18	80.3 ± 42.8	23	160	4.7 ± 1.2	5.7 ± 1.3	9.2 ± 3.6
1990	18	89.5 ± 54.9	25	212	9.2 ± 1.2	9.9 ± 1.3	-7.8 ± 3.6
1991	15	94.1 ± 59.4	21	254	5.5 ± 1.4	5.8 ± 1.4	6.2 ± 3.9
1992	13	97.2 ± 71.7	21	292	2.7 ± 1.5	4.6 ± 1.5	7.3 ± 4.3
1993	11	100 ± 42.3	46	169	5.9 ± 1.6	9.9 ± 1.7	-2.4 ± 4.7
1994	6	93.8 ± 22.7	60	124	5.4 ± 2.3	9.6 ± 2.4	-2.1 ± 6.7

Appendix A (Continued)

Appendix Table 5 Survivorship and Hazard Functions Estimates for Death Events

Age (month)	Cond. Probability		Survival		Hazard (death/time) (1) *1000	
	Female	Male	Female	Male	Female	Male
0-3	0.044	0.036	1	1	0.497	0.407
3-6	0.0154	0.0153	0.9563	0.964	0.173	0.171
6-9	0.0356	0.0567	0.9415	0.9492	0.196	0.316
9-12	0.0171	0.0324	0.908	0.8954	0.096	0.183
12-15	0.0207	0.0196	0.8925	0.8664	0.113	0.107
15-18	0.0052	0.0129	0.874	0.8494	0.058	0.144
18-21	0.0055	0.00234	0.8695	0.8385	0.061	0.026
21-24	0.0039	0.0206	0.8647	0.8365	0.044	0.231
24-27	0.0021	0.0167	0.8613	0.8193	0.023	0.188
27-30	0.0108	0.0091	0.8595	0.8056	0.121	0.101
30-33	0.0095	0.0069	0.8502	0.7982	0.106	0.077
33 - .	0.0962	0.0438	0.8421	0.7927	.	.

(1) Hazard rate evaluated at the mid-interval.

Summary Statistics

Sex	Total	Failed	%Censored
Female	922	144	84.4
Male	784	138	82.4

Test of Equality over Strata

Test	Chi-Square	DF	P
Log Rank	2.3	1	0.1
Wilcoxon	2.3	1	0.1
-2Log(LR)	5.1	1	0.02

Appendix A (Continued)

Appendix Table 6 Survivorship and Hazard Functions Estimates for Sale Events

Age	Cond. Probability		Survival		(1) Hazard (*1000)	
	Female	Male	Female	Male	Female	Male
0 -1	0.00151	0.00078	1	1	0.0041	0.0021
1 - 2	0.00328	0.0156	0.998	0.999	0.0089	0.043
2 - 3	0.00886	0.0361	0.995	0.984	0.024	0.101
3 - 4	0.0129	0.0734	0.986	0.948	0.036	0.209
4 - 5	0.015	0.0675	0.974	0.879	0.041	0.191
5 - 6	0.0145	0.1114	0.959	0.819	0.040	0.331
6 - 7	0.0202	0.1241	0.945	0.726	0.056	0.362
7 - 8	0.0243	0.189	0.926	0.636	0.067	0.572
8 - 9	0.0435	0.0994	0.903	0.516	0.12	0.287
9 - .	0.4332	0.2769	0.864	0.464	.	.

(1) Hazard rate evaluated at the mid-interval.

Summary Statistics

Sex	Total	Failed	%Censored
Female	2176	356	82.9
Male	1352	358	73.5

Test of Equality over Strata

Test	Chi-Square	DF	P
Log Rank	384	1	< 0.01
Wilcoxon	329	1	< 0.01
-2Log(LR)	133	1	<0.01

Appendix B. Selected Computer Output

Appendix B.1 Maximum Likelihood Analysis of Mortality Rates

B.1.1 Lifereg Procedure

Class Levels Values
T 4 1 2 3 4 (T=Age coded as: 1=0-180 days; 2=181-360; 3=361-540; 4=540-720)
Number of observations used = 5618
Data Set = WORK.M
Dependent Variable = Log(TIME180) = log (days/180)
Censoring Variable= MORT
Censoring Value(s)= 0
Noncensored Values= 225 Right Censored Values= 5393
Left Censored Values= 0 Interval Censored Values= 0
Log Likelihood for EXPONENT -1258.388854

Variable	DF	Estimate	Std Err	ChiSquare	Pr>Chi	Label/Value
INTERCPT	1	4.35684025	0.27735	246.7668	0.0001	Intercept
T	3			48.44621	0.0001	
	1	-1.497729	0.296298	25.55103	0.0001	1
	1	-1.2921796	0.303438	18.13452	0.0001	2
	1	-0.5578892	0.308936	3.261056	0.0709	3
	0	0	0	.	.	4
SCALE	0	1	0			Extreme value

Lagrange Multiplier ChiSquare for Scale 26.97614 Pr>Chi is 0.0001.

B.1.2. GENMOD Procedure

Model Information

Description	Value
Data Set	WORK.M
Distribution	POISSON
Link Function	LOG
Dependent Variable	MORT
Offset Variable	LTIME180
Observations Used	5618

Appendix B. (Continued)

Class	Levels	Values
T	4	1 2 3 4

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	5614	2066.7777	0.3681
Scaled Deviance	5614	2066.7777	0.3681
Pearson Chi-Square	5614	89299.2508	15.9065
Scaled Pearson X2	5614	89299.2508	15.9065
Log Likelihood	.	-1258.3889	.

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT		1	-4.3568	0.2774	246.7668	0.0001
T	1	1	1.4977	0.2963	25.5510	0.0001
T	2	1	1.2922	0.3034	18.1345	0.0001
T	3	1	0.5579	0.3089	3.2611	0.0709
T	4	0	0.0000	0.0000	.	.
SCALE		0	1.0000	0.0000	.	.

LR Statistics For Type 3 Analysis

Source	DF	ChiSquare	Pr>Chi
T	3	55.5342	0.0001

CONTRAST Statement Results

Contrast	DF	ChiSquare	Pr>Chi	Type
T1VS T2	1	1.6237	0.2026	Wald
T1 VS T3	1	30.0564	0.0001	Wald
T1 VS T4	1	25.5510	0.0001	Wald
T2 VS T3	1	16.0137	0.0001	Wald
T3 vs T4	1	3.2611	0.0709	Wald

Appendix B (Continued)

Appendix B.2 Maximum Likelihood Analysis for Sale Rates

B.2.1. Lifereg Procedure

Class	Levels	Values
T	4	1 2 3 4
SEX	2	F M

Number of observations used = 8783
Data Set =WORK.M
Dependent Variable=Log(LTIME365)
Censoring Variable=OFFT

Censoring Value(s)= 0
Noncensored Values= -769 Right Censored Values= 9552
Left Censored Values= 0 Interval Censored Values= 0
Observations with Zero or Negative Response= 1220
Log Likelihood for EXPONENT -1225.057976

Variable	DF	Estimate	Std Err	ChiSquare	Pr>Chi	Label/Value
INTERCPT	1	1.28628184	0.125814	104.5233	0.0001	Intercept
T	3		109.6172		0.0001	
	1	2.40190056	0.236248	103.3647	0.0001	1
	1	0.86449079	0.163174	28.06859	0.0001	2
	1	0.46763029	0.163172	8.213184	0.0042	3
	0	0	0	.	.	4
SEX	1	194.7002			0.0001	
	1	2.0519569	0.147057	194.7002	0.0001	F
	0	0	.	.		M

Lagrange Multiplier ChiSquare for Scale 0.350025 Pr>Chi is 0.5541.

B.2.2. The GENMOD Procedure

Data Set	WORK.M
Distribution	POISSON
Link Function	LOG
Dependent Variable	OFFT
Offset Variable	Log(TIME365)
Observations Used	10003

Appendix B (Continued)

Class Level Information

Class	Levels	Values
T	4	1 2 3 4
SEX	2	F M

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	9998	2916.2267	0.2917
Scaled Deviance	9998	2916.2267	0.2917
Pearson Chi-Square	9998	44687.9080	4.4697
Scaled Pearson X2	9998	44687.9080	4.4697
Log Likelihood	.	-1909.1134	

Analysis Of Parameter Estimates

Parameter		DF	Estimate	Std Err	ChiSquare	Pr>Chi
INTERCEPT		1	-1.8509	0.0896	426.2832	0.0001
T	1	1	-2.8387	0.2065	188.9558	0.0001
T	2	1	-1.0058	0.1204	69.8226	0.0001
T	3	1	-0.5172	0.1173	19.4490	0.0001
T	4	0	0.0000	0.0000	.	.
SEX	F	1	-1.8022	0.1051	294.1657	0.0001
SEX	M	0	0.0000	0.0000	.	.
SCALE		0	1.0000	0.0000	.	.

LR Statistics For Type 3 Analysis

Source	DF	ChiSquare	Pr>Chi
T	3	327.8663	0.0001
SEX	1	337.3281	0.0001

CONTRAST Statement Results

Contrast	DF	ChiSquare	Pr>Chi	Type
T1 VS T2	1	77.4874	0.0001	Wald
T1 VS T3	1	126.0094	0.0001	Wald
T1 VS T4	1	188.9558	0.0001	Wald
T2 VS T3	1	16.2934	0.0001	Wald
T3 vs T4	1	19.4490	0.0001	Wald

Appendix B (Continued)

Appendix B.3 Repeated Measures analysis of Live Weight of Cows

B.3.1 Univariate Repeated Measures Tests

Class	Levels	Values	
PARITY	3	1 2 3	(Parity Class number of cows)

Number of observations in data set = 158

NOTE: Observations with missing values will not be included in this analysis. Thus, only 101observations can be used in this analysis.

Repeated Measures Level Information

Dependent Variable	ED	EW	LD	LW	(Season of Calving)
Level of SEASON	1	2	3	4	

Test for Sphericity: Mauchly's Criterion = 0.1829934
Chisquare Approximation = 164.26383 with 5 df Prob > Chisquare = 0.0000
Applied to Orthogonal Components:
Test for Sphericity: Mauchly's Criterion = 0.6641701
Chisquare Approximation = 39.580376 with 5 df Prob > Chisquare = 0.0000

Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PARITY	2	47178.62	23589.31	10.31	0.0001
Error	98	224171.76	2287.46		

Univariate Tests of Hypotheses for Within Subject Effects

Source: SEASON

					Adj Pr > F	
DF	Type III SS	Mean Square	F Value	Pr > F	G - G	H - F
3	24683.68	8227.89	91.37	0.0001	0.0001	0.0001

Source: SEASON*PAR

					Adj Pr > F	
DF	Type III SS	Mean Square	F Value	Pr > F	G - G	H - F
6	1162.95	193.82	2.15	0.0476	0.0614	0.0581

Source: Error(SEASON)

DF	Type III SS	Mean Square
294	26476.22	90.05

Appendix B (Continued)

Greenhouse-Geisser Epsilon = 0.8164
Huynh-Feldt Epsilon = 0.8560

B.3.2 Multivariate Repeated Measures Tests

Repeated Measures Level Information

Dependent Variable	ED	EW	LD	LW
Level of SEASON	1	2	3	4

Manova Test Criteria and Exact F Statistics for the Hypothesis of no SEASON Effect
H = Type III SS&CP Matrix for SEASON E = Error SS&CP Matrix

S=1 M=0.5 N=47

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.26	88.56	3	96	0.0001
Pillai's Trace	0.73	88.56	3	96	0.0001
Hotelling-Lawley Trace	2.76	88.56	3	96	0.0001

Manova Test Criteria and F Approximations for the Hypothesis of no SEASON*PAR Effect
H = Type III SS&CP Matrix for SEASON*PAR E = Error SS&CP Matrix
S=2 M=0 N=47

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.87	2.29	6	192	0.0367
Pillai's Trace	0.13	2.24	6	194	0.0404
Hotelling-Lawley Trace	0.14	2.33	6	190	0.0334
Roy's Greatest Root	0.14	4.58	3	97	0.0048

Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
PAR	2	47178.62	23589.31	10.31	0.0001
Error	98	224171.76	2287.46		

Analysis of Variance of Contrast Variables

SEASON.N represents the contrast between the nth level of SEASON and the last

Appendix B (Continued)

Contrast Variable: SEASON.1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEASON	1	13.66	13.66	0.06	0.8093
PAR	2	275.51	137.75	0.59	0.5560
Error	98	22862.67	233.29		

Contrast Variable: SEASON.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	31671.22	31671.22	188.98	0.0001
PAR	2	924.61	462.30	2.76	0.0683
Error	98	16424.16	167.59		

Contrast Variable: SEASON.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	17842.12	17842.12	69.11	0.0001
PAR	2	80.33	40.16	0.16	0.8561
Error	98	25301.98	258.18		

Appendix B (Continued)

Appendix B.4. Repeated Measures ANOVA of daily milk offtake.

B.4.1. Multivariate Repeated Measures Tests.

Repeated Measures Level Information

Dependent Variable	TIME1	TIME4	TIME7	TIME10
Level of TIME	1	2	3	4
SEASC 4	ED	EW	LD	LW

Manova Test Criteria and Exact F Statistics for the Hypothesis of no TIME Effect
H = Type III SS&CP Matrix for TIME E = Error SS&CP Matrix

S=1 M=0.5 N=5

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.31	9.04	3	12	0.0021
Pillai's Trace	0.69	9.04	3	12	0.0021
Hotelling-Lawley Trace	2.26	9.04	3	12	0.0021
Roy's Greatest Root	2.26	9.04	3	12	0.0021

Manova Test Criteria and F Approximations for the Hypothesis of no TIME*SEASC Effect

Statistic	Value	F	Num DF	Den DF	Pr > F
Wilks' Lambda	0.059	7.1559	9	29.35	0.0001
Pillai's Trace	1.475	4.5165	9	42	0.0003
Hotelling-Lawley Trace	6.894	8.1714	9	32	0.0001
Roy's Greatest Root	5.163	24.0972	3	14	0.0001

Tests of Hypotheses for Between Subjects Effects

Source	DF	Type III SS	Mean Square	F Value	Pr > F
SEASC	3	462015.19	154005.06	1.11	0.3792
Error	14	1947433.49	139102.39		

Analysis of Variance of Contrast Variables

TIME.N represents the contrast between the nth level of TIME and the last

Contrast Variable: TIME.1

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	2605488.30	2605488.30	24.01	0.0002
SEASC	3	1352867.61	450955.87	4.15	0.0267

Appendix B (Continued)

Error	14	1519473.90	108533.85

Contrast Variable: TIME.2

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	943121.51	943121.51	19.43	0.0006
SEASC	3	2312993.83	770997.94	15.88	0.0001
Error	14	679667.13	48547.65		

Contrast Variable: TIME.3

Source	DF	Type III SS	Mean Square	F Value	Pr > F
MEAN	1	30864.46	30864.46	1.54	0.2345
SEASC	3	1050714.51	350238.17	17.51	0.0001
Error	14	279969.95	19997.85		

B.4.2 Univariate Repeated Measures Tests

UniVariate Tests of Hypotheses for Within Subject Effects

Source: TIME

DF	Type III SS	Mean Square	F Value	Pr > F	G - G	H - F
3	1673721.94	557907.31	15.12	0.0001	0.0001	0.0001

Source: TIME*SEASC

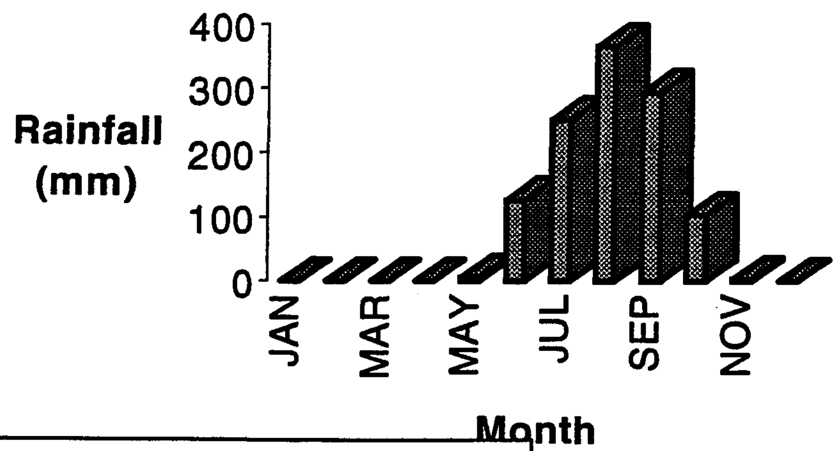
					Adj	Pr > F
DF	Type III SS	Mean Square	F Value	Pr > F	G - G	H - F
9	2513625.65	279291.74	7.57	0.0001	0.0001	0.0001

Source: Error(TIME)

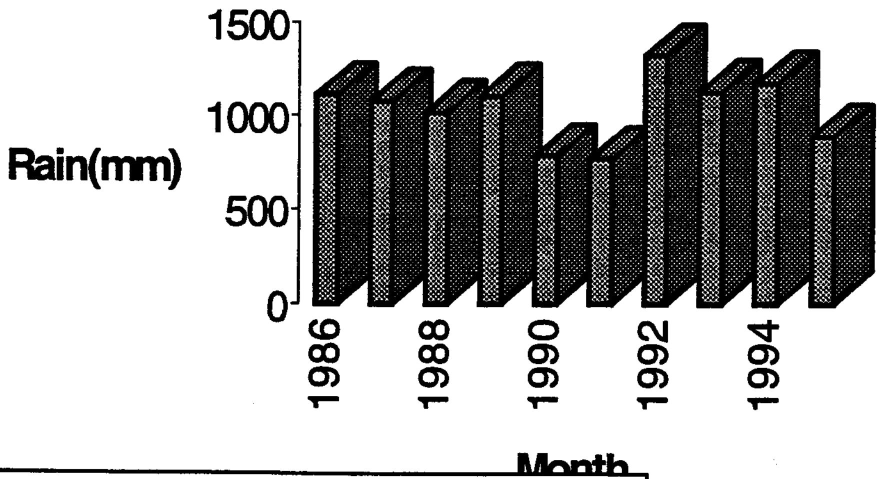
DF	Type III SS	Mean Square
42	1549979.96	36904.28

Greenhouse-Geisser Epsilon = 0.6631
Huynh-Feldt Epsilon = 0.9382

APPENDIX C. Rainfall Distribution in the Study Area



Appendix Figure C.1 Monthly Distribution



Appendix Figure C. 2 Year to Year Variation

Appendix C.2 Milk Extraction Curves