Socio-Economic Analysis of Crop-Livestock Integration in the Savannah of Northwestern Nigeria: A case study on the Zamfara grazing reserve

Omolehin, Ajayi Raphael Adeniyi

Vorsitzender: Prof. Dr. Dr. A Otte

1.Gutacher: Prof. Dr. E- A. Nuppenau

2. Prof. Dr. J. Steinbach

Prüfer: Prof. M. Schmitz

Prüfer: Prof. Dr. B. Honermeier

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ACRONYMS AND ABREVIATIONS

ABU	Ahmadu Bello University
ACGSF	Agricultural Credit Guarantee Scheme Fund
ADP	Agricultural Development Project
CBN	Central Bank of Nigeria
CO_2	Carbon dioxide
FAO	Food and Agricultural Organisation
FLBEM	Farm Level Bioeconomic Model
FRN	Federal Republic of Nigeria
FYM	Farm Yard Manure
GAMS	General Algebraic Modelling Systems
GDP	Gross Domestic Product
GHG	Greenhouse Gases
IAR	Institute for Agricultural Research
IITA	International Institute for Agricultural Research
LGA	Local Government Area
LIMDEP	Limited Dependent variable Econometrics software Package
LP	Linear Programming
SPSS	Statistical Package for Social Sciences
TLU	Tropical Livestock Unit (250Kg)

Local Units and their standard equivalent

Local Units	Standard Units equivalent
1 Bag of millet	100 Kg
1 Bag of sorghum	100 Kg
1 Bag of cowpea	100 Kg
1 Bag of groundnut	100 Kg
1 Bundle of millet	14 Kg
1 Bundle of sorghum	20 Kg
1 Bundle of cowpea	10 Kg
1 Bundle of groundnut	13 Kg

Sources: MOHAMMED. 2000, and personal communication with farmers

1 INTRODUCTION

1.1 Background information

The Zamfara reserve was established by the British colonial administrative power in 1916 to enhance the supply of tropical timber and game hunting and to serve as a shield or wind brake against the ravaging expansion of desertification. The law, establishing the reserve, initially prohibited economic activities such as farming, the grazing of livestock and the construction of dams across rivers in the reserve. All these activities were considered inimical to the environmental balance of the reserve. The reserve was established primarily to guarantee the protection of natural resources and natural habitats (THE FOREST ORDINANCE, 1938). These restrictions on its usage were strictly observed during the first four decades of the reserve's existence (HOFFMANN, 1998). After political independence in 1960, grazing became more frequent in the forest reserve. It was discovered that political considerations favoured the establishment of grazing reserves in Nigeria, and the Zamfara reserve became one of the five pilot grazing reserves in the northern parts of Nigeria.

Environmental problems such as desertification, soil fertility depletion and deforestation have intensified in the past years and so many reserves were established to combat them in Nigeria. It is estimated that the country is currently losing about 351,000 hectares per annum of its land to desertification, mainly due to deforestation caused by human activities. Such conditions are estimated to be advancing southwards at the rate of about 0.6 Km per year. This problem is prevalent in ten northern states including Zamfara and accounts for about 73% out of the estimated total cost of about US$5.110 billion per annum the country is losing due to environmental degradation (FRN, 1999).

It has been well documented that human productive activities and the adoption of environmentally dangerous practices are the major causes of land and environmental degradation. SCHERR (1999) concluded that overgrazing accounted for half of the degradation in Sub-Saharan Africa, followed by agricultural activities, deforestation, and the overexploitation of land resources for other purposes. Production practices adopted by farmers determine to a very great extent the level of investment in soil nutrient management. In their studies on the Sub-Saharan Africa problem of soil nutrient depletion in the early 1990s, STOORVOGEL and SMALLING (1993) discovered that the main loss of nutrients occurred through harvest, crop removal and the inadequate use of organic and mineral fertilizers. More dramatic productivity declines under agricultural intensification have been suggested by a review of the African farm-survey unit and experimental data. The survey revealed that in originally fertile lands, under continuous cropping without nutrient inputs, cereal grain yields declined from 2-4 tons per hectare to under 1

ton per hectare (SANCHEZ *et al.* 1997). The above mentioned observation is very important if a reserve that needs to be preserved is viewed from the standpoint of poor soil nutrient management. Bad nutrient management could create chaos and lead to the extinction of a reserve. This is because cropping without fertilization is a practice that involves using a piece of land for some years and abandoning it for another fresh piece of land. The extinction of the Zamfara grazing reserve will, if it occurs, have far-reaching consequences within and all over the northern Savannah part of Nigeria. It is therefore necessary to evolve production strategies and options that will ensure soil fertility maintenance, and at the same time minimize further deforestation: Failure in adopting such proper management practices can increase damage to the ecological balance and the dynamism of the grazing reserve.

Usually, a reserve is not supposed to have settled villages. However, in the Zamfara grazing reserve, there are four enclave villages, which were founded later after the establishment of the grazing reserve. Tsabre and Shamushalle were founded around the 1940s. The founding of these villages and their consequent encroaching of farming activities have thus opened ways for the additional use of the grazing reserve. It has compounded the man-made environmental problems of desertification, soil fertility depletion, and land degradation, that the reserve was established to fight against. The aim of the government for a grazing reserve is that: it will become a centre of agropastoral innovations, a guarantor of land security, a nucleus for nomadic settlements, a precinct for crop/livestock system integration, and a place for small-scale rather than large-scale holder oriented production. However, the above intention of the government has been compromised (BAKO and INGAWA, 1986). This is because the farm practices the various stakeholders are engaged in are varied and in most cases devoid of deliberate effort aimed at ensuring the maintenance of soil fertility management. Since it is no longer feasible to evict these people from the grazing reserve, there is a need to identify and promote farm practices that will enhance the preservation and sustainability of the grazing reserve as a natural resource. This could be in the form of encouraging practices that enhance soil fertility maintenance in such a way that a substantial harvest could be realised on small parcels of land. This will further minimize the clearing of fresh forestland and thereby further reduce the deforestation of the grazing reserve.

1.2 Objectives of the study

The purpose of this study is to examine and evaluate the various production practices employed by various stakeholder communities in the Zamfara grazing reserve and to determine the driving forces behind their adoption. This is with a view to evaluating the best production practice option in the reserve, using an integrated farming system approach that will see to the long-term sustainability of the grazing reserve and the environment. It is envisaged that the study will provide theoretical and quantitative instruments for the proper management and usage of a

public good such as the Zamfara grazing reserve and similar other ones across the country. The specific objectives to be achieved include the following:

1. To examine and describe the various production practices, particularly livestock and crop-livestock integration farming, used by the rural farmers in the Zamfara reserve,
2. to determine the factors driving farmers' participation in crop-livestock enterprise combination and to evaluate the impact of the adoption of such an enterprise combination on crop productivity in the study area,
3. to evaluate the factors driving farmers' participation in manure contracts and the impact of manure contract adoption on crop productivity in the study area,
4. to compare optimised revenues from pure crop and interaction farming systems and to quantify the additional contributions to crop revenues resulting from multiple participations in manure contracting in the study area,
5. to identify the best integrated crop-livestock production practice or strategy for the utilization of resources within the grazing reserve, that will see to the long-term sustainability of the reserve, and
6. to make recommendations on how the identified and chosen production strategy could be best organised to enhance sustainable agricultural productivity in the area.

1.3 Hypotheses for the study

The hypotheses to be tested include the following:
1. Farmers are responsive to taking advantages of incentives provided by a particular farm practice or "technology". Therefore, incentives that go with a particular practice will enhance farmers' adoption of such a practice. Consequently, the incentives offered, such as manure availability, traction power, the provision of more food, and other socio-physical considerations, will enhance the adoption of crop-livestock enterprise combination as a soil maintenance strategy in the study area.

2. In the same vein, socio-economic characteristics of farmers can induce farmers to participate in adopting certain soil maintenance practices. It is therefore expected that the certainty of a farmer on the duration of stay of a herder's livestock on his field, a prior relationship with herders, tribal closeness to the herder, the level of trust reposed on the herder, and other reasons of importance will lead to farmers' willingness to participate in manure contract adoption.

3. "Technology" or practice adoptions are known to have positive impacts on productivity. Consequently, the adoption of soil maintenance practice such as crop-livestock enterprise combination under the same management, as well as manure

contracting, along with other production inputs such as labour and inputs expenses will have positive impacts on crop productivity in the study area.

4. The combination of crop and livestock enterprises under the same farm management would have short-term benefits of increasing farm production and incomes. The alternative manure contract counterpart has less demand on land resource use. Thus, in terms of a reduction in the land area utilized from the grazing reserve, the manure contract option is by far environmentally friendlier to the long-term survival of the Zamfara reserve, and consequently seems to be a more promising long-term sustainability approach for the reserve.

1.4 Presentation of the study

In order to achieve the above-mentioned objectives, this dissertation is organised and presented in ten chapters.

- Chapter one presents the general introduction to the research background and the problem statement as well as the objectives, hypotheses and the organisation of the entire study.
- Chapter two discusses the research design and describes the socio-economic situation, the farming systems, and the current soil fertility maintenance practices used in the study area.
- Chapter three discusses relevant literature that relates to the study. A review of the damage done by agriculture to grazing/forest reserves was carried out. In addition, the role of agropastoralism and pastoralism in the viability of grazing reserves is also reviewed. The role of institutional factors in natural resource management is equally reviewed. Finally, a discussion of various empirical studies on past adoption practices is carried out and a mathematical programming approach in modelling crop-livestock interaction is equally undertaken.
- Chapter four presents the primary analysis of the social and demographic characteristics of farmers in the Zamfara grazing reserve, their farm size, property rights and land use. It further discusses production activities and farm practices farmers engage in for the purpose of maintaining the fertility of their soils. The factors motivating the adoption of farm practices used, and the determinants of participation in manure contracts by croppers and herders, the mode of payment for contracts, and the crop yields from various farm practices in the study area are equally discussed, as well as the use of labour resource and credit usages.
- Chapter five describes the methodology and structural framework for the study. The framework of a farm level bio-economic model (FLHBEM) was introduced for the study. A discussion of the

econometric approaches used for parts of the study is further carried out here.

- Chapter six presents parts of the econometric model that deals with the adoption of manure contracts and the impacts of the adoption on crop productivity among Zamfara grazing reserve farmers.
- Chapter seven presents the results of econometric analyses on the adoption of crop-livestock enterprise combinations under similar management practices and the impacts of the adoption on crop productivity among adopters in the Zamfara grazing reserve.
- Chapter eight specifies the organisation of a mathematical programming model. Relevant definitions, variables and equations are presented. The objective function and the constraints are as well presented.
- Chapter nine presents the results of the model and scenarios developed from it. The selected scenarios explore the impacts of increasing manure contracting on farm household income and farm size; the sustainability of manure contract based crop production is also discussed. The sustainability of pastoralism in the reserve based on biomass production is equally presented. Also examined is the sustainability of the grazing reserve and the impacts of taxation in stabilising livestock population as well as curtailing excessive agropastoralism, which could otherwise have negative consequences on the grazing reserve.
- Chapter ten presents the summary and the main findings of the study. Policy recommendations and suggestion for future research are also discussed in this chapter.

2 RESEARCH DESIGN AND GENERAL INFORMATION ABOUT THE STUDY AREA

This chapter presents the research design and provides general information about the study area. The research design comprises the selection of the study area, the sampling procedures and the design of the questionnaires. General information about the geographical and socio-economic environment as well as the description of different production practices employed by farmers to maintain the fertility of their farmland in the reserve are also presented here.

2.1 Research design

2.1.1 Selection of the case study area

This study was purposively carried out in the Zamfara reserve, located in Zamfara state of Nigeria, to contribute to the evolving discussion on policy and management options that could halt the fast depletion of natural resources in the nation's forest reserves. The Zamfara reserve is located between 6^0 30' and 7^0 15' east and 12^0 10' and 13^0 05' north in Zamfara state and shares borders with the Niger Republic in the north, Sokoto state in the west and the Ruka Forestry Reserve (THE FOREST ORDINANCE, 1938) in the east. The reserve is viewed as one of the few symbols of nature and rich ecological diversity left in this region. Established in 1916, the reserve has passed through many painful transitional stages. At the inception of the reserve, no grazing, farming or erection of dams was permitted in the reserve (FOREST RESERVE ORDINANCE, 1938). The restrictions in use were strictly observed only during the first four decades of its existence. That was the end of a good era for the reserve, which has been sliding gradually and has become degraded within the context of its rich diversity since then.

After independence in 1960, when grazing became more frequent in the reserve and the political discussion favoured the establishment of grazing reserves in Nigeria, the Zamfara reserve became one of the pilot grazing reserves in Nigeria. Ever since that decision, which was never gazetted, (GEFU, 1994), the Zamfara grazing reserve has seen more trouble and deteriorations in the form of an encroachment on a sizable portion of it for cropping. These cropping activities are being carried out by the inhabitants of the four enclave villages in the grazing reserve as well as pastoral Fulani that have equally embraced cropping with animal husbandry. Consequently, the cropping area, which was just about 2660 ha in 1965, has gradually increased and is currently about 7,310 ha in 2001 (HOF, 2003). Most of the encroachment on the grazing reserve has occurred on the western border of the reserve. It has been documented that most of the allocation of the land to farmers for cropping in the reserve is done on the agreement that

farmers would replant those plots with trees after planting crops on them for four to five years. This agreement, if it existed at all, has never been honoured, and hence all the areas hitherto cleared for cropping have been permanently deforested, (personal communication with reserve official and HOFFMANN, 1998). One of the major impediments facing farmers in the planting of tree stems from inadequate rainfall that could make such an exercise a futile effort. This is because it is often difficult for them to provide water for such trees to grow, as there is no irrigation facility in the grazing reserve to facilitate the success of their efforts. The lack of tree planting is a dangerous trend for the long-term existence of the forest reserve and should be minimized if it cannot be totally halted.

On the other hand, the Nigerian government and individuals have until recently had a poor attitude to the management of reserves and its diverse resources. With the new awareness on the importance of biodiversity as indicated by the Minister for Environment at a recently concluded National Workshop held in Abuja on the National Biodiversity Strategy and Action Plan (NIGERIAN VANGUARD, APRIL 13, 2004), it is important that a study of this type is carried out as follows:

1- To examine the farm production practices in the study area with a view to identify the best option that will be environmentally friendly to the sustainability of the reserve.

2- To examine factors driving these practices so that actions could be mapped out in providing alternative practice(s). These alternative practices should help farmers to realise good productivity objectives.

3- To evaluate the impact of the adopted practice(s) on crop productivity in the study area.

4- To provide recommendations that could form the basis for a better management of the Zamfara reserve and other similar reserves across the country.

The study is therefore timely since it will help to generate ideas on better ways to manage the Zamfara grazing reserve and other similar natural resources.



Figure 2.1: Map of Nigeria showing the 36 states of the federation.

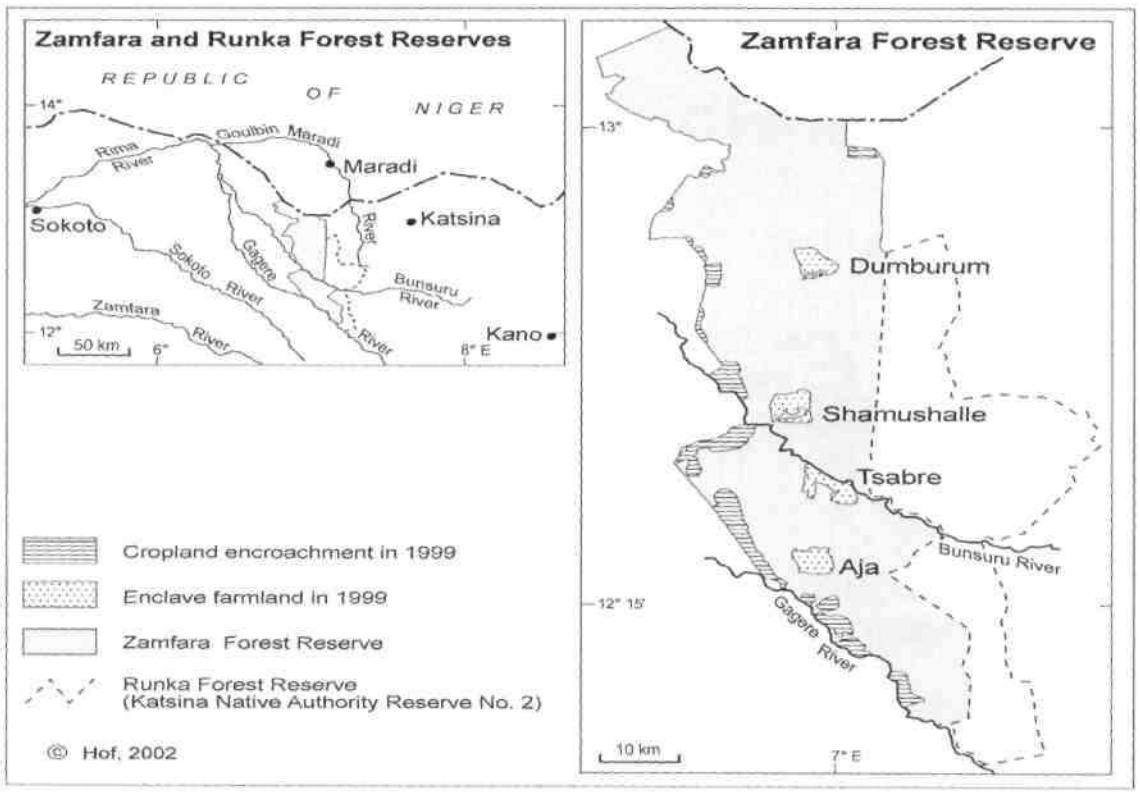
2.1.2 Geographical and demographical features of the study area

The study was conducted in four enclaves, namely Dumburum, Shamushalle, Tsabre and Ajja, all located within the Zamfara reserve as shown in Figure 2.2. The natural vegetation of the Zamfara state is Sudan at the southern fringe whereas Sahelian vegetation dominates the northern fringe. The dominant soils in the entire region and Zamfara are light sandy soils that are poor in organic matter and consequently have low water retentive capacity. The poor and loose composition of the soils in the region makes it imperative that even when chemical fertilizers are used, they must be used in conjunction with organic manure to enhance nutrient uptake and utilization by crop plants.
Due to continued and intensive cultivation, soil productivity has declined drastically over the years and most wooden species are gradually disappearing from fallow vegetation. The intensive cropping of fragile soils has worsened the problem of soil degradation in the entire region over the years.

With a population of 2.069 million and a population density of about 54 persons per square kilometre, continuous intensification and consequently pressure on land is inevitable in the Zamfara state. For instance, the household population in

villages within the reserve has increased tremendously from less than 100 households in the 1930s, to well over 1190 households presently. Due to high natural birth rates, the expansion of production activities is inevitable. The current total estimated population of the villages within the reserve is about 27,250 people. In comparison with 7,310 ha, the area of land that is currently under cultivation, we obtain a per capita land area of 0.27 ha. The growth of the population in the entire state has equally put pressure on the acquisition of new land from the grazing reserve.

The Zamfara grazing reserve, which was formally declared a no farming area, later had to accommodate to grazing. It has recently been discovered that the intrusion of farming into the reserve is not being properly managed and controlled. This lack of control may herald the demise of the so much cherished symbol of ecological biodiversity in the region. This is even so because few of the Fulani, who are supposed to be full-time pastoralists, have also joined the croppers in cutting down the forest to grow crops. It is quite amazing to note that pastoralists, that normally cry out about marginalisation by farmers, on the basis that the croppers have encroached into their grazing areas, are now contributing to the process that could lead to the extinction of their grazing reserve.



Source: Hof, 2002

Figure 2.2: Enclaves in the Zamfara grazing reserve and the state of land cultivation and encroachment in the reserve

2.1.3 Climate and rainfall pattern of Zamfara

The climate of northwestern Nigeria, where the Zamfara state is located, is relatively dry compared to other parts of the country. However, the Zamfara state itself is one of the driest states in the northwestern ecological zone of Nigeria. The average annual rainfall in Zamfara ranges between 290 mm per annum in a bad year to as high as 650 mm in a good year. The rainfall begins towards the end of the month of May and lasts to the early parts of September. A four- to five-month rainy period is the growing season for the rain-fed agriculture practised in the area. Thus, the success of agricultural production in Zamfara and indeed the region depends principally on rainfall in terms of both quantity and the spread of distribution. With a uni-modal rainfall, farmers in the region can cultivate crops in only one season a year. The area is drier than most other parts of the country and the temperature ranges between 14.1^{0}C around December, when there is the cold Harmattan wind to as high as 44^{0}C in the hottest months. The hottest period is between February and April, just before the commencement of the rain. The dry wind blowing across from the Sahara desert coupled with the sun radiation lead to a very high evapotranspiration rate in this region in general and in the Zamfara state in particular. With these adverse weather conditions, the ability of the vegetation to regenerate when, cut down, is greatly impaired. Adverse weather conditions have made it imperative that the grazing reserve must be utilised in a way that ensures effective management of its resources to prevent its eventual extinction.

2.1.4 People in the study area

Two predominant tribes live in the Zamfara reserve. They are the Hausa and Fulani tribe. These two tribes are the closest among the various tribes making up the people of Nigeria in terms of culture and religion. They are generally referred to as Hausa-Fulani at a national level in reference to the closely-knit relationship between them (WORLD PRESS REVIEW, 2001; WIKIPEDIA, 2004 and BUREAU OF AFRICAN AFFAIRS, 2004). There are, however, some distinct differences between these two tribes. While the Hausa are generally involved in the growing of crops, with some of them combining cropping with the possession of animals (agro-pastoralists), the Fulani are predominantly pastoralists. They are either transhumant or nomadic pastoral Fulani, implying that they are involved in migration in search for better pastures for their animals at particular periods of the year. There are also some Fulani that have become sedentary in their mode of production, meaning that they have become settled to produce some crops combined with their normal animal husbandry practices. They combine crop production with livestock rearing to get some crops from their farms to meet family food needs. In 1991, the average population density in the four local government areas (LGAs), within which the reserve is located, was 83 persons per Km^2. The current estimate indicates that about 27,250 persons lived in the enclave villages while about 100,000 people live in villages at the western fringe of the

reserve. These inhabitants of the adjoining villages also utilise resources from the reserve (ARCA, 1995).

2.1.5 Crops grown in the study area

Cereal crops, like millet and sorghum, that are highly drought tolerant, are the major crops that are grown in the study area. Pulses such as cowpeas, soybeans, groundnuts and Bambara nuts are also grown. The major non-food crop grown is cotton. It is grown solely as an income generating crop. Cowpea has over the years also become an important cash crop in most parts of northern Nigeria. Cowpea is regarded as one of the major agricultural trading crops between the southern and northern parts of Nigeria. This is because the lower rainfall in this region enhances the adaptability of cowpea production compared to the south, which is characterised by excessive rainfall for the crop. The cultivation of rice in smaller quantities has equally been observed within the Zamfara grazing reserve (Mane-Bielfeldt, A. *et al*, 1998). Vegetables such as tomatoes, pepper, leafy vegetables and garden eggs are also grown all over the state.

2.2 Study approach and survey design

2.2.1 Study approach

The methodological framework for this study is based on the following five-steps approach:

1- To examine and describe the various production practices engaged by herders and croppers in the study area;

2- to determine the factors that drive farmers' adoption of manure contracts and the impact of the adoption on crop productivity;

3- to determine the factors that drive farmers' adoption of crop-livestock enterprise combination under the same management and the impact of such enterprise combination on crop productivity;

4- to compare crop yields and revenues under regimes of crop-livestock enterprise combination and manure contracts; and

5- to build models to optimise production profits with a view to realistically determining the production practices that will be environmentally sustainable in the context of the various farm production practices.

The aim is to bear in mind the impact of these production practices on the environment so that we can enhance the effective use of resources for farm production in such a way that will ensure the long-term sustainability of the Zamfara grazing reserve. This is with a view to deriving recommendations for the sustainable management of the Zamfara grazing reserve and similar reserves in Nigeria. Such recommendations could be in the form of evolving rules and

regulations on how production should be conducted in an environmentally sustainable manner within the grazing reserve.

2.2.2 Specification of research units

Households rather than individual farmers were considered as the units of observation in this study. This is justified by the fact that there were common criteria that emphasise the importance of households as the major decision making units in the study area. A household is defined as the total number of people living under the same headship and deriving their source of livelihood from the same source (NORMAN *et al.*, 1982). The family head is also responsible for administering the family land. He/she is responsible for taking decisions on what crops to grow, and animals to keep by the family. He therefore cultivates the most important parts of the family fields. He may allocate parcels of family land to family members, which they can cultivate, and use the harvest for themselves. In the African context, all family members are subject to the regulatory rules of the household head as prescribed by the traditional institutions and customs of the people. It is therefore assumed here that there is a consensus among the members of a household to treat internal dissension as a minor issue in their considerations. From the foregoing, the farm household is considered as the basic research unit for this study. This approach was in the past also adopted for various national censuses in Nigeria. Because the entire household is knitted together, an individual in the household lives under the responsibility of the household head. Persons in a household can be related to the head through blood, marriage or by adoption. The notion of a single decision making, as pertains to this study, is different from what is obtained in a bargaining decision making. In the case of bargaining decision making, several decision makers with unequal bargaining power mainly interact in cooperative repeated games (MCELROY, 1990; BOURGUIGNON and CHIAPPORI, 1992). Our notion of a household in this study is restricted to a unified decision making process

2.2.3 Data stratification and sampling approaches

The aim of the sample selection procedure is to give as far as possible an adequate and representative picture of the various households out of the total 1190 farm households in the study area. For this purpose, the study area, covering the 2355 Km^2 wide expanse of the Zamfara reserve, was divided into four areas namely; Dumburum, Shamushalle, Tsabre and Ajja (FORESTRY ORDINANCE, 1938). These were later divided into two zones to facilitate the Probit analysis.

Data was collected from these four and all the adjoining hamlets attached to them. For each of these enclaves and the adjoining hamlets, the lists of the households were collected from the village head, from which samples were randomly selected. Other willing participants subsequently replaced households not willing to participate in the interview. Due to the large number of agropastoralists, a total

list of 228 agropastoralist participants and non-participants was sampled. The first set of the sample was made up of 143 agropastoralist adopters and 85 non-adopters. A total of 85 manure contract adopters (n = 40) and non-contract adopters (n = 45) were also randomly selected. Information was also generated from a few pastoralists in the area, during their stay in the survey period. These sets of observation for each group of farmers sampled for this study were therefore considered adequate and representative of all the households in the Zamfara grazing reserve.

2.3 Data base

In order to achieve the objectives of this study, data were needed on a wide array of socio-economic parameters about respondents. Consequently, a variety of data on the social and demographic characteristics of farm households was collected. These included: the age of farmers, their marital status, the number of wives and people in the household, production inputs and outputs, production methods and practices for soil fertility maintenance, and the reasons for adopting a particular practice. The methods and practices of production, the numbers of crops grown and whether crop and livestock were combined under the same management as well as the reasons behind such a production decision were investigated. Prices of inputs as well as of outputs were also collected in the area. In accordance with the study and its approach, primary and secondary data were collected using appropriate methods.

2.3.1 Primary data collection

A cross-sectional survey was carried out for this study between December 2001 and August 2002. A total of 143 agropastoralist and another 85 non-agropastoralist participants were sampled. The first set of non-adopter agropastoralists was needed to enable the analysis of a Probit model discussed later in chapter seven. Also, 85 croppers who are contract and non-contract participants and some pastoralists were sampled within this period from the enclaves in the grazing reserve. To ensure that all-important data about the household activities were collected, the respondents as well as their family members were interviewed. Exceptions were women who are by nature of their custom generally forbidden from communicating with men and in particular with strangers. The interviews were conducted using standardised semi-structured questionnaires. The relevance of the questionnaires was improved after pre-tests had been carried out in early January 2002 in some of the villages. To facilitate good understanding with the respondents, well-trained enumerators who were of Hausa/Fulani origin and who have been on the job for over two decades served as interpreters. Since tribal affinity is very important in getting accurate information devoid of deceits from the respondents, it was considered essential using enumerators with experience in farmers' culture and language for the interview.

This is because establishing trust among the people of this area entails a lot. It entails seeing somebody who prays in the same Mosque with the farmers, wearing the same dress pattern and speaking the same language with him as well. These are all very important trust facilitators to enable farmers' volunteers on vital information. Because of the respect the people have for their traditional institution, the consent of the village heads was sought to gain access to the people. This in fact facilitated access since the village heads had sent message round through their servants to tell people that we were permitted to work with them in the area.

2.3.2 Secondary data collection

Secondary data was collected through the survey of the existing literature and from the records of available information from organisations and agencies. The Institute for Agricultural Research (IAR), Ahmadu Bello University (ABU) was particularly helpful in providing some information they have on farming activities in the Zamfara state. The Central Bank of Nigeria (CBN) was helpful in providing access to the extent of farm loan finances in Nigeria as well as information on the status of agriculture in the national GDP. Information was also obtained from the Meteorological Department Lagos, the National Planning Commission, and the Food and Agricultural Organisation (FAO) as well as the International Institute for Tropical Agriculture (IITA), and the International Agricultural Institution based in Ibadan Nigeria. The information gathered from the above organisations was used along with the primary data for this study. Some of the information obtained from these sources form part of the reporting in chapter three and are equally used in the modelling aspect of this work.

2.4 Data processing and analysis

2.4.1 Data entry, control and error correction

Data control and error corrections were done prior to the data entry and the compilation of the database. Unclear and contradictory answers in the questionnaires were registered and taken back to the farmers for verification before the final entry was made. The whole farm average was also used to cross-check the extent of outliers responses in the information generated.

2.4.2 Descriptive analysis

Various statistical and mathematical analyses were used to achieve the objectives of this study. Firstly, simple descriptive statistics (mean, standard deviation. etc) were computed to specify the major characteristics of farm households and the values of some parameters of interest pertaining to the farm practices, production and inputs used in the study area. For the graphical presentation of the data and

statistical analysis, Excel for Windows, SPSS software package (Version 12.5) and LIMDEP (Version 8.0) were used.

2.5 Summary

In this chapter, the criteria for the selection of the study area were discussed. The geographical and demographical features of the study area as well as the climate and the people of the region were equally presented. Other issues discussed in this chapter were the study approach, and the specification of the research units. Finally, the sample sizes and the type of data collected were also discussed.

3 REVIEW OF RELEVANT LITERATURE

Although agricultural production is seen as an occupation that is playing an indispensable role in the livelihood of people in most developing countries, farming in general have been seen by many as a threat to the natural environment. In rich as well as poor countries, the human stake in resource utilization is now very high because food needs are acute and rapidly growing (PAARLBERG, 2001). The impact of agricultural production on deforestation and its consequent contribution to environmental problems were identified long ago. Between 1960 and 1990, the world lost an estimated 20% of its tropical forest (BRYANT, NIELSEN, and TANGLEY, 1997). Without doubt, agricultural activities have brought economic benefits that can help to alleviate poverty, but agronomic limitations of forest margins, soils, and climate have raised others question about the scope and sustainability of such production gains. It has been observed that continued deforestation threatens global environment with negative consequences such as carbon sequestering and the depleting of biodiversity. The annual burning from intentional or runaway fires have been known to be causing local damage to humans, destruction to property, creating respiratory ailments and transportation disruptions (CHOMITZ and THOMAS 2000; NEPSTAD *et al;* 1999). The debate centers on how to manage forest margins and particularly grazing reserves so as to simultaneously meet the so-called "critical triangle" of development objectives: economic growth via agriculture, environmental sustainability, and poverty alleviation (VOSTI and REARDON, 1992). The fundamental of this debate is a searching for solutions that can preserve the remaining forest while meeting the livelihood needs of forest margin inhabitants. Growth requirements of regional or national policy makers imply a balance, sometimes termed sustainable intensification (VOSTI, 2002). Due to limitations and the specific research scope, only part of the environmental problems arising from deforestation and degradation will be reviewed here. The literature review is further divided into the following sub-headings: agriculture and deforestation, the negative effects of agropastoralism on grazing reserve environment, the positive impact of agropastoralism on grazing reserve environment, pastoralism activities' impact on the grazing/forest reserve, and sustainable options for the natural resource use under a grazing/forest reserve setting. Manure contracting is considered as a way out for producers under a grazing reserve setting. Further discussion is carried out on the role of institutions in deforestation patterns, models for soil fertility maintenance adoption studies, and the mathematical programming model for household production practices.

3.1 Agriculture as a cause of deforestation and land degradation

The development of the agricultural sector has involved progressive and intensive use of land resources for cropping and grazing and with this, greater control and pressure on local habitats exploitation, leading to environmental damage. The development of the agricultural sector of most countries (along with other sectors of the economy) has therefore involved adaptation to a changing environment. The definition and measurement of land degradation provide one method of monitoring the impact of human activity on the environment and of linking the environment with the economy.

Land degradation has a negative connotation, which implies a loss of something of value within the environmental-economic system. This loss in value may be related to the productivity of land for agriculture and the environment being a host to naturally occurring species of flora and fauna. The environment is also seen as a place for other human activities such as mining, and secondary industries, where human habitation and waste assimilation are also affected.

Agricultural land degradation, in particular, according to GRETTON and SALMA (1997) is significant because it:

- affects agricultural productivity
- leads to the clearance of forests and native grasslands as existing land loses its productivity
- places demand on other natural resources to repair the land (lime for neutralising acidity, water for flushing irrigation salinity); and
- leads to off-site pollution and the loss of productivity and amenity values.

For the purpose of this study, degradation is viewed from two standpoints, the loss of productivity of agricultural land as well as the subsequent loss of forest, which is then cleared for farming.

Tropical and savannah forests as well as grazed forests are rapidly disappearing and thereby incurring serious potential social cost in biodiversity loss and carbon emissions (VOSTI, 2001). VOSTI concluded that small-scale farmers account for about two third of the forest destruction, by converting forestland to agriculture. Most of these farmers are poor and hence move to the forest margins to escape from poverty, and they deforest in order to survive. The act of deforestation is unlikely to slow down until poor people can earn a living and meet their food needs. The economic model of processes generally has one or more of several conceptions of what will limit agriculture's encroachment on the forest, with emphasis on the role of one or two forces behind agricultural expansion. Agricultural profitability has been viewed to generate the impetus for clearing of forest within a certain range of markets. This is particularly true under certain economic conditions such as the special approach used in, for example, CHOMITZ

and GRAY, 1996, on the exploitation of timber in central America (STONE, 1998). Beyond that range or even within it, agronomic unsuitability of land such as low fertility could provide its own impetus for the clearing of more virgin land. This is especially true for those at risk of poverty who mostly rely on new land from forest rather than on purchased inputs for soil fertility maintenance on old lands as the most viable option (CHOMITZ and THOMAS, 2000; VOSTI and WITCOVER, 1996b; VOSTI and REARDON, 1992). This has been the case in most parts of Nigeria where farmers are poor and unable to afford purchasing fertilizers. They abandon old plots and clear new forests.

It has also been emphasized that population growth plays a very vital role in deforestation of the existing forests across the world. PFAFF (1997) emphasized the role of an expanding demand for agricultural products arising from rapid population growth as a major contributing factor to deforestation. CATTENEO (2002) also observed that there are about 16 million people living around Amazon forest who depend on the farming activities in and around the forest for their food needs. The author quoted above is of the opinion that, as the population in this area increases, deforestation is bound to increase. The household population within the Zamfara reserve has increased over the years and whatever is happening to Amazon forest may soon become the expected result in the Zamfara reserve. This is very convincing evidence that an increase in the population of people living in the Zamfara grazing reserve will continue to have negative impacts on the stability of the reserve.

However, new technologies can relieve agronomic constraints beyond the short-term measure (on soybeans, FEARNSIDE, 2001; KAINMOWITZ and SMITH, 2001, and on improved pasture, YANGGEN and REARDON, 2001). It has been emphasised that African rural environment is currently at risk because too many farmers are trying to produce more food at the same time. They do this simply by extending traditional low-input practices - such as shifting cultivation into forestland, into drier and more fragile lands, or by shortening fallow times and thereby creating more soil degradation problems (PAARLBERG, 2001). This has become common practice due to the fact that African farmers are lagging behind in the use of improved inputs, like fertilizers. Perhaps only such inputs can bring about the desired yields while maintaining the current land area under cultivation. PAARLBERG (2001) has discovered that the fertilizer use rate in Africa is about 12 Kg/ha, which is just about a fourth of the level in India and one-thirty sixth of the level in Japan. These existing average values for Africa are grossly inadequate. If considered from the viewpoint of an increased number of mouths that must be fed, it is inevitable that croppers have to encroach on forest and grazing lands to facilitate more food production. Therefore, there is a need to enhance soil nutrients either through the use of modern inputs or locally available alternatives. Experience from India indicates that by switching to highly responsive seeds, fertilizer use, and expanded irrigation, local wheat production doubled between

1964/65 and 1970/71. This not only helped India to avoid famine, it also helped to protect the rural environment. If India had attempted to use traditional low-yielding farming techniques to secure the same wheat production gain, it would have had to plough up an additional 36 million hectares of cropland. This would have resulted in further deforestation, substantial habitat destruction, and soil degradation and starvation would have been inevitable for a country with a population of over a billion (PAARLBERG, 2001).

Evidence is building up in the scientific community that the continued release of greenhouse gases threatens to raise the temperature of the earth and disrupt the climates we depend on. Most of the increase in atmospheric carbon dioxide ($C0_2$) concentrations has come from the use of fossil fuel (Coal, Oil, and Natural gas) for energy. Consequently, 20-25% of the increase over the last 150 years can be attributed to changes in land use. It is evident that the clearing of forest and the cultivation of soils for food production cannot be neglected (CATTANEO, 2002). To solve the problem of environmental degradation resulting from agricultural production, the generation and use of more sustainable agricultural technologies is absolutely critical. This requires focusing not only on agricultural technologies that just meet growth goals or those that meet only sustainability goals, but also on those that meet both growth and sustainability goals. This was echoed by VOSTI, (2001). It will involve not just the use of modern inputs like fertilizers, as far as African farmers are concerned. Since these farmers lack the necessary financial capability to achieve desired outcomes, it may involve an inward looking approach into some of the local technologies. A better way of developing the potentials of the rural poor farmers for effective and sustainable production is by helping them to develop natural local inputs available around them. This calls for an evaluation of the current traditional practices farmers engage in to maintain their soil fertility with a view to identifying options that will be environmentally friendlier and sustainable. Given the nature of the Zamfara grazing reserve, as the only biodiversity bank left in the study area, we need to apply special innovations to ensure its conservation. The next section will involve the review of the various forms of crop-livestock interactions practised in the area with a view to identify their strengths and weaknesses given their suitability or otherwise in a forest or grazing reserve setting.

3.2 The use of crop-livestock interaction for soil fertility maintenance and its probable effects on the environment

Agricultural production entails the production of both crop and livestock. While the first can be described as the act of cropping, the second is termed animal husbandry. There are situations when these activities are done separately while at other times, they are combined under the same management, usually referred to as mixed farming. Mixed farming is also termed crop-livestock integration. In some instances, there could be a loose interaction between two enterprises under

different management, in which the exchange of resources takes place between two enterprises. However, the most popular for many past decades has been the possession of crop and livestock under the same management. This process is often called agropastoralism. There are many characteristics attributed to having crops and livestock under the same management. These, among other things, are discussed below.

3.2.1 Merits of crop-livestock combination

The major characteristic of a mixed farming system is its complimentarity as defined by MCINTIRE *et al.*, (1992), i.e. the supply of inputs from one sector to the other. It includes the use of draught animals and manure for crop production or crop residues as livestock feed. Integration has a long history in Sub-Saharan African countries such as Ethiopia, Madagascar and Nigeria, and is widely employed in the Gambia (THOMAS and BARTON, 1994). Draught animals can assist the farmers to improve soil tillage and to introduce soil conservation practices such as terracing, ridging and broadbed-furrow systems; operations that are unlikely to be undertaken with hand cultivation (THOMAS and BARTON, 1994).

However, the judgement that there has been overgrazing in areas where there is crop-livestock mixture still seems to hold. There has, however, been a misunderstanding. One typical example is the goat, a common component of agropastoral systems. Goats certainly graze and browse eclectically, and can damage rangelands if fed at the same time from other sources (as they often are). But goats have many advantages, such as rapid reproduction, multipurpose production, and the ability to reduce the competition for water by grasses (GOUMANDAKOYE, 1989). It is thus considered that blanket condemnations of goats were probably unwise (DRIESCH, 1982).

Only close study of agropastoral systems can reveal the complex ways in which they are managed, as was shown in many parts of Africa and in Nigeria (MORTIMORE, 1989). The role of cattle needs much more attention. How much pasture is needed to keep animals to fertilize fields with dung? Only careful calculation and measurement can reveal these critical features for farming systems (VAN KEULEN and BREMAN, 1990; BREMAN and TRAORE, 1990).

An essential attribute of crop-livestock enterprise combination is the provision of manure for soil fertility maintenance. Soil fertility depletion is a major constraint to agriculture, notably in farming systems of sub-humid as it is the case also in dry areas, and where the use of artificial fertilizers is known to be very low. Even when the inorganic compounds are applied, cereals may not be maintained under continuous cultivation on nutrient-poor sandy soils with a low buffering capacity (BATIONO *et al.*, 1989). An example of the extension of yields decline as a result of soil fertility depletion has been reported by SRIVASTAVA *et al* (1993). Organic

materials applied in bulk have been shown to improve soil texture, promote better absorption of moisture, reduce nutrient run-off and prevent crusting of the soil surface (WATTS PADWICK, 1983). Even small quantities of organic materials have been identified to have the capability to bring about marked improvement in the cation exchange capacity status of soils. The supply of manure has been seen as a major benefit of crop-livestock enterprise combination and is often the only means of maintaining organic matter levels and sustaining the soil fertility in cropping systems in developing countries. Many of results of manure trials conducted in tropical Africa are given by WATTS PADWICK (1983), SANFORD (1989) and MCINTIRE *et al.*, (1992). They all bear testimony to the importance of manure in crop production in tropical Africa.

Crop residues from crops grown for human consumption are an important component of farming in most developing countries and are important sources of nutrients for livestock in the dry season. At a certain time of the year, the levels of crude protein and phosphorus in the residues of fertilized crops can be two or three times higher than those available from native pastures (THOMAS and BARTON, 1994). Crop residues can thus compensate for the loss of natural grazing as a result of increased cultivation and burning. They help to reduce the overstocking of rangeland, which can otherwise result in land degradation. The importance of crop residues as feed in West Asia and North African countries was described by NORDBLOM (1988). In Asia and Latin America, MCDOWELL and HILDEBRAND (1980) estimated that crop residues and by-products can contribute 30-90% of livestock feed on small mixed farms. In Sub-Saharan Africa, the contribution of crop residues to feed intake in ruminants was discussed by SANFORD (1989). On an annual basis, it was said that the proportion of feed to be derived for cattle from crop residues may be as high as 43%, increasing to about 80% in the peak months of the dry season. Having highlighted some good attributes of crop-livestock enterprise combination or agropastoralism, there are some attributes of the system that are rather opposite to the goal and aspiration of having sustainable and environmentally friendly production systems. These weak points of agropastoralism are discussed below.

3.2.2 Demerits of crop-livestock combination:

There are many negative environmental consequences trailing the practice of crop-livestock enterprise combination where it is practiced. THOMAS and BARTON (1994) classified these negative consequences into six categories as shown: 1. Degradation of vegetation resources due to overgrazing, 2. Increased soil erosion due to the removal of vegetation, 3. Deterioration of soil erosion due to rapid run-off, 4. Vegetation removal and soil compaction (decreased infiltration capacity), 5. Displacement or reduction of wildlife populations by reducing habitats; competition for food and water resources; introduction of diseases; impact of burning; increased poaching and killing of wildlife considered as pests or

predators of livestock, 6. Increased soil erosion resulting from the re-allocation of crop residues from mulch to livestock feed and fuel. This is because the residues that were originally used for mulching are now utilized as livestock feed within the integrated system. Many of the problems itemised above are beginning to manifest in the Zamfara grazing reserve due to the problem of many Fulani joining their Hausa counterparts to cultivate crops along with their normal pastoral life. It was also shown that some of the perceived advantages derived from crop-livestock combination systems have lots of disadvantages as discussed.

Manure production for soil fertility maintenance has been taunted as one of the best attributes of crop-livestock enterprise combination. However, it has been observed that crop-livestock farmers in Sub-Saharan Africa rarely keep sufficient numbers of animals, or manage these animals in a way to provide enough manure. Therefore, nutrients to maintain fertility without the application of other techniques including fallowing, the growing of legumes, the incorporation of crop residues and the use of chemical fertilizers are limited (THOMAS and BARTON, 1994). It has always been suggested that animals are kept for a number of social and economic reasons and that the major objective of a farmer is crop production to guarantee subsistence and income. The production of manure was in various studies considered a secondary purpose of keeping animals as part of farm business and not a major reason for keeping animals. However, it has been found from the results of this study that the most important decisive factor for farmers to keep animals with cropping activities. It is the nature of crop-livestock relations among the farmers, which combines the two operations under the same management. In the Zamfara reserve, the cropping activity is seen as the major activity and the animal aspect as a subsidiary. This is not an attempt to diminish the importance of manure, particularly in the absence of chemical fertilizers, since it is known that manure has played and is still playing an important role in soil fertility maintenance in developing countries. But manure is seen as being very bulky in nature, making its carriage and subsequent use less efficient (THOMAS and BARTON, 1994). However, the increased use of manure in the absence of declining fallow and fertility has witnessed some recognition (RAVNBORG, 1990). The question as to whether the quantities applied are sufficient to maintain fertility is open to examination and further debates. In most areas of Africa, small ruminants predominate but they are rarely integrated with crop production and forage is not grown and the manure of the small animals is rarely returned to cultivated plots (RAVNBORG, 1990). In Asia, ruminants are managed intensively through tethering and stall-feeding, depending upon the season and the availability of grazing land (DOYLE *et al.*, 1986). Restricting the movement of animals obviously produces more usable manure, but this is rarely sufficient to maintain fertility in continuously cropped land without the use of additional techniques for soil fertility maintenance. However, such a management system of restricting animals' movement is not practiced in most parts of West Africa and particularly in Nigeria, where animals are left to roam about looking for feeds.

Crop residues are very important source of feeding for livestock in an integrated farming system, where both crop and livestock are managed together. It has, however, been said that the level of the intensity of crop residue use is closely correlated with the availability of alternative sources of fodder, in particular natural grazing. For example, in Thailand, average holdings are 4.28 hectares and 83% of this is used for cereal production. The remainder is utilised for vegetable and fruit production with only 0.03 hectares available for grazing (KHAJARERN and KHAJARERN, 1984). The land devoted to forage production in the above-cited example is effectively wasteland, being field boundaries and bunds. This is in a locality where livestock contributes 17% to total farm income. The situation is similar in many other Southeast Asian countries (DOYLE *et al* 1986). Under these conditions, farmers have the alternative of using agricultural residues to maintain their livestock. Some aspects account for the efforts made in recent years to upgrade these residues by chemical treatment and supplementation (DIXON, 1985). It is not economically or socially feasible to replace crop production for human consumption with the development of fodder crops for livestock, especially in poverty-ridden countries. That is, in countries where population density remains high, and food production is lagging behind population growth, food is seen as a major problem. Under Nigerian crop-livestock enterprise conditions, no land is devoted at all to forage production, making the system a very peculiar one in terms of the premium placed on the production of forage to feed livestock. Under these circumstances, we literally assign zero for that component and yet animal production is considered to be a part of the farm business activities within the Nigerian context. The effect of non-forage production in the Zamfara reserve is the additional pressure that will be exerted on the grazing reserve, i. e. the pastures, by the additional livestock of the agropastoralists. The case in Zamfara is even worse since animals of agropastoralists will graze consistently near the homestead, exposing the areas closer to the homestead to severe soil erosion and other agents of land degradation.

There are examples of crops that have potential as providers of both human food and animal fodder. Groundnut hay is an important feed resource for livestock in West Africa. However, labour demands do not always allow the best use of these resources, since the crop is not always harvested at its peak feeding capacity due to conflicts with other cropping activities (THOMAS and BARTON, 1994).

There is evidence that some pastoral groups are beginning to cultivate crops in response to a decline in the availability of grazing land (TOULMIN, 1983). The increased usage takes two main forms. The first is the extension of cultivated area. This has been very considerable, if extrapolation is made from few available studies in Nigeria and other African countries. In the Tapoa area of Burkina Faso, the proportion of land in cultivation rose from 9.5% to 25.2% between 1956 and 1986, a 166% increase or 3.3% per year. By 1986, 66% of the best land, class A,

was occupied as well as 36.3% of the bad land, class C (SOW, 1988). In other parts of Burkina Faso, the area cleared for cultivation increased from 32.2% to 65.3% between 1975 and 1987 (VAN POPPEL and LEKKERKERKER 1991). In parts of northern Mali, where there are extensive sandy soils of similar quality, agricultural land expanded from 28% to 55% of the total area between 1957 and 1987 (THOMAS and BARTON, 1994). This is similar to the present situation in the Zamfara grazing reserve and other grazing reserves in Nigeria that are currently experiencing encroachment by croppers into the grazing area. If this trend is not checked, it may snowball into the extinction of the reserve in years to come. That will be a defeat to the environmental and biodiversity protection, and to the objective for establishing the reserve.

The emphasis here is not on establishing the superiority of separate pastoralism and cropping systems. It is rather to bring out the negative impacts of the crop-livestock enterprise combination in a grazing reserve or a forest reserve. Apart from those negative impacts that were discussed above, the traditional socioeconomic links between farmers and pastoralists are usually disturbed by the reduced mobility of the now settled agropastoralists and, consequently, the loss of pasture due to the encroachment of cropland. An increase in the number of livestock kept by farmers has therefore aggravated the competition for available crop residues, and is thereby hampering the traditional manure contract exchange system (HOFFMANN, 2002).

Since the combination of crop and livestock enterprises under the same management is riddled with so many problems, particularly the tendency to convert more grazing areas into farming areas to the detriment of the forest biodiversity, it will be a good idea to have a system that allows the two enterprises to operate under different management. In this way, a synergy could evolve between the two groups. The synergy would facilitate the availability of manure to the croppers as well as facilitate the availability of crop residues to the herders in the same community within and outside the reserve. This might be a way out and an opportunity to realise a system that will enhance the long-term sustainability of the Zamfara grazing reserve.

3.3 Does pastoralism play a prominent role in deforestation and environmental degradation?

Livestock production has been viewed to have negative impacts on rangeland and consequently the environment. As stated by STEINFELD *et al.*, (1997), livestock production systems are currently being scrutinised with regard to their negative environmental impact, even though globally recognised for their contribution to the income and welfare of the poor (LIVESTOCK IN DEVELOPMENT, 1999). The assertion made above could still be regarded as an echo from the old usual colonial belief and theory of carrying capacity. Some authors (SCOONES 1995;

TOULMIN 1995) suggested that in the Sahel, overgrazing has no major long-term effect on rangeland forage production. This is in contrast to the proponents of the optimum carrying capacity that has been canvassed for so many years. One of the past held assumptions in African rangeland science was the belief, by many colonial regimes, that pastoralists behaved irrationally. This paradigm became one of the elements that persisted even after the colonialists themselves had departed (BAKER, 1975). Other elements were an entrepreneurial view that rangeland should be producing beef for national or world markets. That paradigm produced policies to enforce, and often draconically, the de-stocking and the privatisation of land. The theoretical basis of this paradigm was a concept of ecological equilibrium, a notion that is now being strenuously re-examined by ecologists (DE ANGELIS and WATERHOUSE, 1987). A new paradigm has, however, arisen which is based on the theory that most arid and semi-arid ecosystems never achieve equilibrium (WARREN and KHOGALI, 1991).

The effect of "overgrazing" and the overshooting of the "carrying capacity" have featured prominently in the annals of rangeland degradation and desertification. Yet the inspection of these concepts by ecologists and pastoral agronomists finds them to be flimsy tools for examining local pastoral systems. The re-examination of old concepts is one of the forces behind the adoption of a "new paradigm" in rangeland ecology. In this new paradigm, it appears that for the great majority of those Sahelian rangelands that were condemned in many semi-popular accounts to millennial damage, grazing has actually inflicted much less damage than drought and desiccation. The only exceptions here are the limited areas where cattle populations are among settled farmers. It has generally been accepted that the real problems associated with overgrazing appear to be limited to the restricted areas of agropastoralism. In areas where pastoralists have access to feed other than from rangeland, the situation is known to improve. It is assumed that stock density could be higher if stock were fed supplements from the fields, giving them a secure basis from which they can only marginally damage semi-natural pastures; and if herds were much more stationary than in transhumant or nomadic pastoralism (WARREN and KHOGALI, 1991). The types of areas envisaged have seen a continuous expansion of arable land, progressively restricting the area available for grazing. Where serious encroachment on grazing land has occurred, there is more pressure on the remaining, usually poorer rangeland (BONFIGLIOLO, 1988). Calculations show that draught animals that are in most cases two in number cannot possibly provide enough manure, so more animals are needed. If manure is to be produced in sufficient quantities, about 16 ha of grazing land is said to be needed for every 1 ha of crops in the Sahel; the equivalent ratios are 10:1 in the northern Sudan Savannah and 8:1 in the Southern Guinea Savannah (BREMAN and TRAORE, 1990).

Most authorities now believe that for the bulk of the rangelands in the Sudano-Sahelian area, grazing is by far a less important factor required for the good growth of the vegetation than rainfall (HIERNAUX *et al.*, 1990). To this end, two

kinds of evidence have been identified. The first is the observation that the chief control on the numbers of stock is the low nutritional quality of dry-season pasture. This severe constraint means that there are seldom enough cattle to damage the wet season range (HIERNAUX, 1984; ELLIS and SWIFT, 1988). The second model of grazing on semi-arid pastures shows that the animals themselves suffer critically under intense grazing. Stocks are reduced to very small numbers; well before irreparable damage can be done to the range itself (NOY-MEIR, 1978).

It is, however, true that grazing can change the floral composition of pastures. In the northern Sahel, selective grazing removes *Cyperus conglometratus*, a nutritive plant (FAUK *et al.*, 1983). The grass *C. biflorus* (haskanit or cram-cram) has disappeared from large parts of central Sudan, despite its efficient dispersal system (SULIMAN, 1988). However, grazing is said to have both positive and negative effects. Grazing may remove dead material, which would inhibit the growth of new shoots. Grazing also promotes tillering and prevents excessive water consumption, thereby extending the growing season (BELSKY, 1986). It was also discovered that it can stimulate the uptake of fodder value (HIERNAUX and DIARA, 1986a). Even though it was argued that the watering-points act as "centres" or "poles" of desertification in rangeland (GLANTZ, 1977; IBRAHIM, 1984; SINCLAIR and FRYXELL, 1985), this assertion has been repeatedly questioned. In central Sudan, only 7 out of a sample of 77 of these "piospheres" (areas of intense grazing around watering points) had expanded, even in drought years (HELLDEN, 1984). It has been said that piospheres may even be improved when cattle bring nutrients towards the watering-point from the surrounding rangeland. Although livestock may damage a small circle around the watering-point itself (the so called "sacrifice zone"), cattle may fertilize pastures in an annular zone beyond, raising the productivity (GEORGIADIS *et al.*, 1989; PERKINS, 1991; HANAN *et al.*, 1991).

It has been observed under extreme situations that there could be a management in which boreholes are so close and animal numbers so great that rangeland will be damaged. Grazing will not be extensive enough to provide nutrients to improve some of the piospheres. But in most West and East African Sahel Savannah, such levels of damage have not yet been attained (WARREN and KHOGALI, 1991). The argument further reinforces the doubt about the concept of carrying capacity, which has been the popular bedrock of the tool for reproaching African pastoralists (LAPREY, 1983). For instance, in an FAO African Agriculture report, (FAO AFRICAN AGRICULTURE, 1986), livestock population were in certain communities noted to range between 50 to 100% above the carrying capacity. There may be observed instances where the acceptable carrying capacity limits were exceeded. However, if the logic of the above statement is considered, there appears to be a number of dubious assumptions behind such statements (WARREN and KHOGALI, 1991). This is because the assumption of equilibrium, as earlier stated, is seldom correct, even if ever achieved in semi-arid ecosystems. Second,

most estimates of carrying capacity were of "economic carrying capacity" (for cattle): this carrying capacity refers to livestock that is needed to produce the maximum off-take, usually for sale (BROWN, 1971). Yet most African pastoralists are not interested in this alone, for they subsist on their herds by milking and in some cases bleeding them (THOMAS and BARTON, 1994). We must therefore accept different standards of animals, and consider that rangelands can carry more of these standards prescribed, depending on the purpose the animals are meant for (ABEL and BLAIKIE, 1989; BEHNKE and SCOONES, 1991). As observed by WARREN and KHOGALI (1991), if pastoralists want to produce animals that satisfy other criteria, they may reduce their cattle densities. This decision concerns the health of cattle and usually not the rangeland. Third, the carrying capacity was measured on the assumption of fixed paddocks, with no facility for moving animals between different types of ranges and standards of productivity, which is what nomadic pastoralists normally do (BEHNKE and SCOONES 1991). Finally, the early foreign range "experts" knew little of the subtle adaptations of the cattle breeds used by nomads. Before arriving at the conclusion of the overshooting of the carrying capacity, they should have improved knowledge on the cattle breeds used by African nomads (WESTERN and FRENCH, 1986). The new paradigm in rangeland ecology has gained large support. But there are still major questions to be asked about the ecology of grazing, the economics of degradation, and the efficacy of different pastoral strategies to meet different objectives, and the policy responses to these findings. Different policies will be needed for different environmental and social situations, and a differentiation of these has barely begun (BEHNKE and SCOONES, 1991). However, what is very important at this point is a recognition of the fact that pastoralism in the Zamfara grazing reserve may not in any way have endangered the reserve. What really has a potential ability to do so, is agropastoralism that does not encourage the migration of animals, i.e. grazing confined to limited areas rather than even grazing all over the reserve. Above all, this leads to a demand for more land for cropping, thereby encouraging further deforestation and degradation of the grazing reserve. The question is, can we have an evaluation of all the methods adopted by farmers to maintain soil fertility with the aim of identifying a better pathway to intensification? This will enhance the choice of a method that is environmentally friendlier and sustainable in the use of the reserve.

3.4 Importance of manure and manure contracts for farm production among rural farmers

Animal manure is the major source of soil nutrients in rural Nigeria. The volume and modalities of manure application are influenced by factors such as the access to manure, the herd size, and the access to manure exchange contracts, the income and the social status of sedentary farmers, the access to grazing land, the type and availability of fodder resources, the management of manure and the season of collection and storage (SCOONES and TOULMIN, 1995). It has been established

through research that one tropical livestock unit (TLU) can produce about 7 tonnes of fresh manure per year if stabled all day. This is said to decline to 2-3 tonnes of usable manure per year, representing 30-40% recovery, if the animals are stabled only overnight (SCHLEICH, 1986). It has equally been established that the application of 3 t/ha of manure plus livestock urine produced grain and stover yields that are much higher than if only the same quantity of manure was applied to the field (POWELL *et al.*, 1992). This is an indication of the greater importance of manure applied *in situ* by corralling and this happens if own animals or animals from contracting herders are camped on farmers' fields. ABDULLAHI and LOMBIN (1978) found that over an 11-year period, no additional grain and stover response to fertilizers was obtained if the manure applications to sorghum and millet were greater than 7.5 t/ha per annum.

Studies on the utilisation of compost and farmyard manure (FYM) for crop production in many parts of Africa since the 1930s were conducted (BECKLEY, 1934; BECKLEY, 1937; and MEHLICH, 1965). From the 1960s, the use of organic fertilizers, particularly livestock manure, might be considered to be the bedrock of agricultural production in many developing countries. Manure use has increased progressively among rural farmers and it is now used by well over 95% of all smallholder farmers in Kenya other and East African countries, for example. An increasing use of livestock manure in Nigeria was widely reported by MORTIMORE *et al.* (1990), MORTIMORE and ADAMS (1998) and WILLIAMS *et al.* (1995). The benefits of manure use in crop production are improvements in soil physical properties as well as the provision of N.P.K and other mineral nutrients. The application of livestock manure increases the soil organic matter content, and this leads to an improved water infiltration and water holding capacity as well as an increased cation exchange capacity. Manure and urine raise the soil pH level and accelerate the decomposition of organic matter while also contributing to termite activity (BROUWER and POWELL, 1995). If inorganic fertilizer, especially nitrogen, is combined with manure, the manure reduces soil acidification and improves the nutrient buffering capacity and the release of nutrients (WILLIAMS *et al.*, 1995). Despite the wide recognition of manure (STANFORD, 1987; PROBERT et al., 1995), its utilization level in semi-arid West Africa has been hampered (MCINTIRE *et al.*, 1992). Some of the reasons advanced for the low level utilisation include the inadequacy of manure supply from the small herds of sedentary farmers and the high cost of manure transportation and spread on the field (WILLIAMS *et al.*, 1995). To solve this problem, croppers usually invite transhumant herders to camp their livestock on fields for some nights so that manure and urine are voided on the field. AGBOOLA and KINTOMO (1995) observed that such a practice provided large amounts of manure, though without labour of the farmer involved. Also, POWELL *et al.* (1996) attested to the importance of manure contracts as an emerging phenomenon among croppers and herders in some developing countries. It is a contract based on the exchange of manure for crop residues. MOHAMMED (2000) also did studies in the Dunaye

district of the Wamakko local Government Area of Sokoto State in Nigeria. He observed that crop farmers are engaged in manure contracts with the herders in which herders provided manure through corralling by camping their animals for days on the farmers' fields. In return, herders are often given grain or money. In MOHAMMED's studies, it was discovered that croppers that were involved in the manure contracts had better yields than those that were not involved. This contractual arrangement is gradually emerging as a new traditional institution. This is an exchange that has evolved as a consequence of the felt needs of the two groups, requiring each other's services and goods for which there is yet no formal institutionalised market arrangement. The arrangement has helped the parties involved because: it can be carried out without money; it allows herders to get nutritious feed for their herds when the pasture nutritional level has deteriorated; it allows herders access to grains they do not have and for whose purchase they probably have no money, it enables croppers to improve the fertility of soils; and finally, it encourages friendliness between herders and croppers who are naturally considered to be stiff competitors for land resources. It is thus hoped that this system of mutual exchange will help to bring about sustainable production in the Zamfara grazing reserve. If we could therefore have production practices in which crops and animals are under separate management, this will be a better option in a reserve setting. This is because a lot of literature has confirmed that the combination of the two enterprises under one management in a place like the Zamfara reserve/grazing reserve could cause more damage than good (THOMAS and BARTON, 1994).

3.5 Institutional and property right factors in farmland and range land degradation

Another reason that has been adduced for farmers' contributions to environmental degradation is a lack of secure property rights. It has been reasoned that if farmers do not have assured long-term access to land, they do not bear the full cost of resource degradation. If they are not sure they will receive the benefits of their investments, they are more likely to pursue unsustainable farming practices and fail to invest in improving and conserving resources (HAZELL and GARRETT, 1996). There are many theories that have been put forward to justify the various land tenure systems and the effect on land or range management.

Three of these theories are much relevant here. The first is the one proposed by HARDIN (1968, 1988), which was termed the "tragedy of the commons" theory. The second is the "property rights school" approach proposed by DEMSETZ (1967) while the third is the "assurance problem" approach developed by RUNGE (1981, 1984), BROMLEY and CERNEA (1989). HARDIN'S theory of the tragedy of the commons has become the dogma of community development in Africa. It postulates that pastoralists would degrade the resources they use if they were left to their own devices. Because it is believed that herders own their livestock

individually, the range they use is "open access". Herders, it is argued, will seek to intensify the exploitation of a resource without competing for restrictive titles. Because the benefit of increasing production (that is adding another animal to their stock) will accrue to individuals, the cost of degrading the resource will be borne by everyone. It is argued that since each herder follows the same strategy, there is a 'tragic' movement towards the overexploitation of resources. Herders are aware of the decline of pasture, but self-interest, the tragedy, will prevent them from doing anything about it. The hypothesis that comes from the tragedy of the commons, directly links resource degradation to a "common" system and suggests that a sustainable environmental policy can only be achieved by the promotion of private property and/or by coercive measures. The argument is that the costs of exploiting a pasture are mainly costs of externalities – costs everyone using the resource has to bear- and the logic that follows is that the resource will never be rationally used unless those benefiting individually have to pay for the costs of their actions. It was consequently suggested that privatisation is the solution to solve this problem. This theory has been severally challenged on the basis of its assumption of a fixed carrying capacity, which has been debunked as having no basis in the African pastoral systems. This is because the so-called common grazing ranges are yet to suffer irreparable damage as envisaged by this theory of the tragedy of the common.

In the property rights theory, the evolution of individual rights to land and the mechanisms to enforce such rights are considered to be related to the levels of resource productivity, the effects of population pressure, and the application of rural technologies (DEMSETZ, 1967). It is contended that under increased population pressure, the intensification of land use is reflected in a shift from opportunistic grazing - where pastures are exploited in periods of maximum production and then left to recover - to more continuous resource utilization. It is believed that the intensification of land use would occur first on more productive resources, such as fertile dry season grazing areas. The theory is deeply rooted in economics. In this theory, it is assumed that the value of property determines the nature of the rights that pertain to it. Accordingly, it is argued by the earlier proponents of the theory that common property regimes exist where resources have a low value and where the cost of control over their use is relatively high (DEMSETZ, 1967). It is further argued that, as a resource acquires a greater value, or level of scarcity, the prevalence of individual maximizing behaviour provides an incentive to over-exploit it. It is only then that institutional innovations will occur to conserve resources and this generally takes the form of a shift from non-exclusive forms of access to individual rights. It has been reasoned that providing greater control over resource use incurs costs and that it is only feasible if the costs of policing are less than the benefits afforded by the control of the resource. It has been noted that while this provides an explanation of the changes in property rights in some locations, it does not explain why some scarce and highly productive resources, like Swiss Alpine meadows, have persisted as commons for thousands of years (NETTING, 1978).

In the assurance problem, much of the debate on common property was refuted as a basis, using the tragedy of the commons and concentrating on studies of the conditions under which communal property systems have come, or might come into being. It is assumed by the tragedy of the commons that all rural producers in a community practise the same livelihood. They have the same interest in a resource and can act entirely independent of their fellow producers. This assertion has been viewed to be manifestly untrue for most inhabitants of rangelands, including pastoralists, living in rural communities in the developing world (LANE and MOOREHEAD, 1995). It was equally argued by RUNGE (1984) that, if expectations, assurances and actions can be co-ordinated to predict behaviour, there is a lower necessity for herd owners to pursue "free rider" strategies. Indeed, co-operative behaviour might be encouraged as a utility maximizing strategy. According to RUNGE, the institutions of society exist to co-ordinate and predict behaviour so that there may be significant incentives for a group to develop institutions, which promote voluntary co-operation. He suggests an 'assurance problem' exists as a key to understanding how public goods are used and might be managed in the future. In further work, RUNGE, (1986) elaborates on his early studies by suggesting that, where communities have low incomes, they are critically dependent on local agricultural and natural resource bases. They face a high degree of uncertainty with respect to income streams, and communal forms of tenure that are cost effective and efficient. He argues further that relative poverty imposes a strict budget constraint on rural communities with regard to transaction costs (costs of policing, registering and adjudicating titles), making the management of a private property regime too costly for subsistence farmers to bear. At the village level, RUNGE argues that production decisions of individuals are based on the expected decisions of others, and this places a premium on the importance of customs, rules and conventions that co-ordinate decisions in a community. Furthermore, in differentiated rural communities, a certain number of producers will have interest in free riding on customary institutions. But if a critical mass within a community coalesces around co-operative norms, a communal property can come into being. He further suggests that the more homogeneous a community is, the more likely optimal outcomes are. On the contrary, the more heterogeneous a community is, the more difficult co-operation becomes. By implication of this analysis, outcomes such as overgrazing do not necessarily arise from the strict dominance of a free-rider strategy (although resource misuse may still occur), but from the inability of interdependent individuals to co-ordinate and enforce actions in situations of strategic interdependence (RUNGE, 1986).

A wealth of evidence is now becoming available to show how customary tenure systems in Africa have been undermined by the inability of rural producers to co-ordinate their actions, and that this inability is often due to the imposition of unsuitable land tenure legislation and pastoral policy by both donors and post-

colonial states. Field experience and theory are converging to show that, where local producers are given the opportunity and the resources to develop their own management institutions and tenure systems, they are well able to do so.

The Zamfara reserve, as a property, is under the control of the state and local government authorities, who have been very ineffective in monitoring the activities going on in the reserve. If the situation is not remedied, the Zamfara grazing reserve might soon join the legion of failed state public goods. As a way out, there is a need to entrust the control and management of the reserve to the various village authorities. Government should only play a supervisory role. This could go a long way in giving the people a sense of belonging that will elicit better management of the forest reserve. What is really needed is enlightening farmers and herders that they have a stake in the sustainability of the reserve, and also educating them in the benefits of good environmental and biodiversity preservation. This will go a long way in curtailing environmental abuse in the grazing reserve. If an appropriate government strengthens such indigenous systems and facilitates their adaptation to changing circumstances, instead of replacing them, it will facilitate better management of common natural resources. If adequately empowered, farmers are often able to take account of resource interdependencies and establish regulations that recognize the rights of many users over the same land. Such regulations were recognized to be very important in watersheds or drought-prone areas that require the ability to move animals over wide areas as an integral part of risk management (HAZELL and GARRETT, 1996).

3.6 Approaches to the study of the adoption of practices and the study of the impact of the adoption

In the course of performing his duties, a farmer has to make numerous decisions both on a day-to-day basis and for long-term planning. Many of these decisions are related to the adoption of specific practices used in the farming operations. One of the appropriate models to analyse this type of decision problem is a qualitative response model, which is also known as a binary or discrete or dichotomous model. In specifying a binary adoption decision model, a random variable Y (dependent variable) takes the value of 1 if the event occurs and 0 otherwise. The probability of an event occurring depends on a vector of an independent variable X and a vector of unknown parameters ε. The early work of ROGER (1962) explains the determinants of innovation, diffusion and adoption. Two major groups of paradigms for explaining adoption decisions can be found in literature: the innovation-diffusion, and the economic constraint paradigms. The innovation-diffusion model, following the work of ROGERS, holds that access to information about an innovation that is the key factor determining adoption decisions (also AGRARWAL, 1983). The appropriateness of the innovation is taken as given here, and the problem of technology is reduced to communicating information on technologies to potential end users. By emphasising the use of

extension, media, and local opinion leaders, or by the use of experimental station visits and on-farm trials, "sceptic" non-adopters can be shown that it is rational to adopt (ADESINA and ZINNAH, 1993).

In contrast, the economic constraint model (AIKEN *et al.*, 1975) contends that economic constraints, reflected in asymmetrical distribution patterns of resource endowments, are the major determinants of the observed adoption behaviour. A lack of access to capital (HAVENS and FLINN, 1976) or land (YAP and MAYFIELD, 1978) is seen as determining significantly constrained adoption decisions. While attempts have been made to assert the superiority of the economic constraint model over the innovation model (HOOKS *et al.*, 1983), such conclusions have been challenged (NOWAK, 1987).

Many other concepts have recently been developed and used to quantitatively determine adoption processes. One of these concepts, which are implicitly used in one form or the other in agricultural economics literature (GOULD *et al.*, 1989; NORRIS and BATIE, 1987; LYNNE et al., 1988 ADESINA and ZINNAH, 1993), suggests that the perceived attributes of innovation conditions determine adoption behaviour. Farmers, as reasoned, have subjective preferences for technology characteristics (ASHBY and SPERLING, 1992; ASHBY *et al.*, 1989) and these could play a major role in technology or practice adoption. The adoption or rejection of technologies or farm practices by farmers may reflect rational decision making, based upon farmers' perceptions of the appropriateness or inappropriateness of the characteristics of the practices under consideration.

It was shown that by extending the analysis to cover the attributes of the technology or farm practice, ex-post adoption studies could further increase utility for directing appropriate technology development (ADESINA and ZINNAH, 1993). AKINOLA (1987) showed that the socio-economic characteristics of farmers contribute a lot to the determinants of farmers' participation in a tractor hiring scheme in southern Nigeria.

In the present study, a combination of the socio-economic characteristics of farm households and the attributes of the farm practices is used to determine why a farmer in the study area adopts the farm practice he is engaged in. Many studies have simultaneously evaluated the determinants of the adoption as well as the impact of the adoption on productivity and profitability. In the determination of reasons for farmers' adoption, yields and profitability, for instance of recombinant bovine somatotropin rbST (BARHAM, 1996; STEFANIDES and TAUER, 1999; TAUER and KNOBLAUCH, 1997; FOLTZ and CHANG, 2002), the HECKMAN approach was used. What is known as the HECKMAN approach is determined by using a Probit model whereas an inverse mill, which is the probability prediction of the adoption, is now used as a variable in the right hand to run an OLS model to determine the impact or effect of the adoption on productivity and profitability.

In the same vein, KHANNA (2001) used a similar approach to evaluate the adoption of soil maintenance technology and the impact of the adoption on nitrogen production. The same approach was employed by FERNANDEZ-CORNEJO (1996) in the study to measure the impacts of profits and input adoption. Also, it was used by FUGLIE and BOSCH (1995); WU and BABCOCK (1998) similarly used the same approach to determine the various measures of input adoption on the productivity per acre of land. The so-called HECKMAN (1976) and LEE (1983) approach was employed by KHANNA (2001) so as to correct for double-selectivity while analysing the implication of two inter-related adoption decisions for yields per unit nitrogen. COOPER and KEIM (1996) also corrected for a double selectivity bias, but examined the implications of the adoption for only one of the sub-groups' observations. This type of approach is employed in determining the factors that determine the adoption of manure contract and its impact on crop productivity. This is because it allows an unbiased treatment of both adopters and non-adopters in such a way that the dependent variable is 1 for adopters and 0 for non-adopters. Therefore, the use of the inverse mill from the adoption prediction as an independent variable in the adoption impact equation makes the treatment unbiased. Moreover, the adoption of crop-livestock enterprise combination and its impact on crop productivity in the Zamfara reserve is investigated.

Another notable modelling approach in use for the evaluation of the adoption determinants is Logit and Tobit modelling. The Logit probability distribution is of the form:

$$F(w)=L(w) = \frac{e^{w}}{1+e^{w}} \quad . \qquad \text{.....(3.1)}$$

It has been shown that the probability and logistic distribution functions are very close in the mid-range, although the logistic distribution has slightly heavier tails (AMENIYA, 1981). It has been said that it is difficult to distinguish statistically between Logit and Probit unless one has extremely large numbers of observations (AKINOLA, 1987). It has, however, been claimed that a Logit model requires generally more data than the Probit model and that its dependent variable must be specified in a ratio form unlike the Probit in which it can have values ranging between 1 and 0. A Probit model has been used for this study because of the low number of observations and other advantages, as follows ascribed to Probit modelling approaches. The Probit functional form is bounded between 0 and 1 and hence the problem of the predicted values being outside the probability range is overcome. It has further been said that a Probit model compels the disturbance term to be homoscedastic. Because the form of the probability function depends only on the distribution of the difference, the error terms can be associated with one particular choice (AMENIYA, 1981; DOMENCICH and MCFADDEN, 1975; HILL and KAU, 1973).

Lastly, a brief review of mathematical modelling will be presented since such a model will be used to evaluate the most sustainable option among the production practices engaged by farmers.

3.7 Mathematical modelling approaches to the study of household production

The literature on suitable models for simulating integrated crop-livestock systems is growing. A recent review was undertaken by BREMAN (1993), and ORIADE and DILLON, (1997). Other notable literature took a prominent position on crop-livestock interaction. Most of the modelling approaches has been derived from linear programming and has been widely used for the prediction of supply response and farmers' income under different agricultural policy scenarios (HAZELL and NORTON, 1985). It was emphasised by VOSTI, WITCOVER and CARPENTIER (2002) that linear programming (LP) models should be developed to explicitly account for the biophysical and economic factors determining farmers' activities that could bring about deforestation as well as land use decisions. However, the most appropriate (LP) modelling procedure must of necessity be derived from the motive of the modeller. Therefore, new biophysical modelling approaches have recently been developed. The motives are the simulation of the productivity increase of pasture, and the status of yield consequences of soil nutrient balances. In most models, the amount of organic matter in the soil is regarded to be prominent (BARBIER and HAZELL, 1999). Bioeconomic models are increasingly being used to examine issues involved in the interplay among economic units (such as watersheds, fishing grounds, and rangeland areas). They examine how individuals respond singly and collectively to and manage multiple biophysical processes to generate human welfare. Consequences are changes in the stocks and qualities of natural resources (BARBIER, 1996; BARBIER and HAZELL, 1999; BOUMAN et al., 1998; KRUSEMAN *et al.*, 1995; RUBEN, KUYVENHOVEN, and KRUSEMAN, 2001; SACHIRICO and WILEN, 1999, 2001; SMITH, 2001).

Modern bioeconomic models explicitly identify and account for changes in biophysical inputs (for example, soil nutrients), their availability, their impact on crop growth, and how this affects economic decisions on land use management. In turn, decisions alter input stocks for the next period. This modelling approach has an advantage over traditional accounting models (as in GITTINGER, 1984). Activity analyses overlook or oversimplify biophysical factors (TOMICH *et al.*, 2001). The bioeconomic model has recently entered development modelling (BARBIER and HAZELL, 1999). A bioeconomic model links mathematical programming formulations of farmers' resource management decisions to biophysical models that describe production processes as well as the condition of natural resources. The main objective of the approach is to address both agricultural production and environmental concerns (BARBIER and HAZELL, 1999). However, it has been asserted that the development of bioeconomic models in developing countries has been slow because the situation is more complex than in developed countries. First, farming systems of developing countries are less specialised and tend to combine a larger range of interlinked activities such as

crops, livestock, forestry, and off-farm activities (RUTHENBERG 1980; BEETS, 1989). Second, most farming systems in developing countries include livestock and tree management. Modelling these activities requires the use of a dynamic framework and requires information about the length of the planning horizon. Also, the discount rates, the returns on investment, the depreciation of capital and the loan repayments must be considered, most of which are hardly available in developing countries (BARBIER and HAZELL, 1999). Third, farming systems of developing countries rely more directly on the condition of local natural resources than on external inputs. The conditions of natural resources result from complex biophysical processes, which are difficult to quantify. Fourth, land degradation, such as erosion and soil mining, is more critical in developing countries for ecological and social reasons.

Several linear programming models for the simulation of land degradation have recently been developed, including variables such as soil erosion (BARBIER, 1998) and soil nutrient organic matter depletion (PARIKH, 1991; KRUSEMAN *et al.*, 1995). Furthermore, natural resource management in developing countries is usually besieged with problems that go beyond farm boundaries. This feature has been included in recent community-level models (KEBE, 1992; TAYLOR *et al.*, 1996; BARBIER and BENOIT-CATTIN, 1997). Finally, rapid changes in population and markets in developing countries are said to have posed limitations to the value of static analysis. Despite all these limitations, bioeconomic modelling has been adjudged in recent times to be a better option in dealing with production and environmental issues arising from processes and systems. The programming aspect of this study essentially makes use of bioeconomic modelling. This is in view of the fact that the Zamfara gazing reserve was not initially designed for agricultural purpose. Now that crop production activities have come into the grazing reserve, it is worthwhile to have recommendations that will encourage practices that are environmentally friendlier and sustainable. Both aspects, from the viewpoint of crop production and the grazing reserve's sustainability, enter and long-term productivity of the reserve is one of the goals of this study.

3.8 Summary

The relevant literature on the effects of agriculture on the environment and on forest degradation was reviewed in this chapter. Crop-livestock interaction can have both positive and negative effects on the environment depending on the type of the interaction pathway, and practice adopted by farmers. The role of pastoralism in deforestation and environmental degradation was equally reviewed. It is evident that the migratory type of pastoralism, being practised by Africans, does not allow degradation as viewed by writers from the developed world. The importance of manure in soil fertility maintenance in enhancing sustainable crop production in developing countries was equally stressed. It was emphasised that production would be more difficult to accomplish by the farmers in the reserve

without manure. Manure is, however, not to be considered a straight substitute for the conventional fertilizer that is often not within the reach of poor farmers. Emerging manure contracts between herders and croppers aimed at facilitating interdependency relationships to enhance productivity between these two producers were discussed. This relationship can be seen as having enhanced the good cooperation between croppers and herders in most places where it has been practised.

The role of property rights and traditional institutions in farmland and rangeland degradation was further discussed and it was emphasised that farmers will be much willing to maintain land or range properties when their right to such property is assured.

Finally, the empirical approach to the study of adoption and the mathematical programming that was introduced for modelling crop-livestock interactions were discussed. It was concluded that there are factors that usually drive farmers to adopt a particular production practice, while on the other hand, it was shown that bio-economic models are the most suitable approach to modelling crop-livestock interactions. Because of the economic and biophysical relationships they can be involved in a depiction of the entire production processes if the environmental wellbeing is taken into consideration.

4 FIELD SURVEY AND EMPIRICAL FINDINGS

This chapter presents the analyses of the main findings of the field survey. It begins with a brief description of the socio-economic characteristics of farm households in the study area as well as the level of resource use. Expenses on inputs and labour used by the households for farm production are also enumerated. Furthermore, the production practices adopted by the farmers and the reasons why they adopted those particular production practices is highlighted. Finally, the information presented here represents an empirical basis for the subsequent econometric models and the final programming model for optimising resource utilisation. This is important for the sustainable use of the Zamfara reserve resources bearing in mind the need to evolve a production strategy that will be environmentally friendlier to the grazing reserve. This is necessary for the continued existence and survival of the grazing range within the reserve as well as for preserving a rich natural biodiversity bank in the region.

4.1 Farm households and their resource endowment

4.1.1 Socio-economic characteristics of farm households

In Table 4.1 and 4.2, data on the average size of households for both croppers and agropastoralists in the two zones within the Zamfara reserve are presented. Information presented on these Tables includes farmers' age, household size and the education level of the household head in the study area. The survey shows that the average household size ranged between 8.5 and 9.44 for croppers in the Ajja-Tsabre and Dumburum-Shamushalle zones respectively, with rather higher figures of 12.56 and 15.73 for agropastoralists in Ajja and Dumburum respectively. It can be clearly seen that in each of these zones, the agropastoralists' households are much larger than the households of the croppers with ($t = 2.39$) as shown in Table 4.2.

Furthermore, the mean difference between the household sizes of agropastoralists and croppers is statistically significant with the ($T = 5.01$) as shown in Table 4.3. This could be due to the fact that additional hands are needed to cater for the larger animal numbers owned by agropastoralists in this zone.

With regards to the age of the household head, the agropastoralists are found to be slightly older than the croppers with an average of 45.74 and 48.51 respectively in Ajja-Tsabre and Dumburum-Shamushalle as opposed to the croppers, which were 43 years on average for Dumburum-Shamushalle croppers. The mean difference in the age of agropastoralists and croppers is shown to be statistically significant with ($T = 2.3$) as shown in Table 4.3. The crop-livestock enterprise combination is an old tradition and the fact that younger people are not so much associated with it means that it could be easy to persuade the croppers in the reserve to shelve that production system in the long run. As will be shown later, the crop-livestock enterprise

combination poses serious danger to the long-term survival of the Zamfara grazing reserve. This is because more land is needed to facilitate and sustain agropastoralism as a farming system. Another reason why younger farmers are not combining animal husbandry with cropping might be connected with the fact that the acquisition of livestock requires a lot of savings over a long period of time.
The education levels attained, based on years of schooling, are similar for all categories of farmers for the two zones. Indeed the most popular education in the area is the system based on the Islamic religion knowledge.

Table 4.1: Results showing selected socio-economic characteristics of croppers' households

Characteristics	Ajja-Tsabre zone		Dumburum-Shamushalle zone			
	Mean	St. dev	Mean	St. dev	T-statistic	P-value
Age of head	43.45	11.91	43.39	11.21	-0.02	0.98
Household size	8.66	6.75	9.44	4.29	0.62	0.53
Education level of head[a]	2.94	1.59	2.59	1.52	-1.05	0.29
N	47		38			

Source: own data, 2002
Note [a]. The index for the educational level is the average value of a qualitative variable defined as follows: 0 = never gone to school; 1 = had one year of Arabic education; 2 = had two years of Arabic education; 3 & 4 = had three and four years of Arabic education; 5 & 6 = had western form of primary education and 7 = had secondary education.

Table 4.2: Results showing selected socio-economic characteristics of agro-pastoralists' households in Ajja-Tsabre and Dumburum-Shamushalle

Characteristics	Ajja-Tsabre zone		Dumburum-Shamushalle zone			
	Mean	St. dev	Mean	St. dev	T-statistic	P-value
Age of head	45.74	12.75	48.51	12.45	1.32	0.19
Household size	12.56	7.24	15.73	8.63	2.39*	0.02
Education level of head[a]	2.44	1.69	2.65	1.50	0.76	0.45
N	72		71			

[a] as in table 4.1 above. Source: own data, 2002.
* Indicates significant level of 10%,

Table 4.3: Results showing comparison of selected socio-economic characteristics of croppers' and agropastoralists' households

Characteristics	Agropastoralists		Croppers			
	Mean	St. dev	Mean	St. dev	T-statistic	P-value
Age of head	47.29	12.70	43.42	11.53	2.30*	0.02
Household size	14.01	8.05	9.01	5.76	5.01***	0.00
Education level of head[a]	2.55	1.59	2.78	1.56	-1.07	0.29
N	143		85			

[a] as in table 4.1 above. Source: own data, 2002

*, *** indicate significant level of 10% and 1% respectively

4.1.2 Land resource in the study area

At the early stage of agricultural development, when the population was very low and there was an abundant supply of land, shifting cultivation was a common and popular farming system in entire Nigeria. Farmers adopted shifting cultivation as a soil fertility maintenance strategy. Under this system, a piece of virgin land is cultivated for two or three years and then left fallow for many years to enable the soil to regain its fertility. However, due to population increase and migration, land became scarce and grossly inadequate to accommodate the old farming systems of shifting cultivation by farmers. Tables 4.4, 4.5, 4.6 and 4.7 show the distribution of holding sizes among farmers of the various groups in Zamfara. Croppers with manure contracts have on the average a land area of 1.8 ha per household while croppers without manure contracts have a slightly lower size of about 1.7 ha per household. There is no statistical significance between the mean difference of contract and non-contract farmers as shown in Table 4.4. Also, taking all the croppers together, the household farm holding at the Ajja-Tsabre and Dumburum-Shamushalle zones are about 1.7 ha respectively.

However, agropastoralists at Ajja-Tsabre and Dumburum-Shamushalle have farm sizes of about 3 ha and 2.5 ha respectively. The larger farm sizes at Ajja-Tsabre could be a result of less pressure on land due to lower population as already shown in Table 4.2. Moreover, a comparison of the farm holdings of agropastoralists and croppers indicates that there is a statistically significant difference in the means of the farm sizes of these two groups (Table 4.7). While agropastoralists have an average of 2.8 ha, croppers have about 1.7 ha per household. Further analysis in Table 4.8 shows that the farm size of the agropastoralists is significantly higher than that of the croppers with manure contracts. The overall results have shown that agropastoralists have bigger farms and are more likely to have the craving for more land acquisition from the grazing reserve. However, looking at the area being cultivated currently and the household land holding, it appears that there are

people not residing in the reserve cultivating crops in the forestland. There might be a need for further studies in future to explore this possibility.

Table 4.4: Average farm sizes (ha) per household cultivated by croppers with and without manure contracts

Characteristics	Contract croppers	Non-contract croppers	T-statistic	P-value
Farm size (ha) mean	1.78	1.58	-0.81	0.42
St. deviation	1.39	0.93		
N	40	45		

Source: own data, 2002

Table 4.5: Average farm sizes (ha) per household for croppers in the study area

Characteristics	Ajja-Tsabre zone	Dumburum-Shamushalle zone	T-statistic	P-value
Farm size (ha) mean	1.67	1.68	0.04	0.97
St. deviation	1.25	1.07		
N	47	38		

Source: own data, 2002.

Table 4.6: Average farm sizes (ha) per household for agropastoralists in the study area

Characteristics	Ajja-Tsabre zone	Dumburum-Shamushalle zone	T-statistic	P-value
Farm size (ha) mean	3.17	2.48	-1.47	0.14
St. deviation	2.13	3.41		
N	72	71		

Source: own data, 2002

Table 4.7: Comparison of farm sizes between agropastoralists and croppers

Characteristics	Agropastoralists	Croppers	T-statistic	P-value
Farm size (ha) mean	2.83	1.67	-3.56***	0.000
St. deviation	2.85	1.16		
N	143	85		

Source: own data, 2002. *** indicates significant level of 1%

Table 4.8: Results showing comparison between farm sizes of agropastoralists and manure contract croppers

Characteristics	Agropastoralists	Croppers	T-statistic	P-value
Farm size (ha) mean	2.83	1.77	-2.27*	0.03
St. deviation	2.85	1.38		
N	143	40		

Source: own data, 2002. * indicates significant level of 10%.

4.1.3 Land tenure systems in the study area

The land tenure system in Nigeria and indeed in Zamfara state has been undergoing considerable changes over the years. Initially, land ownership was formally vested in the customary traditional institution, which forbids land from being sold. Under such a customary arrangement, land is viewed as a collective property and the maintenance of such a property is often defective. However, with the right to individual ownership through purchase, land could now be personally owned and such a personal property is jealously maintained to enhance its productivity. Table 4.9, and 4.10 show the land ownership types that are available in the study area. It is now a common phenomenon that people own land, bought by themselves, which they can in turn dispose of as and when they wish. Consequently, about 21% of the croppers' households in Ajja own land that was purchased, while in Dumburum, about 28% of the farmers said they had rightly purchased the land they were cultivating. The results, however, indicate that inherited land still dominates the tenancy systems in the study area. While among croppers in Ajja-Tsabre about 63% of the farmers acquired the land they are cultivating through inheritance, in Dumburum-Shamushalle the figure is about 57%.

Looking at the agropastoralists as another group of farmers at the zonal level, about 28% of them at the Ajja zone use land already acquired through purchase. 32% of the farmers at Dumburum-Shamushalle have land that was purchased. The propensity to buy land is higher for both categories of farmers at Dumburum-Shamushalle. This could be due to the high population density in this area and easy access roads to market centres in urban centres due to the proximity of these communities to a major motor way. The general assessment, however, is that land owned through inheritance still predominates over other land ownership forms in the whole area.

In reference to reports by the Zamfara grazing reserve officials during the fieldwork, all land in the reserve belongs to the government, and farmers have only been allocated land for temporary use and such land could be recovered later. The implication of this is that these farmers have limited property rights over the land they are cultivating as they could be asked to relinquish such land at any time,

possibly when the government thinks such land is not to be used again. This can also enable the government to make legislations that could help regulating the use of land in the grazing reserve in a way that is conformable with a preservative tenet so as to minimise degradation. Provided that the government is able and ready to monitor the on-going activities in the grazing reserve, improvements may occur with regards to resource use. However, since the farmers have used some plots for well over fifty years, they more or less claim permanent rights over such land. That must have explained the reason for the sellings and resellings that have taken place over time to the extent that they now claim to have rightly purchased the plots being cultivated by them. But the truth is that these farmers have no legal claim to any land in the grazing reserve. Even in most parts of northern Nigeria, land in villages is regarded as belonging to the whole community and, therefore, what people have is a customary right to land. This means that an individual member of the community can use a piece of land and can pass it from one generation to another, but has no right to sell such land.

Table 4.9: Classification of land ownership forms for croppers' farms in the study area.

Zones	Purchased		Inherited		Rented		Leased		Gift		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Ajja-Tsabre	8	21.05	24	63.16	1	2.63	0	0.00	5	13.16	38	100
Dumb-Shamu	13	27.66	27	57.45	0	0.00	3	6.38	4	8.52	47	100

Source: own data, 2002.
Dumb = Dumburum, Shamu = Shamushalle.

Table 4.10: Classification of land ownership forms for agropastoralists' farms in the study area

Zones	Purchase		Inherited		Rented		Leased		Gift		Total	
	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%
Ajja-Tsabre	20	27.78	39	54.17	0	0.00	0	0.00	13	18.06	72	100
Dumb-Shamu	23	32.39	36	50.70	2	2.82	2	2.82	8	11.27	71	100

Source: own data, 2002

In the study area, farmers' fields are usually fragmented. Small parcels of land are usually scattered far apart from each other. It is usual for farm households to have between two to three or more fields as shown in Tables 4.11, 4.12 and 4.13 for manure contract, non-contract croppers and agropastoralists respectively. From these Tables, while the majority of the contract farmers have just one field, more of the non-contract farmers cultivate at least two fields at a time. However, there is a difference in the number of fields cultivated by manure contract farmers in Ajja-Tsabre and Dumburum-Shamushalle as shown in Table 4.11. This is because only one farmer in Dumburum-Shamushalle has just one field while others have more.

On the other hand, for agropastoralists, the majority of them cultivate at least three fields at a time for both the Ajja-Tsabre and Dumburum-Shamushalle zones (Table 4.13). Since these fields are usually small fragments, they make farm mechanisation difficult and uneconomic. Manual labour is therefore the predominant labour resource found as pertains to other developing economies. In addition, households lack the ability to use high yielding inputs like chemical fertilizers and improved varieties of seeds.

Table 4.11: Average numbers of fields cultivated by manure contract croppers in the study area

Zones	One field		Two fields		Three fields		Four fields		Five fields		> Five fields		Total	%
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%		
Ajja-Tsabre	9	34.62	3	11.54	2	7.69	7	26.92	4	15.38	1	3.85	26	100
Dumb-Shamu	1	7.14	6	42.86	3	21.43	0	0.00	3	21.43	1	7.14	14	100
Chi-square = 12.25*														

Source: own data, 2002. * indicates significant level of 10%.

Table 4.12: Average numbers of fields cultivated by non-contract croppers in the study area

Zones	One field		Two fields		Three fields		Four fields		Five fields		> Five fields		Total	%
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%		
Ajja-Tsabre	4	19.05	11	52.38	4	19.05	1	4.76	1	4.76	0	0.00	21	100
Dumb-Shamu	3	12.50	4	16.67	6	25.00	7	29.17	2	8.33	2	8.33	24	100
Chi-square = 11.05														

Source: own data, 2002

Table 4.13: Average numbers of fields cultivated by agropastoralists in the study area

Zones	One field		Two fields		Three fields		Four fields		Five fields		> Five fields		Total	%
	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%	Freq	%		
Ajja-Tsabre	15	20.83	12	16.67	18	25	8	11.11	15	20.83	4	5.56	72	100
Dumb-Shamu	4	5.63	18	25.35	17	23.94	11	15.49	15	21.13	6	8.45	71	100
Chi-square = 11.26														

Source: own data, 2002

4.2 Production activities of households in the Zamfara grazing reserve

There are two major economic activities engaged in by households in the Zamfara reserve. These include animal husbandry that is indigenous to the pastoral Fulani and cropping by the Hausa tribe. Despite the fact that some Fulani are now engaged in some cropping activities, they do not regard themselves as being "real" farmers; nor are they regarded as such by their Hausa neighbours. Rearing of cattle is the main occupation and source of livelihood of the Fulani people in the reserve. As expressed by ECKERT (1997), the major fear of the Fulani is the recurrent extension of cropland at the expense of rangeland. They have expressed fear about the problems of the scarcity of cropland and land degradation, as they also become increasingly dependent on farming to produce crops for their own food needs (ECKERT, 1997). The fact that the Fulani are now picking up interest in cropping shows that they are themselves part of the problems they were hitherto worried about since they are bound to contribute to deforestation and encroachment into the grazing reserve.

The Hausa on the other hand are croppers but some of them now have animals as part of their farming enterprise. Since there is a problem of manure for crop production, these farmers use manure from their animals to fertilize their soils. There are no Fulani practising cropping alone in the study area, but more of them are beginning to combine cropping with animal husbandry. It is evidently clear that we presently have more Hausa practising agropastoralism than Fulani. Because the evaluation of production adoption practices carried out later in chapter six and seven were along the lines of adopters and non-adopters of a particular practice, the Fulani involved in any of these practices were too few to allow separating them for analysis on tribal basis.
Presently some of the farmers that have no animals in the Zamfara grazing reserve use manure from contracts with herders to fertilize their soils. While there are also some who are yet getting involved in manure contracts, the process is just beginning to expand among the people in the area.

4.3 Types of manure contract practices in the Zamfara grazing reserve

There are basically two types of contracts that have been identified in the study area. The first is the contract that takes place immediately after harvest in which the Fulani approach the croppers to allow their herds to graze on the crop residues left on the field. This particular one is referred to as stubble or residues manure contract. In this case, the animals eat up the crop residues on farmers' fields while camping on the field as well to void their manure there. In some rare cases, the herder may have to pay some money for the residues but this is not the case in the Zamfara reserve.

The other form of contract usually takes place around April and early May when there are no more residues on the field and the animals graze from the nearby bush

and stay on the field over the night. In this case, it is the cropper that approaches the herder, and under this circumstance, he pays the herder an average of one bag of millet for a herd of 50 cattle staying on his field for seven days. If he has no grain to pay with, he could pay an equivalent amount of money for the service rendered (MOHAMMED, 2000). Among the farmers sampled as manure contract participants, it is shown in Table 4.14 that 18 of them, representing 45%, participated in manure contracts immediately after the harvest of crops while 22 of them, representing 55%, said they participated in contracts just before the beginning of cropping. This is the period of the year when the need for soil fertility improvement becomes very important to farmers in preparation for the planting of crops.

Table 4.14 Results showing contract participation of farmers at two different periods of the year in the reserve

Periods of contract	Number of farmers	Percentage	Cumm. %
After harvest (October)	18	45	45
Before planting (May ending)	22	55	100
Total	40	100	

Source: own data, 2002.

4.4 Household labour distribution by activities on farms

Since labour is a very important input in agricultural production processes in the area, it could become a limiting factor, especially at the peak of the production season. Farmers use manual labour since the scale of operations among such small-scale holders makes mechanisation an infeasible task. The economic condition of these farmers is such that they are too poor to afford any form of mechanisation. Tables 4.15 and 4.16 show the allocation of labour to various uses in the area among croppers and agropastoralists. Labour expended by croppers on production on own farms is ranging from about 532 man-hours/ha in Ajja to 723 man-hours at the Dumburum zone. Some croppers, due to smaller farm sizes and lack of animals, have surplus labour. They hire out labour to other farmers in the neighbourhood. The hired out labour in Ajja was 108 man-hours, while at the Dumburum zone it was lower, about 85 man-hours/ha. Agropastoralists expended less labour on crop production. At Ajja, it was about 367 man-hours/ha, while at Dumburum, it was 425 man-hours/ha. There is statistical significance in the mean difference of the labour used by agropastoralists in Ajja-Tsabre and Dumburum-Shamushalle as shown in Table 4.16. However, due to the additional man-hours needed for grazing animals, there was barely any surplus labour to be hired out by these households. A farmer in Ajja expends 1932 man-hours to graze his animals per year while a farmer at the Dumburum zone expends about 2115 man-hours for the same purpose. It must be emphasized that family labour is the main resource available for this purpose.

Table 4.15: Household labour in man-hours and its distribution by activities among croppers in the study area

Characteristics	Ajja-Tsabre zone		Dumburum-Shamushalle zone		T-statistic	P-value
	Mean	St. dev	Mean	St. dev		
Labour on family farm	532.50	242.67	723.16	399.30	-0.24	0.80
Labour hired out	108.17	166.50	84.74	133.86	0.70	0.48
N	47		38			

Source: own data, 2002

Table 4.16: Household labour in man-hours and its distribution by activities among agropastoralists in the study area.

Characteristics	Ajja-Tsabre zone		Dumburum-Shamushalle zone		T-statistic	P-value
	Mean	St dev	Mean	St. dev		
Labour on family farm	366.55	73.67	425.30	109.89	-3.76***	0.000
Labour hired out	9.50	7.55	10.66	10.43	-0.76	-0.45
Labour for grazing/yr	1932.35	801.74	2114.60	1119.33	-1.12	0.27
N	72		71			

Source: own data, 2002

4.5 Credit market in the study area

Credit is of great importance in any productive activity, and a lack of credit can be an impediment to the procurement of necessary inputs for farm production. Farmers in the Zamfara reserve revealed that there was absolutely no access to formal credit at all for production in the area. Even in a situation where such credit institutions are available, there is apathy among rural farmers about banking and lending procedures in Nigeria. Farmers consider it too cumbersome and expensive to visit banks, as they consider it to be a time wasting venture. It has also been noted that if such loans are available, only an insignificant number of farmers can benefit due to an inadequacy of governmental funding support. For instance, the highest number of beneficiaries from the Zamfara state, in any year over the last five years, is about three hundred farmers from the federally guaranteed credit loan scheme for farmers, that was granted through formal financial institutions. That is definitely too few a number of beneficiaries of credit in a state with a population of over two million (see Table 4.17). It can be noted from the Table below that Zamfara state farmers are the second most disadvantaged, after Jigawa state among the states in the northwestern part of Nigeria, regarding this loan guarantee scheme. Because of a lack of credit institutions serving these people, they have to rely on self-savings to carry out production. It is therefore difficult for them to buy

modern inputs like chemical fertilizers, improved seeds and insecticides. For this reason, farmers use available low inputs as means of production and soil fertility maintenance. Such locally devised materials for soil fertility include manure and local seeds from previous harvests.

An equally important reason that has encouraged some farmers to adopt manure contracts in the study area is the lack of a formal institutionalised market for manure transactions. This lack of a formal market has lead to the evolution of an informal institutional arrangement to facilitate the exchange of manure for grains or crop residues between herders and farmers.

Table 4.17: Loans guaranteed by the Agricultural Credit Guarantee Scheme Funds (ACGSF) for northwestern states of Nigeria in (N000): 1996-2000

tates	1996		1997		1998		1999		2000	
	Person	Amount	Person	Amount	Person	Amount	Person	Amount	Person	Amount
igawa	334	2,183.5	213	1,977.0	127	783.0	12	127.0	9	813
.aduna	2,357	24,031	1410	19,364.0	1,370	25,780.5	744	11,951	961	13,184
.ano	579	8,739.0	530	7,415.0	451	6,020.0	744	9,618	429	8,318.0
.atrina	2,005	26,606	1,229	28,073	1,630	35,745.9	1,398	48,767	1,005	31,258
.ebbi	855	8,931.5	865	9,433.5	541	5,382.0	789	6,717.5	408	6,090.0
okoto	1,438	9,915.5	853	7,006.3	1,104	8,578.0	1,079	10,349	1,305	33,634
amfara	0	00	250	1,546.5	308	5,828.0	286	2,615.0	308	9,268.0

Source: Central Bank of Nigeria statistical data (CBN, 2001).

4.6 Manure and fertilizer use by farmers in the study area

Fertilizer use is virtually non-existent among the majority of the farmers in the study area. Even if fertilizer is used at all, the level of usage is grossly inadequate. Table 4.18 shows that among the 45 croppers that are not involved in manure contracts and therefore do not use manure, only 18 used fertilizer. The mean fertilizer used is 6.33 Kg/ha. While among the 40 farmers that are involved in manure contract, only 11 used fertilizer. Their mean fertilizer used is 9.50 Kg/ha. However, croppers that are involved in manure contracts have a mean manure use of about 745 Kg/ha. Moreover, as shown in Table 4.19, the study revealed that only 17 of the 72 agropastoralists in the Ajja-Tsabre zone use fertilizer at a rate of 9 Kg/ha, while 16 of the 71 farmers in the Dumburum-Shamushalle zone use fertilizer at about 14 Kg/ha. The major types of fertilizer used in the study area include N.P.K., 15:15:15, Urea and to some extent any other mixtures of fertilizer farmers could lay their hands on.

Looking at the quantity of fertilizer used by all groups of farmers, it can be noted that the quantity used by croppers with or without integration is by far too low to be meaningful in terms of yield increases. When compared with the recommended rate of between 150-300 Kg NPK/ha depending on the type of crop (BARNETT,

1975), the fertilizer use by these farmers is negligible. It is indeed difficult for these farmers to have any meaningful crop production if manure through contract or from own livestock is not available.

The manure use is lower by agropastoralists in Ajja-Tsabre than that of Dumburum-Shamushalle, apparently, due to smaller herd size and consequently lower manure production. The mean manure use is about 560 Kg/ha in Ajja-Tsabre, while in the Dumburum-Shamushalle zone, it is 1370 Kg/ha. The mean manure use among agropastoralists in these two zones is seen to as statistically significant as shown in Table 4.19. This is possibly due to a presence of more cattle owned by the households in the Dumburum-Shamushalle zone as shown later in Table 4.21. It was, however, discovered that the mean manure usage by all agropastoralists and manure contract adopters were 847 Kg and 743 Kg/ha respectively, and there was no statistical significance between manure used by these two groups. The adoption of crop-livestock enterprise combinations has facilitated the availability of manure as a soil maintenance medium in the study area, either from own animals or through manure contracts. There are, however, factors that have facilitated the adoption of crop-livestock enterprise combination and manure contracts among these farmers. These factors are discussed below.

Table 4.18: Fertilizer and manure used by croppers in the study area in Kg

Inputs	Croppers with no manure contract		Croppers with manure contract	
	Mean	St. dev	Mean	St. dev
Fertilizer Kg/ha	6.33[a]	5.07	9.50[b]	11.89
Manure Kg/ha			742.70	1132.47
N	45		40	

a(N=18); b(N=11).

Source: own data, 2002

Table 4.19: Fertilizer and manure used by agropastoralists in the study area in Kg

Inputs	Ajja-Tsabre zone		Dumburum-Shamushalle zone		T-statistic	P-value
	Mean	St dev	Mean	St. dev		
Fertilizer Kg/ha	8.24[a]	19.52	13.77[b]	53.07	-0.83	0.41
Manure Kg/ha	559.95	553.63	1369.93	1280.67	-4.71***	0-000
N	72		71			

a(N = 17), b(N = 16). Source: own data, 2002

4.7 Crop-livestock enterprise combination and soil fertility maintenance in the study area.

Crop-livestock combination has been practised for long as a traditional agricultural production method in the entire northwestern Nigeria. Under this arrangement, a farmer possesses fields where crops are planted and has few cattle and other small ruminant animals like goats and sheep. The crop residues are usually fed to livestock during the dry season when pastures dry out. The remaining pasture is probably destroyed by bush fire while manure droppings from animals are used for the improvement of soil fertility. The manure from animals in the household has been of good advantage to these farmers. Even if there is money to enable the application of some quantity of fertilizers, the light and porous nature of the soils in these areas of the country make the use of organic manure a necessity so as to provide a binding effect for soils to retain moisture. Such binding is also needed to prevent any fertilizer applied from being leached away.

Out of the total 228 households randomly sampled for the adoption of agropastoralism for the purpose of this study, 143 of them practised crop-livestock enterprise combinations while 85 of them practised only cropping. Another set of questionnaires was administered for the adopters and non-adopters of manure contracts. This was made up of 40 adopters and 45 non-adopters respectively. Households were asked to give reasons why they practised agropastoralism as a method of production. The reasons stated by the respondents are presented in Table 4.20 below. These reasons range from the desire to have more income to other factors based on customs and traditional beliefs. Zamfara state and indeed the entire northwestern region have a traditionally Islamic culture, where animals are needed for religious festivals. It is therefore not surprising that tradition is one of the factors determining the decision of farmers to adopt livestock husbandry as part of the farm household enterprise. While cattle are very relevant in the production of milk that is considered important during Ramadan fasting, sheep are particularly useful for Muslim festival celebration. At Ajja, about 21% of the households said more income is their motive for having animals within their production system while about 24% said it was the traction power provided by the animals. However, the largest share, 25% of the households, said it was the advantage of having manure from the animals that motivated them to integrate animals into their cropping activities. There is equally the belief that the animals could be sold when farmers are financially hard pressed. These reasons given are also true for the Dumburum-Shamushalle zone where 17%, 24%, 32% and 13% of the households respectively indicated that income, traction power, manure and savings were their reasons for keeping livestock. Manure was particularly the most important determining factor in the farm households' decision as to whether or not own livestock. This is so because manure is traditionally used as a means of soil fertility maintenance.

However, there are some farmers in the study area who do not own livestock, but who still use manure as the most important soil replenishment option. These other farmers, approximately 50% of them, replenish their soil through manure contracts, as will be discussed later.

Usually, animals owned by households range from small ruminants like goats and sheep to big animals such as cattle, camels and donkeys. However, for the purpose of uniformity, animals owned have been converted to Tropical Livestock Units (TLU). The number of cattle determines the quantity of manure a farmer gets for use on his crops, as it was empirically determined that a well fed cattle will void 1.1 Kg DM of waste per night if made to sleep in a shed (OMALIKO, 1981).

At Ajja-Tsabre, farmers have an average of about 5 TLU per household as against 9 TLU per household in the Dumburum-Shamushalle zone. As could be seen in Table 4.20, the mean difference in the number of livestock owned by farmers in the two zones is statistically significant. In effect, the cattle number determines the quantity of manure available for crop production in these two zones. As farmers in the Dumburum-Shamushalle zone consequently have more manure than those at the Ajja-Tsabre zone, they are better off in terms of manure production. There are more animals in the Dumburum-Shamushalle zone probably as a result of the nearness of this zone to bigger markets where farmers can sell their animals. Animal products such as milk and life small ruminants including goats and sheep are good cash resources. The nearness of these two zones to fairly motorable roads at Gidan-jaja and to Katsina, a bigger and a more economically viable state must have influenced farmers to own more animals. Manure voided by animals is collected and moved to the fields for the purpose of fertilizing the soils.

The number of animals owned by farmers is very important, as this will determine the quantity of manure a household gets from his herd. It will motivate the household to acquire more land for the purpose of getting more crop residues to feed his animals at the off-season period. This will further exacerbate the deforestation of the reserve. For this reason, it was documented that farmers usually allocate more land to themselves for farming from the reserve and later get such allocations approved through their links with prominent individuals in government (ECKERT, B.1997).

Table 4.20: Reasons for households' crop and livestock enterprise combination in the study area

Reasons for combining animals with crop enterprise	Ajja-Tsabre zone Freq	%	Dumburum-Shamushalle zone Freq.	%	All agropastoralists Freq.	%
More income	15	20.80	12	16.90	27	18.20
Traction power	17	23.60	17	23.90	34	24.50
Manure	18	25.00	23	32.40	41	28.70
Savings	14	19.40	9	12.70	23	16.10
Food	5	6.90	6	8.50	11	7.70
Tradition	3	4.20	4	5.60	7	4.90
Total	72	100.00	71	100.00	143	100.00

Source: own data, 2002

Table 4.21: Number of livestock in TLU owned by farm households in the study area

TLU No	Ajja-Tsabre zone	Dumburum-Shamushalle zone	T-statistic	P-value
Mean	4.93	9.06	2.76**	0.007
St. dev	4.45	11.89		
N	72	71		

Source: own data, 2002

4.8 Expenses on and revenues from livestock production in the study area

The possession of livestock has many expenses that go along with it and many of the farmers in the study area are well aware of the livestock expenses they have to meet in order to get the best out of their livestock. There are three major sources of expenses on livestock as shown in Table 4.22. The first is feeding costs incurred on supplementary feed in the dry season when there is not enough pasture for the animals to graze on. It should be noted here that out of the 143 farmers, 107 farmers actually said they practice supplementary feeding during the dry season while the remaining 36 farmers did not supplement their animal feed during the dry season. The reason why this group of farmers did not use supplementary feeding might be due to the small size of their herd as well as a lack of financial resources to buy supplementary feed. It cost a farmer about N6,610 on the average to purchase additional feed for an average of 7 TLU in the household livestock during the dry season.

Secondly, 132 of the total farmers stated they incurred expenses for grazing of their animals. It cost a farmer an average of about N50,000 (US$370.37) for the labour needed to graze a herd of about 7 Tropical Livestock Unit (TLU) per annum, which is the total average of livestock for the households in the reserve. It shows that labour for grazing animals is a very vital component of farm production inputs in the crop-livestock enterprise combination in the study area.

Thirdly, veterinary services are equally essential, but were not fully used by all farmers, as only 51 out of the total of 143 farmers made use of veterinary services for their animals. This might be connected with the fact that some farmers regard veterinary services provided by the government agency as an avenue for government to assess them for cattle tax. And a majority consequently prefers the use of traditional medicines when there is a need to treat their animals.

Table 4.23 shows the average incomes from livestock of a few agropastoralists in the area since not all were able to generate income from the animal sub-sector of their farm. This is because farmers have social reasons other than income for raising livestock. At the Ajja-Tsabre zone, 13 farmers said they made income from selling animals and animal products like milk. The average income of this group of farmers was N133,535. On the other hand, 24 farmers claimed to have generated income from animals in the Dumburum-Shamushalle zone and they had an average income of N384,279. There is a statistically significant difference between the mean incomes generated from farm animals in these two zones. The larger numbers of animals in Dumburum-Shamushalle as well as the nearness to markets could be the reasons behind this difference.

Table 4.22: Results showing sources of expenses and expenses on animals in the study area

Expenses	Ajja-Tsabre zone		Dumburum-Shamushalle		T-statistic	P-value
	Mean	St. dev	Mean	St. dev		
Grazing costs	49640[a]	16866	50436.36[b]	141179	-0.20	0.84
Feed costs	5428[c]	10620	7814.50[d]	133.86	-1.10	0.27
Vet. costs	1386[e]	1488	1860[f]	2451	-0.83	0.41

a(N = 30), b(N = 33) , c(N = 54), d(N = 53), e(N = 25), f(N = 26).
Source: own data, 2002

Table 4.23: Results showing gross revenues from animals by agropastoralists

Expenses	Ajja-Tsabre zone Mean St. dev N = 13	Dumburum-Shamushalle Mean St. dev N = 24	T-statistic	P-value
Revenues	133,535 153988	384,279 237795	-3.42**	0.002

Source: own data, 2002. ** indicates significant level of 5%.

4.9 Manure contract adoption for soil fertility maintenance by croppers

Though many farmers have livestock in the study area, as part of their production enterprise, there are many other farmers in the area that do not own livestock. The aspiration of every household is to have livestock but the initial capital to acquire animals is high and could be up to N20,000 for a small female cow of good stock. For this reason, not all can afford to have livestock. Since croppers without livestock also need manure that has become a very important input in crop production, this group of farmers have to get their manure from herders. However, there is currently no formal market for manure in the study area. But an informal traditional exchange method, referred to as manure contract, has evolved over the years to serve as an exchange mechanism between herders and croppers. Herders usually need crop residues to augment feed needs of their cattle during the long dry season beginning in November, after crops have been harvested, and lasting till May of the following year. Since many crop farmers have no animals that could use their residues, herders come and approach croppers to allow their herds to camp on the fields, to eat up the residues for a particular number of nights and to void their manure. There are two types of contracts in the study area. The first is the contract that takes place immediately after crops have been harvested. At this time, there are crop residues on the field and it is the herders that approach the farmers for this contract so that their animals can have access to the residues on the farmers' fields. The second contract takes place before the land preparation for cropping, and it is the farmers in need of manure that approach the herders for this kind of contract so that manure can be deposited on their fields. Under this arrangement, the animals feed in the bush and camp on the farmers' fields for many nights to deposit manure. In return, farmers part with grain or money as a compensation for the manure deposited on their fields. There are many reasons behind the motives of adoption. They are presented in the following section.

4.9.1 Factors motivating the adoption of manure contracts

As presented in Table 4.24 below, there are a number of reasons behind the adoption of manure contracts by farmers. A "relationship" of the herder with the farmer is seen as an important factor. This is because having a prior relationship with another may help to have a good understanding of the personality one is

dealing with. Also, the integrity of a person, regarding whether one could engage in a manure contract with him or not, is covered by "relationship". About 35% of the farmers therefore stated that they would be ready to enter into a manure contract only with a person if they knew him and have had something to do with him in the past.

Secondly, tribal affinity and trust in the herders ranked as an important condition that determines whether a cropper will be ready to undertake a manure contract with a herder. The tribal affinity here is meant to convey the closeness of two tribes in relation with other tribes in Nigeria. In most communities, people are more confident doing business with people of the same or closer tribes, based on the fact that such a person will most probably not engage in cheating. The Hausa and Fulani are closer to each other in terms of cultural relations than other tribes in Nigeria. Their geographical closeness has also made them develop affinity for each other.

Furthermore, in the same vein, a person that is already known to be trustworthy is easily engaged in with contract than somebody with an otherwise perceived character. It must be stated, however, that such a contractual agreement between herders and croppers is a sign of good social understanding and cooperation. Most respondents did testify that such mutual trust helped them to foster better understanding and the spirit of interdependency among the croppers and herders. It has thereby helped to reduce conflicts between each other.

Fourthly, there are people who said they participated in contracts only because they have seen other farmers participating with noticeable benefits. These farmers look up to what others do, and therefore based their decisions to participate in manure contracts on the success of others around them. In total, 15% said they participated in contracts because they have seen other farmers do it.

Table 4.24: Factors motivating farmers to participate in manure contracts as a soil management strategy

Factors	Frequency	Percent	Cumulative %
Relationship	14	35.0	35.0
Tribal closeness	9	22.5	57.5
Trust	9	22.5	80.0
Because others do the same	6	15.0	95.0
Other reasons	2	5.0	100.0
Total	40	100.0	-

Source: own data, 2002.

Also, apart from these general factors, the proposed duration of the stay of livestock of herders on farmers' fields may determine the willingness of a cropper to participate in a contract as shown in Table 4.25. This is so because the number

of days spent by the animals on the field will determine the quantity of manure deposited on the farmer's fields. It was found, as presented in the table below, that 7 days is the minimum a farmer is ready to accept for a contract. Consequently, an overwhelming percentage, 62.5% of the 40 croppers engaged in contracts, said that they would be ready to participate in a contract if the herders were ready to camp their animals for at least 7 days on their fields. However, 30% indicated that the herd must camp for at least 30 days before they can participate in a contract. Moreover, the quantity and quality of residues on the farm will determine the bargaining power on the number of days spent to be agreed by a farmer for a contract. Fields with grain stalks mixed with legume residues like beans or groundnut will be more attractive for contract since such mixtures are considered very rich for the nutritional requirement of animals. A conservative estimate has shown that with 50 cattle staying on the farmers field for 7 nights, the quantity of manure voided may add up to around 385 Kg on his field. However, farmers see the whole contract arrangement as a socio-cultural practice, other than a pure economic activity. It does help in uniting the two groups in the area over the usage of resources available for production. Finally, the number of animals a herder possesses will determine his eligibility for contract participation, as a cropper will be much more willing to participate in a contract with a herder having a large herd. It is evident from this observation that, the more cattle a herder has, the more will be the quantity of manure the participating contract cropper will obtain as benefit. This is further discussed in the next section below.

Table 4.25: Duration of animals' stay on fields as a determinant of croppers' participation in manure contracting

Number of days stay	Frequency	Percent	Cumulative %
7 days	25	62.50	62.50
14 days	3	7.50	70.00
30 days	12	30.00	100.00
Total	40	100.00	

Source: own data, 2002

4.9.2 Number of cattle as an important factor for manure contract participation

The result from field observation reveals that rural croppers will accept participation in manure contracts if the terms of participation are favourable. Thus, they would want to be guaranteed that they would get an appreciable quantity of manure in exchange for either crop residues or grain so as to enhance the fertility of their soils. To this end, some of the croppers, about 25%, stated they would participate in manure contracts with herders if the number of cattle in the herd were not less than 20. Another group of farmers, representing 35%, confirmed that the cattle in a herd must be 30 before they can endorse their participation in a manure contract. Consequently 35% of the respondents also claimed that the cattle

in a herd must be at least 50 before they can agree to participate in a manure contract with a herder. Farmers in this group were in the modal class that is later used in the modelling aspect of this work. Lastly, 5% of the farmers said there must be at least 60 cattle in the herd before they can engage with a herder in a manure contract (Table 4.26). It is very clear from the behaviour of the croppers, that they realised that the larger the number of cattle involved in a contract is, the more manure they get, and a higher number of cattle will consequently attract croppers to participate in manure contracts. However, the number of cattle also goes along with how long the cattle camp on a field during the contract. The combination of the two above help determining the extent of the manure quantities croppers will get for the maintenance of their soil fertility. Therefore, a cropper wants an appreciable number of days, which will guarantee him a maximum quantity of manure derivable from the contract.

Table 4.26: Number of animals preferred for manure contract exchange by croppers

Number of cattle	Frequency	Percent	Cumulative %
20	10	25.00	25.00
30	14	35.00	60.00
50	14	35.00	95.00
60	2	5.00	100.00
Total	40	100.00	

Source: own data, 2002

4.9.3 How the herders are paid for their participation in manure contracts

Manure contracts are based on mutual trust. They are never tied to the official signing of any agreement and as such they are regarded as an informal institutional arrangement that has evolved in place of the vacuum created by the absence of a formal institutionalised market. Even though there is no official signing of agreements, a contract is still a two-way flow of benefits. Even though there is no precise quantitative measure of the benefits in either way, both participants derive benefits that are physically visible to each other. Rough estimates of the quantity of manure a cropper obtains from a contract lasting for 7 days with 50 cattle are around 385 Kg. In exchange, a cropper parts with 100 Kg of millet as a gift or payment to the herder. There are two types of contracts. The first is manure–residues contract. It occurs immediately after crops have been harvested in November. The other is a manure-grains contract which takes place at a period when there are no residues, in which case a cropper gets the cattle to camp on his field where there is nothing to feed on. But cattle feed on the bush and camp in the night on the farmer's field to deposit manure. In this case, a cropper pays the

herder based on whatever they agree on. However, such a contract is not as popular as the former. In case of the former, that is the manure-residues contract, residues that are considered to be rich on the field, which the animals eat, compensate for the manure voided in the process. The 45% of participants who get zero payment probably belong to the category of croppers who participated in manure-residues contracts only. For croppers who participated in the second type of contract, there are various payment modes adopted to compensate the herders as shown in Table 4.27 below. About 15% of the farmers in this category said they normally paid the herder with the crop residues they keep in stock such as cowpea and groundnut haulms. These they have collected and kept when their grains and pulses were threshed, since at this point in time, there are no residues on the farms. A very small number of croppers, 5%, said they sometimes give some money to the herders for camping their animals for some nights. Most of the time, the manure voided on a field is paid for with grain equivalents of about 100 Kg (1 bag) for 50 cattle staying on the field for at least seven days. Other modes are unspecified gifts, respectively. The impact of this result is that trading of manure through the use of money as a medium of exchange is far from being developed in the area. Manure will be, for some time, continued to be exchanged through the informal arrangement that is currently prevailing.

Table 4.27: Mode of payment of the croppers to the participating herders for manure contracts

Payment mode	Frequency	Percent	Cum %
0	18	45.0	45.0
Manure/residues	6	15.0	60.0
Manure/money	2	5.0	65.0
Manure/grain	7	17.5	82.5
Manure/other gifts	7	17.5	100.0
Total	40	100.0	

Source: own data, 2002

4.10 Crop production and average yields among the various categories of farmers

In Zamfara state, farmers grow a variety of crops, most of the times in mixtures. There are many reasons why they practise the mixed cropping system. Many crops in a mixture could act as an insurance against the failure of a particular crop. Moreover, many crops in a mixture help farmers to prevent the spread of pests and diseases. It also helps sustaining the family food security, and it has been established that total yields from the mixtures per hectare are usually higher than the yields obtained from sole cropping. Under this production system, farmers get more yields from their crops (GRIMES, 1962; EVANS, 1960; WEBSTER and WILSON, 1966). Farmers in the study area grow many crops and the most important ones are

millet, sorghum, cowpeas, cotton and groundnut. All of these crops except cotton serve both as food crops for the family as well as cash crops. However, while millet is highly regarded as a food crop and produced by all households, most of the harvest from other crops is sold to raise money for family needs.
Due probably to the higher manure use of the agropastoralists, their yields are higher than those of the croppers not involved in manure contracts and even higher than those of the croppers involved in manure contracts.

The mean yields of crops grown by agropastoralists in the study area as presented in Table 4.28 are: 716 Kg for millet, 714 Kg for sorghum, 1037 Kg for cotton, 779 Kg for cowpea and 194 Kg for groundnut. However, the mean yields per hectare for manure contract participants were: 1019 Kg for millet, 673 Kg for sorghum, 1112 Kg for cotton, 490 Kg for cowpea and 226 Kg for groundnut. The T-test has shown that there is no serious significant difference between the yields of crops grown by agropastoralists and those grown by manure contract participants in the study area. Apart from millet and cowpea, that were barely significant at 10% level, others are basically statistically the same.

On the other hand, yields from croppers without manure were as expected the lowest in the area as shown in Table 4. 29. The yields per hectare were: 651 Kg for millet, 183 Kg for sorghum, 324 Kg for cotton, 313 Kg for cowpea and 128 Kg for groundnut. The T-test indicates that there is a statistically significant difference in the mean yields of almost all crops grown by manure contract and non-manure contract croppers in the area. This has gone a long way to show the very important position of manure occupation in soil fertility maintenance in the study area. It is thus hoped that many of these non-adopters of manure contracts will avail themselves of this soil maintenance practice to enhance the productivity of their soils. This would ensure sustainable crop productivity without having to encroach on uncultivated portions of the grazing reserve.

Table 4.28: Comparison of mean yields of mixed crops per hectare for agropastoralists and manure contract croppers in the Zamfara reserve

	Agropastoralists			Manure contract farmers			
Crops in mixture	N	Mean Kg/ha	Std. dev	N	Mean Kg/ha	Std. dev	T-value
Millet	143	715.95	586.11	38	1019.12	861.11	-2.55*
Sorghum	123	713.74	345.43	30	673.27	485.87	0.53
Cotton	65	1036.68	873.59	26	1111.68	1227.10	-0.33
Cowpea	140	778.98	558.64	35	489.56	727.08	2.57*
Groundnut	94	193.71	157.09	20	226.38	159.77	-0.83

Source: own data, 2002. * indicates significant level of 10%.

Table 4.29: Comparison of mean yields of mixed crops per hectare for manure contract and non-contract croppers in the Zamfara reserve

	Manure contract farmers			Non-contract farmers			
Crops in mixture	N	Mean Kg/ha	Std. dev	N	Mean Kg/ha	Std. dev	T-value
Millet	38	1019.12	861.11	45	651.02	939.48	1.85*
Sorghum	30	673.27	485.87	34	183.39	246.71	5.16***
Cotton	26	1111.68	1227.10	29	323.97	518.47	3.16**
Cowpea	35	489.56	727.08	39	312.59	275.87	1.41
Groundnut	20	226.38	159.77	20	127.55	129.66	2.15*

Source: own data, 2002.
*, **, *** indicate significant level of 10%, 5% and 1% respectively.

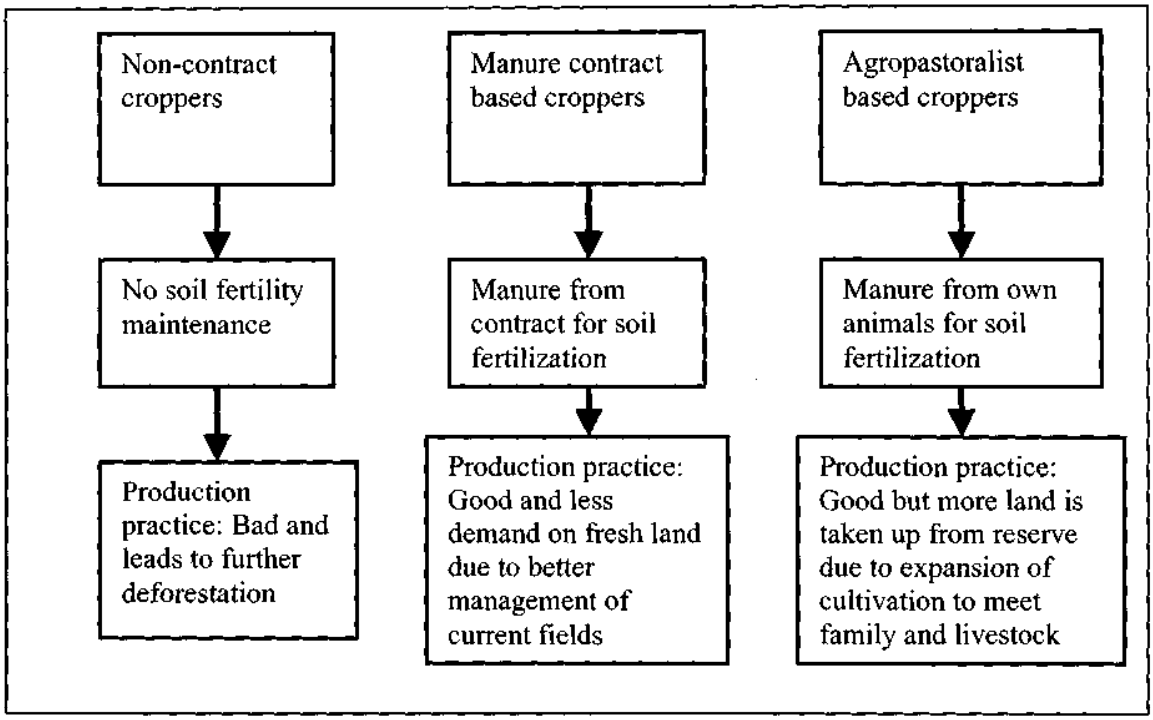
4.11 Implications of the various production practices in the Zamfara reserve

Table 4.30 below shows the implications of the three types of production practices as far as soil fertility maintenance is concerned in the Zamfara grazing reserve. The non-contract croppers are the farmers that do not use any fertilization for soil fertility maintenance. Their crop production yields are usually poor as has been observed in Table 4.29. These farmers cultivate a piece of land for two to three years after which they abandon the land and relocate to a fresh piece of land. If this practice is allowed to continue, it will lead to further deforestation of the grazing reserve or farmers will continue to use the same land, thereby degrading it further.

On the other hand, manure contract croppers are farmers that are engaged in manure contracts with herders to get manure for maintaining the fertility of their soils. They have a better crop output in comparison with the former since they are able to maintain their soils. Consequently, the incentive to deforest and degrade the grazing reserve is minimal with contract croppers. However, the question is what is the impact of such cropping practices on grazing land?

Agropastoralists are people who raise animals with crop production under a joint management system. Because of the many objectives they have for production which include crop residues for their animals, their farms are normally larger as has been observed in Table 4.7. The larger numbers of household members also imply that more food will have to be produced to cater for family food needs. The combination of the two factors above mean that agropastoralists have a high incentive to demand additional land thereby causing deforestation and they could therefore contribute to degrading the grazing reserve more than other users.

Table 4.30: Different production practices employed by farmers for soil fertility maintenance and their implications



Source: Own observation from field results

4.12 Summary

In this chapter, socio-economic characteristics of the farmers in the study area such as age, education background, and household size were presented. The type of land ownership systems, farm size, production activities and labour available and their usage were equally discussed. The non-availability of credit facility, which has dire consequences for input use, was equally highlighted. Also were presented in the chapter the use of manure contracts and of agropastoralism as major production practices adopted for soil fertility maintenance and with the quantity of manure used by contract croppers and agropastoralists in the study area highlighted. The factors motivating the adoption of these mentioned production practices were also presented. Finally, crop production and average yields under various production practices were compared in the study area.

5 METHODOLOGY AND STRUCTURAL FRAMEWORK FOR THE STUDY

In this chapter, the overall methodology of the study and the structural framework of the models employed are discussed. Because of the various components contained in this study, a multiplicity of approaches and methods have been employed to achieve the various objectives of the study. The methodology of the study basically comprises econometric modelling techniques and a mathematical programming model, in the General Algebraic Modelling System (GAMS) format. The econometric models involve the estimation of Probit and Regression Models for farmers' adoption of soil fertility maintenance practices and the estimation of the impact of the adoption on crop productivity in the study area respectively. A combination of LIMDEP Econometric Software version 8.0 and SPSS software version 12.5 were used for running these models. The mathematical programming was developed to explore the optimum production revenues possible under two given soil fertility maintenance practices. This is with a view to identifying the most sustainable option, given the fact that the Zamfara reserve is a conserved area, where grazing and cropping have co-existed due to certain social exigencies. It must to be borne in mind that while these social exigencies are being met, efforts must be made to preserve the reserve as much as possible, as a natural resource and biodiversity bank. Efforts must also be made to maintain its ability to function on a sustainable basis as a grazing reserve.
The data used for the models were collected and processed during the field research. The data was collected from farmers' households in the Zamfara reserve located in the Zamfara state in the northwestern geopolitical zone of Nigeria, and covered the 2001 production year. Farmers in the survey area are mainly small-scale operators with few of them having fairly big plots.

Quantitative measures such as the relationship between input usage and the current land available for crop production, the current manure exchange to sustain the area currently under production and further possibilities of the expansion of manure contracts for the benefits of all farmers were investigated and compared with the crop-livestock combination for the production of manure. The likely effects on the sustainability of the reserve of all farmers becoming agropastoralists are compared with the effects of all croppers not having animals but depending on pastoralists for manure exchange. Even though opinions are highly divided in the literature reviewed in chapter three with regards to the issue of the carrying capacity, the model is envisaged as a planning tool and therefore measures are taken to analyse the effect of enforcing cattle taxes. To control the level of livestock in the reserve, taxes can be introduced. Since agropastoralists seem to have been viewed with the high tendency to cause degradation, it was thought that such a tax might force them to abandon animal husbandry, since animal husbandry is not considered their major occupation as is the case with

pastoralists. That will be a welcomed development for the sustainability of the grazing reserve since the traditional pastoralists will still be able to function well. Their livestock husbandry business will take advantage of residues and they will be ready for contracting with croppers that have abandoned livestock keeping.

5.1 Structure of the model

The model used for this study, as earlier stated, is a combination of econometric and mathematical programming models. The econometric model comprises of the evaluation of the practices farmers adopt to maintain the fertility of their soils as well as the impact of such measures on farmers' crop productivity. The second aspect involves the use of a farm level bio-economic modelling (FLBEM) approach to explore farm production revenues under the two practices used by these farmers, so as to come up with the best options. Options that will maximize resource use and at the same time take into consideration the maintenance of the soil fertility status of the presently cultivated area without necessarily cutting down more of the forest/grazing reserve in the nearest future. Mostly, primary data as well as some exogenous parameters obtained from the statistical analyses are used as inputs for running the mathematical model as illustrated in Figure 5.1. Some results from the field study were used in the mathematical programming model, while averages of some parameters from the econometric models are also used. The objective function is designed to maximize the net income of crop production under the two practices of soil fertility maintenance, subject to technical constraints on production. The long-term effect of the practices on the grazing reserve encroachment as well as on the determination of the current stock level was explored. To see if the pasture is not currently being overstretched is necessary for its sustainability. The possibility of the current livestock sustaining contracts for all croppers is equally explored as well as a cattle tax policy measure for controlling stock, should there be a future threat to pasture/livestock equilibrium. It is also felt that taxation might discourage agropastoralism and encourage specialisation of activity by the stakeholders in the reserve. This would be preferred since so much evidence is available that suggests that agropastoralism poses a danger to an established grazing reserve or forest reserve.

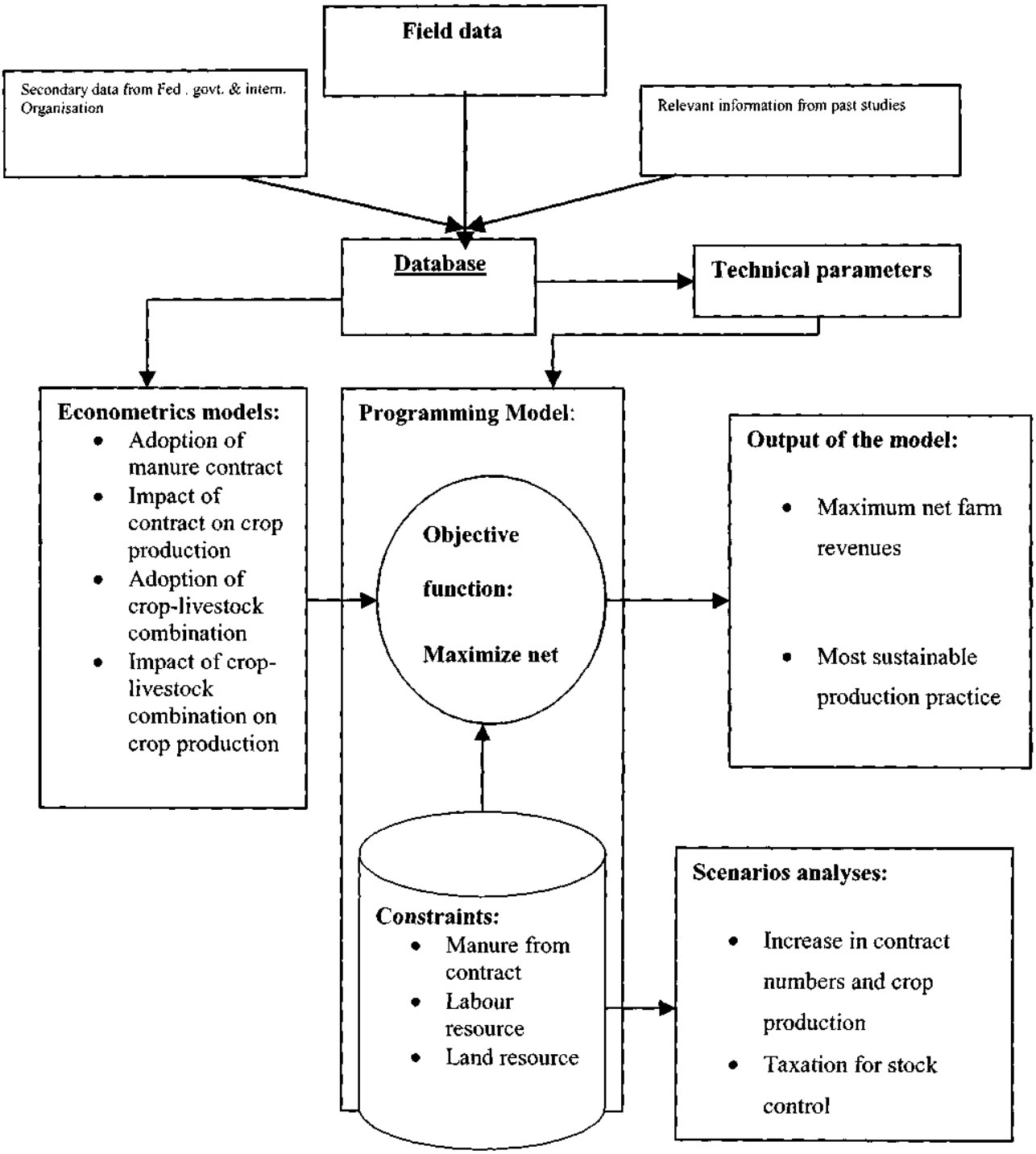
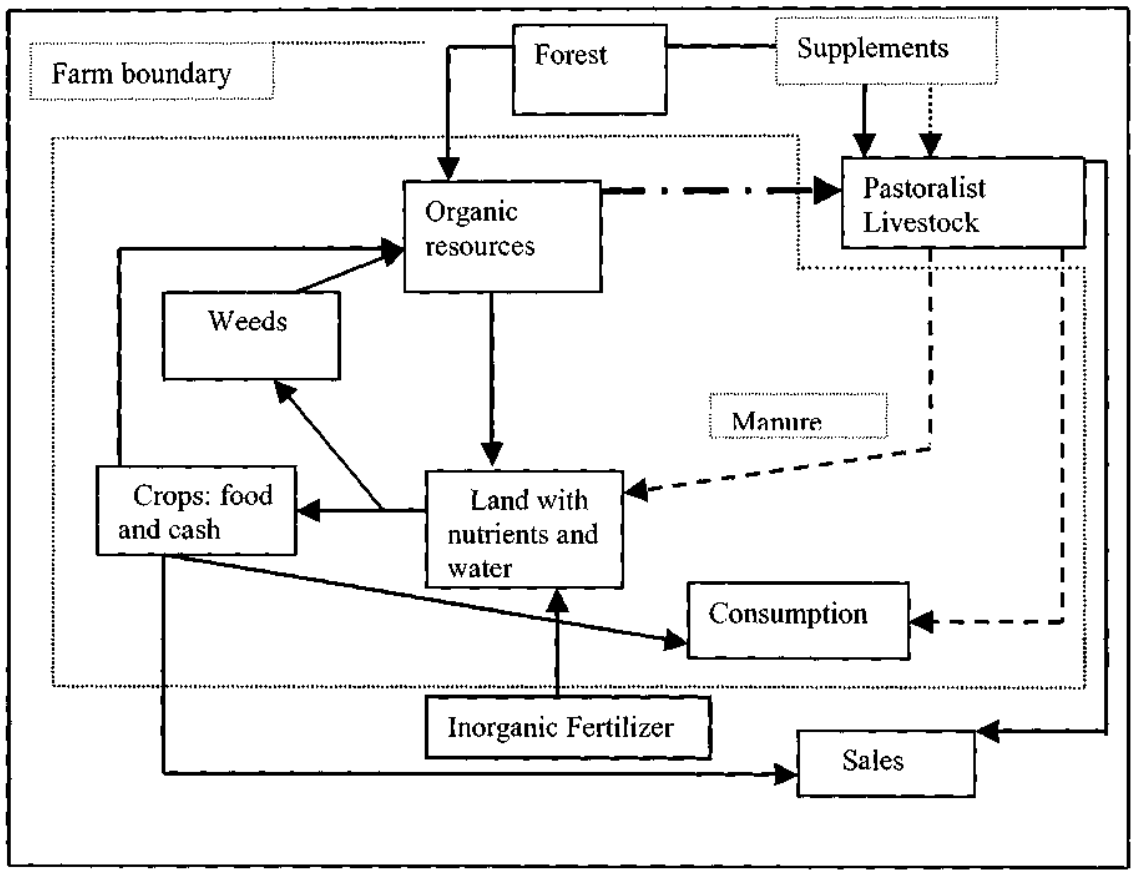


Figure 5.1: Sketched diagram of the structure of the FLBEM model

5.2 Types of soil fertility maintenance practices employed by farmers in the Zamfara grazing reserve to sustain the fertility of their soils

There are three practices farmers in the area engage in for soil fertility maintenance on cropped fields. The first is the production of crops without either manure or inorganic fertilizers. Since farmers in this group do not have access to chemical fertilizers and have not yet embraced the manure contract option as a means of generating manure for cropping, their soils are low in productivity. However, farmers in this group also do not have livestock that could help them obtain manure. It has been well documented in literature that this type of farming is far from being sustainable, whether in a reserve area or other locations. This is because under this system, farmers will be left with the option of changing fields if the current soil is depleted, thereby leading to the cutting down of more forest (deforestation) or with the option of cultivating previously cropped areas, leading to very poor yields. At times, no yields may be recorded at all (GRETTON and SALMA, 1997; VOSTI and REARDON, 1992; CHOMITZ and THOMAS, 2000).

The second is the production system based on manure contracts as a basis for generating manure for soil fertility maintenance. It is gradually gaining grounds as an alternative for farmers who have no livestock to secure manure for maintaining the fertility status of the cultivated fields.



Source: own diagram.

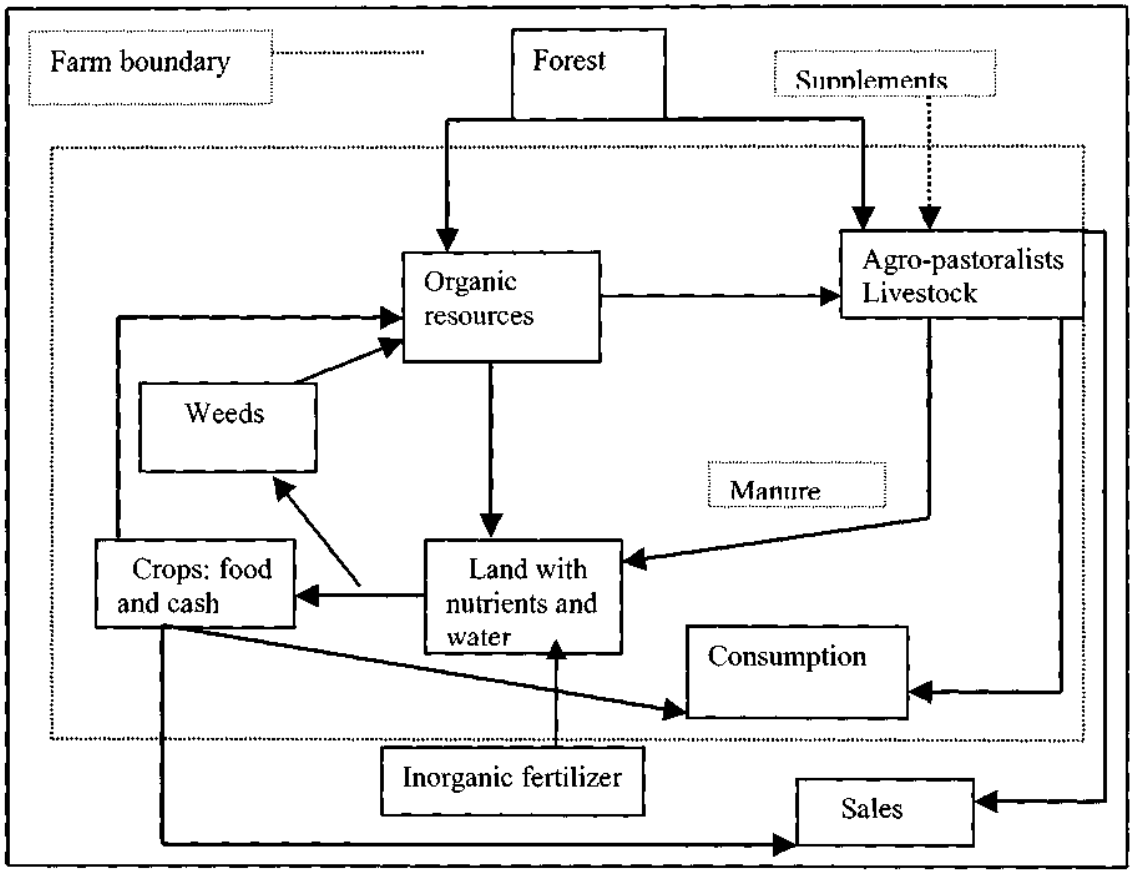
Figure 5.2 Sketched diagram of crop-livestock interaction based on manure contracting in the Zamfara grazing reserve

Figure 5.2 shows a typical sketch of a farm with croppers and pastoralists interacting to exchange productive resources for their mutual benefit.
In this farm setting, croppers receive manure from herders who are outside the farm boundary. For the maintenance of the fertility of their soils to enhance production, farmers engage in manure contracts with herders, while herders, on the other hand, receive crop residues and sometimes monetary rewards for the manure exchange with the croppers. This type of synergy has developed as a medium of exchange through a local arrangement to enable the parties involved to meet their needs. The croppers are able, through their crop production activities, to meet the food needs of their families in addition to some marketed surpluses to generate income for the family. This type of association existing between crop and livestock has been termed crop-livestock integration based on loose association since the two activities are under separate management (MCINTIRE *et al.*, 1992).

The third is the type of production in which we have crops and livestock under the same management. These farmers grow crops and have livestock at the same

time. Crop residues are fed to livestock at off-season while the manure produced by livestock is used for soil fertility maintenance. This type of production arrangement is said to have contributed to the unfriendly relationship between herders and croppers since the manure-residues exchange between them is highly affected when croppers now have livestock that will make use of own residues (MCINTIRE *et al.*, 1992). The system has also been labelled as having the capacity to degrade the forest more strongly, especially in areas very close to the settlement. Due to the uneven grazing of the pasture, it exposes the area to persistent overgrazing and exposure of soil. Run-off resulting from wind or water erosion is a consequence thereof (THOMAS and BARTON 1994). Figure 5.3 illustrates the livestock within the farm boundary showing a clear difference from the sketch in Figure 5.2. Manure from farmers' livestock is used for cropping fields while crop residues from crops are fed to livestock.

It should be noted here that livestock from the crop-livestock combination farms also graze in the Zamfara grazing reserve, but they graze persistently close to the settlements and therefore not very far away from the settlements. This is in divergence from the livestock of pastoralists, who are very adept to transhumance activities. Farmers also occasionally buy feeds to supplement their animals' diets. The use of inorganic fertilizer is seen as very insignificant and the level used might not be sufficient to make any appreciable impact on crop yields. It is equally viewed that in a crop-livestock combination farm, more land will be needed since there is the objective of producing residues to meet animal needs at all periods of the year (THOMAS and BARTON, 1994). This makes the system to be at variance with the view of conservationists, who feel that it could lead to more deforestation since an expansion of cropping will mean more forest must be cleared. The interaction taking place is as shown by comparing Figures 5.2 and 5.3. This interaction is evaluated using the mathematical programming model with the objective of examining the most sustainable pathway to intensification. Bearing in mind the sustainability of the reserve as a grazing reserve as well as an important natural biodiversity bank left in that region of Nigeria, it is essential to minimize ecological negative impacts.



Source: own diagram.

Figure 5.3 Sketched diagram of crop-livestock enterprise combination in the Zamfara grazing reserve

5.3 Summary

A structural form of the modelling approach for this work was discussed in this chapter. We use a combination of econometric models and the farm level bio-economic model for various components of this study to achieve the various objectives stated earlier in chapter one. The econometric model deals with the evaluation of the factors driving farmers to adopt various farm practices aimed at ensuring soil fertility maintenance as well as the effect of those practices on crop productivity. Some of the mean variables from these analyses will become important parameters later in the programming model. The purpose of the programming is to evaluate two practices which will ensure optimum net farm income while at the same time meeting the goal of sustainable crop production keeping in mind the sustainability of the grazing reserve where cropping has become inevitable due to certain social exigencies.

6 THE ECONOMETRIC MODELS AND RESULTS

The structure and general outline of the FLBEM model were highlighted in chapter five. In this chapter, the details of the econometric modelling aspect of the study and some empirical results are discussed. The approach involves an evaluation of the determinants of farmers' participation in the adoption of manure contracts. Farmers' participation in crop-livestock enterprise combinations under single management is the focus of the discussion in chapter seven. An evaluation of the various adoption practices ensures a better understanding of the reasons underlying farmers' decisions to engage in a particular production practice. An econometric model is employed to evaluate the impact of the adoption of the two practices as options for soil fertility maintenance. We ascertain the effect of these practices on farmers' crop outputs to assess if a particular practice can sustain crop production under conditions of low capital availability. Prior to the discussion of the analysis and results of the econometric models, the theoretical background that underlines the adoption study of new farming practices is presented.

6.1 Theoretical and statistical considerations of modelling adoption behaviour and its impact on crop productivity

A considerable review has been done on previous adoption studies in chapter three of this study. In this light, we proceed to elaborate on the specific statistical model that is used for this study.

Multivariate Logit and Probit models as well as their modifications have been used extensively to study adoption behaviour of farmers and consumers (NERLOVE and PRESS, 1973; SCHMIDT and STRAUSS, 1975; GARCIA *et al*, 1983; AKINOLA, 1987; AKINOLA and YOUNG, 1985; ADESINA and ZINNAH, 1993). Following RAHM and HUFFMAN (1984), farmers' adoption decisions are reasoned to be based upon utility maximization.

As has been stated earlier, a first step is to estimate the determinants of farmers' participation in the adoption of manure contracts as a strategy for soil fertility maintenance. Secondly, the estimation of the impact of the adoption of this soil fertility maintenance strategy on crop productivity is evaluated.

In the first step, it is assumed that the adoption of soil fertility maintenance strategies by different categories of farmers is a linear function of farm household characteristics and the attributes inherent in these soil maintenance practises. However, the decision of a farmer to adopt or not is based on self-selection rather than on random assignment. Thus, adoption A_i should be endogenised using an index function model (e.g. HECKMAN, 1976; MADDALA, 1983; and GREENE,

1997). The index to estimate farm household adoption of manure contracts and crop-livestock enterprise combination is stated as:

$A_i^* = Z_i'\gamma + \mu_i$ .....(6.1)

Where A* is an unobservable index variable denoting the difference between the utility of adopting these soil fertility maintenance practices (U_{1i}) and the utility of not adopting (U_{0i}). If $A^* = U_{1i} - U_{0i} > 0$, then the individual household i will adopt a chosen soil fertility maintenance strategy. The term $Z'\gamma$ provides an estimate of $U_{1i} - U_{0i}$, using farm household characteristics and the attributes of the soil maintenance practices, Z_i, are explanatory variables, while U_i is an error term unobserved by the researcher and assumed to be normally distributed $U_i \sim N(0,1)$. This model is estimated with a standard Probit log-likelihood function.

On the other hand, to model the impact of the soil maintenance practices on crop productivity, we assumed that crop yield, Y_i, is a linear function of a vector of explanatory variables (X_i) and (A_i^*) (TRAUER, L. W, and W.A. KNOBLAUCH, 1997). As a linear equation it can be written as:

$Y_i = X_i\beta + \delta A_i^* + e_i$ .....(6.2)

Where e_i is a normal random disturbance and A_i^* is a 0 or 1 dummy variable for the adoption and non-adoption of soil maintenance practices. The vector X_i represents inputs such as labour and inputs expenses on crop production. Using equation (6.1) and (6.2), and following a similar study by FOLTZ and CHANG (2002), the expected crop yields Y_i can be obtained by:

$$\begin{aligned} E[Y_i] &= E[Y_i/A_i=1]* Prob(A_i=1) + E[Y_i/=0]*Prob(A_i=0) \\ &= X_i\beta+\delta+E[\mu/A=1]) *Prob(A=1) \\ &\quad +(X_i'\beta+E[\mu_i/A_i=0])* Prob(A_i=0) \\ &= X_i'\beta+\delta Prob(Z_i'\gamma+\mu_i>0) \\ &= X_i'\beta+\delta\Phi(Z_i'\gamma) \quad .....(6.3) \end{aligned}$$

Where Φ is the normal cumulative density function for u_i, and u_i is the unobservable error term as stated earlier. Thus, $\Phi(Z_i'\gamma)$, the probability of a farm household i, adopting a soil fertility maintenance practice serves as the instrumental variable for A_i^*, which is the adoption probability in the equation (6.4) to avoid biasing the estimators.

The two models to be estimated are therefore:-

$A_i^* = Z_i'\gamma+\mu_i$ ..... (6.4) i.e. Probit for adoption determinants.

However, the Probit parameters are estimated using maximum likelihood methods. According to GREENE (1990), after taking the logs, the Probit model is as presented below:

$$\text{Log L} = \sum_{f_i=0} \log(1-\Phi_i) + \sum_{f_i>0} \log\left[\frac{1}{(2\Pi\sigma^2)^{\frac{1}{2}}}\right] - \sum_{f_i>0} \frac{1}{2\sigma^2}(f_i - X_i\beta)^2 \Sigma\text{—}(f_i - X_i\beta)^2 \ldots\ldots (6.5)$$

The first summation is over farmers that are not involved in the adoption of manure contracts or crop-livestock enterprise combination, corresponding to the probability mass that is in the left-hand tail.

$Y_i = X_i'\beta + \delta A_i^* + e_i$ ..... (6.6)

for the impact of adoption on productivity.

These two models (6.4 and 6.6) are used to achieve the objectives of determining the factors that facilitated the adoption of the various farm practices for soil fertility maintenance in the study area and the impact of these practices on farm productivity. Estimations of the above model are carried out using the LIMDEP for (Limited Dependent Variable) econometric statistical software package version 8.0.

6.2 Determinants of households' participation in the adoption of manure contract practices in the Zamfara grazing reserve

The descriptive results presented in chapter three elaborated on the characteristics of households in the study area regarding crops grown and yields as well as the factors that determine the participation in soil maintenance practices. The objective of this chapter is to present the factors that determine the participation of farmers in manure contracts. In line with the econometric model, the impact of adopting soil fertility maintenance strategies on crop productivity is also demonstrated. We attempt to answer the following questions:

1. What factors determine farmers' adoption of manure contracts as a soil fertility maintenance strategy in the Zamfara grazing reserve?
2. What is the impact of the adoption of manure contracts as a soil fertility maintenance practice for crop productivity?

6.2.1 Variables in the adoption participation of manure contracting as a soil fertility maintenance strategy

Six explanatory variables were observed to determine the decisions of farmers to participate in manure contracts. These are:

- the duration of time a herder is willing to camp his livestock on the cropper's field,
- the prior contract relationship between cropper and herder,
- the tribal closeness of the cropper to the herder,
- the trust existing between the cropper and the herder,
- the observation that others farmers participate in contract, and

- other reasons not explicitly stated by the farmers.

A careful observation of the variables shows that the duration of time the herders are willing to allow their animals stay on the field "DURASTAY" is purely based on the manure quantities that would be made available through farmers' participation in contracts. It is within the ambit of farmers' rational behaviour as a motive of what amount of manure they would gain from participating in manure contracts. This is in recognition of the fact that, the longer the livestock is camped on their fields, the more are the quantities of manure that will be voided on their fields. This is considered favourable for the fertility of the fields, thereby leading to an improvement in the nutritional status of their soils. It is therefore expected that a mutual arrangement that allows the herds to stay longer on croppers' fields will elicit a positive decision for participation in manure contracts by the croppers. Farmers' response on this variable was obtained by asking the farmers to indicate the number of days they will expect a herder to camp their animals on their fields.

The second explanatory variable is the prior contract relationship of the croppers and herders "RELATION". A non-formalised contract agreement is considered risky. Defaults by either of the parties involved can occur, and consequently, under this informal institutional business arrangement, care is taken in selecting a partner with utmost certainty of non-default. Since there is no better way of guaranteeing non-default, each party is more comfortable with someone it has had a prior informal business relation with. Prior relations are usually very important in guiding the decisions of farmers to participate in manure contracts.

The third variable is tribal affinity with the herder. People usually have more confidence in people from their own tribe. Under the rural settings of these farmers there is no yet accepted legal basis in getting agreements executed. Therefore, verifying a person of the same tribe who is willing to engage in manure contracts will encourage the cropper to participate in a manure contract. In fact, there is a very close relationship between the Hausa farmers and the Fulani herders. To the extent that they are said to be people of the same origin and bounded together by the same culture and religion, they have an affinity for each other. This accounts for the reason why they are generally referred to as Hausa-Fulani. This is because there is basically no difference between the two tribes from the point of view of culture and religion. Because of this understanding, they have come to regard themselves as the closest tribes among the numerous existing tribes in Nigeria.

The fourth variable is "TRUST" in the other partner involved in the manure contract. People are generally more comfortable with a person they feel they can trust when it comes to dealing with each other in an informal contract that has no legal backing and as such trust is an essential ingredient in guiding the decisions of the croppers. It is also significant here because there is the feeling that a religious bond exists. It is the general opinion among the people in the study area that a Muslim brother can be more trusted than a person of another religion.

Religion is therefore very important consideration in finding partners for manure contracts in the study area and religion factor can therefore be very vital in deciding whom to trust for contracting.

The fifth variable was termed "BANDWAGON". Farmers said they adopted the practice because they have seen other farmers doing it. Lastly, we use the variable termed "OTHER REASONS", that farmers could not describe explicitly as the reasons for their participation in adopting the manure contract practice are a bundle. All variables, apart from the number of days the herders are willing to camp their animals on farmers' fields, are binary or dummy variables taking the values of one or zero.

The impact of the farm households' participation in manure contracts on farmers' crop productivity is also investigated. Under this question, crop yield is the dependent variable. It is a proxy variable for productivity measurement. Three explanatory variables are used: labour in man-hours employed in production per hectare, input expenses incurred per hectare and the manure contract participation prediction from the manure contract adoption model. Since all farmers under investigation did not participate in manure contract adoption, the probability of participation was obtained from the execution of the previous adoption model. Labour and input expenses are very important variables in farm production and it is expected that there will be a positive relationship between yields and the use of labour and input expenses as well as manure use, arising from contract participation.

Table 6.1: Dependent and independent variables in the model for manure contract adoption

Dependent Variables	Model Description	
Manure contract adoption	Probability of adopting manure cropping for soil management	
Yields of crops in crop farming	Yields of crops per hectare in grain equivalents	
Dependent Variables	Yields of crops/ha in grain equivalents	
	Variable description	Type Variable
Socio-cultural reasons	Duration of days animals stay on field (DURASTAY)	Numeric
	Prior relationship between croppers and herders involved (RELATION)	Dummy
	Tribal closeness of croppers and herders (TRIBE)	Dummy
	Mutual trust between croppers and herders (TRUST)	Dummy
	Because I see other farmers participate (BANDWAGON)	Dummy
	Other reasons not immediately specified (OTHER REASONS)	Dummy
Inputs used for crop production	Labour expended on crop production	Numeric
	Input expenses incurred by crop production	Numeric
	Predicted probability of manure contract participation	Numeric

6.2.2 Decisions of farmers to participate in manure contract adoption

The model of the decisions to adopt manure contracts as soil fertility maintenance management identifies the characteristics that stimulate households to adopt this management strategy as opposed to those who do not. This model attempts to determine these factors associated with the adoption of manure contracts strategy for soil fertility maintenance and is specified in an explicit form as:

$$Pr(MAMURE\text{-}C) = f(DURASTAY, RELATION, TRIBE, TRUST, BANDWAGON, OTHERS\ REASONS;) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (6.7)$$

That is, the probability of the participation in manure contract adoption for soil fertility management depends on the set of explanatory factors that drive the desire of farmers to participate in the adoption process. Due to the relatively small number of 85 respondents sampled in the four enclaves, the results of the pooled data for the two zones – Dumburum-Shamushalle and Ajja-Tsabre - is presented together as one since a fairly large observation is needed to run this type of model.

6.2.3 Determinants of the decision to participate in manure contracting by all croppers in the study area

In Table 6.2, the general responses by croppers to factors that determine croppers' decisions to participate in manure contract adoption as a strategy for soil fertility management are as shown. The model predicts 96.47% of the observations correctly with a chi-square significance of 86.39. All six variables explaining the adoption have coefficients that are significantly different from zero. Three variables, the duration of livestock stay on the field, the tribal closeness and the trust reposed in the herders, are positively associated with the adoption of manure contract participation in the study area. This attests the importance of informal institutional arrangements for manure contracts. The veracity of the motives claimed by farmers and the significance of their results show without any doubt that manure contract adoption has taken roots in the study area. Herders and croppers are poised to ensure and maintain the fertility and sustainability of their soils by contracts.

Looking at the variables, the duration of stay of the livestock on the fields of croppers during contracting is the most important determinant of farmers' participation in manure contract adoption. The longer a herder agrees to camp his animals on the field, the more likely a cropper is willing to participate in manure contracting. This is because the longer the animals stay on the field the larger is the quantity of manure that will be voided on the field and the better is the fertility of the soils. In the same vein, the prior contract relationship with the herder is found to be negatively significant. This may be an indication of the fact that a business relationship of this type in the past has turned sour. Consequently this does not encourage farmers' participation in manure contracts. On the other hand, tribal closeness of the parties involved, and the level of trust in each other can serve as a guarantee to allay the fear of cheating. These two factors will encourage croppers to participate in manure contract adoption as a strategy for soil fertility management. The last two reasons, the observation that other farmers participate in manure contracts and other reasons not specifically defined, are statistically significant, but they are negatively associated with manure contract participation.

Table 6.2: Results of the Probit model for the adoption of manure contract participation by all croppers in the study area.

Variables	Coefficients	St. deviation	T-ratio	P-value
Duration of stay on field	0.37***	0.075	4.85	0.000
Relationship with herders	-2.69**	0.86	-3.07	0.002
Tribal closeness	1.72**	0.61	2.84	0.005
Trust reposed on contract partner	1.08*	0.53	2.05	0.040
Because I see other farmers participate in manure contract	-1.12*	0.47	-2.37	0.018
Other reasons	-2.24*	0.95	-2.36	0.018
% Correctly predicted = 96.47 Model CHI-SQ = 86.39*** Log Likelihood function = -15.44 N = 85				

Source: own data, 2002

* = Significant at 10% level, ** = Significant at 5% level, *** = 1% level.

6.2.4 Impact of manure contract participation on crop productivity

The second issue of concern is to see if the adoption of manure contracts along with other variables has significant impact on crop productivity in the study area. To determine this, model 6.6 in section 6.1 was used in its explicit form as shown:

Yields = f (Input expenses, P-manure_C, Labour) ..... (6.8)*

Yields are a function of the input costs expended on crop production, the probability of farmers' participation in manure contracts and the labour used in crop production. The decision to look at the impact of the adoption on crop productivity is born out of the belief that the farmers could make rational decisions to participate in the adoption of processes that are beneficial to them. This is because the practice in question has the ability to positively influence their crop productivity and hence their income and the general welfare of the farm household.

6.2.5 The impact of manure contracting on crop productivity of croppers in the entire study area.

The overall results from all croppers sampled demonstrate that inputs seem to play an important role in the productivity of farmers' crop yields. It can be seen that the expenses on inputs used, manure contract adoption and labour expended on production, are all positively associated with crop productivity. The positive signs on the coefficients of these variables show that the higher their use intensity by the croppers is, all things being equal, the higher are the crop yields. Input expenses and labour were significant at the 5% and 10% level of probability respectively, while the manure use probability, an important variable of our investigation, is significant at the 10% level of probability. This clearly confirms the hypothesis that the croppers' participation in manure contracts has a positive impact on farmers' crop productivity in the area. This is a reflection on the fact that manure contracting is serving as an alternative means for soil fertility management among the resource-poor farmers in the area. In general, these farmers are too poor and can therefore not afford the conventional chemical fertilizers as means of managing the fertility of their soils, and so tend to prefer manure contracts.

Table 6.3: Results showing the impact of manure contracting on crop productivity for croppers

Dependent Variable		*Mean*	*Standard deviation*
Yields of crops in grain equivalent		*1339.54*	*941.65*
Explanatory Variables	Coefficients	St. error	t-statistic
Constant	0.407	0.264	1.54*
Input expenses	0.137	0.041	3.35**
Probability of manure use	0.481	0.271	1.78*
Labour used	0.672	0.322	2.09*
R-square = 0 .21			
R-adjusted = 0.18			
F-statistic = 6.99***			
N = 85			

*, **, *** = Significant at 10%, 5% and 1% respectively
Source: own data, 2002

6.3 Summary

In this chapter, theoretical and statistical considerations for modelling adoption behaviour as well as the impact of such an adoption on crop productivity were discussed. Various variables were estimated in the adoption of manure contracts.

Impacts of manure contract adoption were equally highlighted. It was discovered that most of the identified variables driving farmers to adopt manure contracts, were statistically significant in explaining farmers' decisions to adopt manure contracts. It was found that the probability of manure contract adoption has a positive and significant impact on crop productivity. Labour and production expenses were found to be important in facilitating the crop productivity among manure contract adopters in the area. The results obtained have gone a long way in demonstrating the important role manure contracting is beginning to play in sustaining crop production in the Zamfara grazing reserve.

7 DETERMINANTS OF HOUSEHOLDS' PARTICIPATION IN CROP-LIVESTOCK ENTERPRISE COMBINATION AS A SOIL FERTILITY MAINTENANCE STRATEGY IN THE ZAMFARA GRAZING RESERVE

This chapter is aimed at evaluating the factors driving farmers' participation in the adoption of crop-livestock enterprise combination and the impact of the adoption on crop productivity. The chapter seeks specifically to answer the following questions:

1). What are the factors driving farmers participation in the adoption of a crop-livestock enterprise as a combination under a single management?

2). What is the impact of the adoption of crop-livestock enterprise combination on crop productivity?

7.1 Variables in the participation of crop-livestock enterprise combination adoption in the Zamfara reserve

The evaluation is based on the estimation of models 6.4 and 6.6 in section 6.1. A total of 228 households, comprising those that are involved in crop-livestock enterprise combination, were sampled in the four enclaves of the grazing reserve in 2002. The area covered is a very wide expanse divided into two regions, which are Dumburum-Shamushalle and Ajja-Tsabre. The population structures and the nearness of these communities as well as a similarity in their locations with respect to the major roads were the criteria for the grouping. Dumburum and Shamushalle have a larger population and are closer to the major motor road while Ajja and Tsabre are smaller and distant from the motor road.

Data for the adoption of farmers' participation in crop-livestock enterprise combination was grouped into two groups with 109 respondents from Dumburum-Shamushalle and 119 respondents from Ajja-Tsabre respectively.
The participation of farmers in crop-livestock enterprises under the same management is the dependent variable. There are seven explanatory variables that serve as driving forces in hypothetically guiding the decisions of farmers to participate in adopting crop-livestock enterprise combination as a soil maintenance practice. They are:

- the family size of the farm household,
- the traditional practice of the people,
- the food security driven purpose,
- the means of saving for farm households,

- the manure availability,
- the provision of traction power,
- additional income generation.

The impact of the adoption of the mixed form of enterprise on crop productivity is equally investigated. Yields of crops are measured in grain equivalents as a proxy variable for productivity. Indicator variables included labour, input expenses and mixed enterprise combination as prediction from the adoption model.

According to KEBEDE *et al.* (1990), family size "FAMLSIZE" has been recognised to play a vital role in the adoption of any particular farm practice or technology. In the African context, families are known to play dual and opposing roles in determining what occurs on the farm (AKINOLA, 1987). On the one hand, a family provides labour and management inputs. But it also has certain demands, which motivate the adoption of new practices, or technologies, that may increase the farm income as a means to meeting the food demand. Furthermore, as a measure of strength, family ties have effects such as encouraging the household head to improve the earning power of the household. This is because many family workers tolerate, for a time extremely bad conditions of employment or very poor wages with the aim of building up the household's productive capital base. This puts the farm head in a financially advantageous position to spend more money on the adoption of new practices, especially when the practices in question demand a higher expenditure. For example, the addition of animal husbandry to a cropping enterprise requires that additional expenditures on animal feed and health will be incurred. Conversely, family demands for cash may compete with the financial resources of the farm enterprises. Dependency of relatives on the farm operator may weaken his motivation to work harder. If he knows that his financial success might result in more claims from the poorer members of his family, he may tend to work less. Hence, the actual relationship between the size of the family and the adoption of a crop-livestock enterprise combination will depend on the balance of these effects.

The other variables discussed below have been recognised in literature as qualitatively crucial in guiding the decisions of farmers to combine animal and crop enterprises (ABIASSI, 2001; NDUBUISI, 1999). With respect to the traditional practice of the people "TRADITION", we argue that the people of these communities are predominantly Muslims. They use animals such as cattle, sheep and goats in periodic Muslim festivals. The desire to have animals as part of farm business prevents farmers from buying animals at exorbitant prices during celebrations. It is important as part of the decision making process to possess livestock as part of their farm business. The majority of the respondents actually confirmed that keeping animals and cropping is seen generally as part of their normal life.

Moreover, food security ("FOOD") entered the model as a variable. Food security is very important, since animals, especially cows, produce milk for family use and are a source for sales. The traditional food of the people in northern Nigeria, particularly of the Hausa and the Fulani, is millet, usually made into a porridge called "Fura". This is prepared with fresh milk called "Nono". Therefore, the desire to have milk is very crucial in farmers' decisions to participate in crop-livestock enterprise combination.

The variable savings, "SAVINGS", was equally relevant in explaining the adoption decisions. Farmers sell some of their livestock to generate income whenever they need money and, as such, the keeping of animals is seen as a form of savings, since the animals can be converted to money when required. Savings are therefore seen as one of the motives driving the desires of a farm household to embark on a crop-livestock enterprise combination.

Another important factor in explaining adoption patterns for combining animals with cropping is to ensure the availability of "MANURE". Farmers combining crops and animal husbandry regard manure as an important input for crop production. The availability of manure depends heavily on livestock possession. Farmers therefore base their decisions to practise mixed enterprise combination mainly for the purpose of obtaining manure for the maintenance of soil fertility (POWELL, 1986).

Moreover, to ensure an availability of animal power, "TRACTION" is viewed as an important factor in farmers' decisions to adopt crop-livestock enterprise combination. In the fragile region of Zamfara there are few trees coupled with sandy soils. Farmers lack access to motorised tractors. The local available alternative is animal draught power. The possession of animals such as bulls is very important to facilitate the conduct of some farm operations. Draught animals play a significant role in farmers' decisions to adopt crop-livestock enterprise combination as a production practice.

Farmers obtain income from products such as crops, and animal by-products including milk and meat. The desire for higher income is seen as very crucial in farmers' decisions to combine crops with animals. The variable "MOREINCO" captures that desire. Several studies (FOLTZ and CHANG, 2002; KHANNA, 2001; ADESINA and ZINNAH, 1993; ZUREK *et al.*, 2000; BURTON *et al.*, 2003; SAHA *et al.*, 1994; CAMERON, 1999; AKINOLA, 1987; KEBEDE *et al.*, 1990; SHIYANI *et al.*, 2002; ERSADO *et al.*, 2003) justify farmers' desire to increase income as an incentive for increasing production. New practices are thus geared towards higher

yields and income and it is believed that farmers will be willing to adopt a practice that has the potential of increasing their income.

Table 7.1: Dependent and independent variables in the model for crop-livestock enterprise combination under single management.

Dependent Variables	Model Description	
Crop-livestock adoption	Probability of adopting crop-livestock enterprise combination under single management for soil management	
Yields of crops in crop-livestock enterprise	Yields of crops per hectare in grain equivalents	
Independent Variables	Variable description	Type variable
Socio-economic reasons	Family size of the respondent (FAMLSIZE) Traditional practises of the respondent (TRADITION) To meet the food need of the respondent (FOOD) To enable the respondent save (SAVINGS) To enhance the availability of manure (MANURE) To ensure animals for traction power (TRACTION) To guarantee more income (MOREINCO).	Numeric Dummy Dummy Dummy Dummy Dummy Dummy
Inputs used for crop production	Labour expended on crop production Input expenses on crop production Predicted probability of crop-livestock enterprise combination participation	Numeric Numeric Numeric

7.2 Determinants of the decision to participate in crop-livestock enterprise combination

In unmasking the factors that determine households' participation in adopting crop-livestock enterprise combination, it is anticipated that certain socio-economic factors and inherent characteristics are key predictors for the adoption. They are key factors influencing the adoption participating process of the households. Since the data set used here is fairly large, the Probit model is the most suitable option for testing the factors that determine the decisions of farmers. The explicit form of the Probit model estimated is stated as follows:

Pr(Agropastoralism) = f(FAMLSIZE, TRADITION, FOOD, SAVINGS, MANURE, TRACTION, MOREINCO). ……(7.1)

In the second step, the OLS was adjusted to the selectivity bias by using the estimated probability of crop-livestock enterprise combination to determine the impact of the participation. The results are presented in the sections below.

7.2.1 Determinants of the decision to participate in crop-livestock enterprise combination in Dumburum-Shamushalle.

Table 7.2 below presents the results of the Probit estimations of the factors significantly influencing the decisions of farm households to participate in crop-livestock enterprise combination under single management. The Probit model predicts about 65% of the observations, with a chi-square significance of 14.90. Four out of the seven variables have coefficients that are significant. They are positively associated with the probability of adopting crop-livestock enterprise combination. The size of the farm household was found to be highly significant at the 1% level of probability and this is very understandable given the fact that the combination of the two enterprises, crops and animals, requires a lot of labour. The larger the size of the family is, the greater is the tendency and the capacity of the household to adopt a crop-livestock enterprise combination. Families of large size will provide the much needed labour to facilitate cropping and animal husbandry under single management.

The traditional way of life of these farmers is to keep livestock. This will ensure the availability of animals for the Muslim festival celebrations. The desire to have animals for festival celebration is paramount in farm households' decisions to adopt both crop and livestock.

The desire for animal traction to facilitate farm operations is considered important in farmers' decisions to adopt crop-livestock enterprise combination as a viable production practice in the area. These farmers are generally poor and cannot afford tractors. Having working bulls proves to be a good substitute for mechanized tractors. The desire for draught power to work on the farm was almost significant and this factor will encourage farmers to adopt the production practice of mixed farming with crops and animals.

In the same vein, the desire for more income from both crops and animals is a strong motivating factor encouraging farmers to adopt crop-livestock enterprise combination. Hence, the desire for more income will serve as a motivating factor for the adoption of crop-livestock production enterprise combination.

With relevance to our study objectives, it was found that manure availability is positively correlated and statistically significant in explaining farmers' adoption of crop-livestock enterprise combination. This is because farmers believe that keeping animals along with cropping will guarantee them access to manure for cropping.

As shown in Table 7.2, savings are negatively associated with adoption. This is not surprising, since farmers in this area are closer to the main motor roads. They participate very well in trading; they may have no need to save but rather trade with their cash income. Therefore, as a motive for adopting animal husbandry, they will rather want to use available fund to boost their off-farm trade at off-seasons.

Lastly, the motive of food provision is not significant but positively associated with crop-livestock enterprise combination. Food provision as a motive will therefore encourage farmers to adopt, since the adoption will help them to have more food and equally shore up the family's nutritional needs.

Table 7.2: Results of the Probit model for the adoption of crop-livestock enterprise combination in the Dumburum-Shamushalle zone

	Probit Model		
Variables	Coefficients	t-ratio	P-value
Size of the household	0.053*** (0.018)	2.93	0.003
Traditional way of life of the people	0.68* (0.41)	1.65	0.098
Availability of more food	0.19 (0.44)	0.43	0.66
As means of saving	-0.27 (0.41)	-0.65	0.51
Availability of manure for crop	0.68* (0.34)	2.01	0.05
Availability of traction power	0.59 (0.41)	1.46	0.14
Additional income for the farmer	1.10*** (0.36)	3.02	0.003
% Correctly predicted = 65.14 Model CHI-SQ = 14.90* Log likelihood function =-67.99 N = 109			

*, * *, * * * = Significant at 10%, 5% and 1% levels respectively
Number in parentheses is standard deviations. Source: own data, 2002.

7.2.2 Determinants of the decision to participate in crop-livestock enterprise combination in Ajja-Tsabre

Table 7.3 presents the results of the Probit estimation influencing the decisions of farm households to adopt the crop-livestock enterprise combination practice in the Ajja-Tsabre area. The Probit model correctly predicts 60% of the observations, with a chi-square significant of 5.13. Three of the seven variables have coefficients that are significantly different from zero and are positively associated with the probability of farm households to adopt the crop-livestock enterprise combination practice under single management in this region. In Ajja-Tsabre, the household size was also an important factor in farmers' decisions to possibly adopt the crop-livestock practice, because of the high level of labour required to run the combined farm business. Labour is required for both crops and animals and family labour is the most important component of farm labour. The bigger the size of the family, the more labour is available for farm works.

The traditional production requirement of having animals to celebrate Muslim festivals also drives the desire to adopt crop-livestock enterprise combination as a farm practice in this area. However, in contrast to the Dumburum-Shamushalle zone, desires for more food now play an important role in the farm households' decisions to adopt crop-livestock enterprise combination. The traditional food of the people in this area is millet, usually processed into a porridge called "Fura" and eaten with fresh milk called "Nono". The inclusion of livestock in the farm business along with crops will enhance the ready availability of milk needed for consumption. It ensures the nutritional values of the people. Also, the fact that these households are distant from any known markets makes the purchase of other sources of protein impossible. Milk in processed forms can be found in Dumburum-Shamushalle. The importance of milk from own animals for the nutritional needs of households in this zone is of great significance. The desire for more food for the family will further encourage the decisions of farm households to adopt crop-livestock enterprise combination. Saving fund was, however, found to have no significant relationship to the adoption.

The desire for more income is almost significant and positively associated with the crop-livestock enterprise combination practice. Therefore, keeping animals as part of farm business will help farmers to increase the household income.

Finally, the desire for animal traction power is found to be also significant in farmers' decisions to adopt crop-livestock enterprise combination. It shows the importance of traction power in farm production activities in the area.

Table 7.3: Results of the Probit model for the adoption of crop-livestock enterprise combination in the Ajja-Tsabre zone

	Probit Model		
Variables	Coefficients	t-ratio	P-value
Size of the household	0.33* (0.17)	1.94	0.052
Traditional way of life of the people	0.59* (0.35)	1.66	0.098
Availability of more food	0.63* (0.41)	1.58	0.115
As means of saving	-0.20 (0.38)	-0.53	0.60
Availability of manure	0.38 (0.31)	1.200	0.230
Availability of traction power	0.70* (0.36)	1.97	0.048
More income for the farmer	0.41 (0.30)	1.38	0.169
% Correctly predicted = 59.98 Model CHI-SQ = 5.13* Log likelihood function = -79.41 N = 119			

*, * *, * * * = Significant at 10%, 5% and 1%level respectively.

Number in parentheses is standard deviations. Source: own data, 2002.

7.2.3 Determinants of the decision to participate in crop-livestock enterprise combination by all farm households

Models with limited dependent variables usually require a larger number of observations, to ensure better results (GREENE, 1997). For this reason, the model estimation involved pooled data for all farmers for the purpose of ensuring best results. The Probit model shows that all factors with the exception of traction power are significant in influencing the decisions of farm households to adopt crop-livestock enterprise combination. The Probit model correctly predicts 60% of the observations, with chi-square significance of 13.33. Six of the seven variables estimated were found to be significant. The implication is that data pooling lead to improved results. It can be shown that all the variables, taken together, collectively display decisions to participate in crop-livestock enterprise combination as a strategy to increase soil fertility. It has been discovered that in the process of farmers trying to improve the fertility status of their soils, they also fulfil other notable objectives such as traditional religious duties, meeting food

needs, meeting manure needs, as a form of savings, meeting farm power needs and increasing the general level of their income.

Table 7.4: Results of the Probit model for the adoption of crop-livestock enterprise combination by all farmers in the study area

	Probit model		
Variables	Coefficients	t-ratio	P-value
Size of the household	0.040*** (0.012)	3.41	0.0007
Traditional way of life of the people	0.50* (0.27)	1.84	0.066
Availability of more food	0.50* (0.24)	2.08	0.038
As means of saving	0.53* (0.25)	2.14	0.033
Availability of manure for crops	0.54* (0.26)	2.22	0.027
Availability of traction power	0.42 (0.27)	1.55	0.12
More income for the farmer	0.61*** (0.24)	2.59	0.009
% Correctly predicted = 60.09 Model CHI-SQ = 13.33* Log likelihood function = -151.29 N = 228			

*= Significant at 10% level, ** = Significant at 5% level, *** = 1% level.

Number in parentheses is standard deviations.
Source: own data, 2002.

7.3 Impact of the adoption of crop-livestock enterprise combination on crop productivity

Having established the determinants of farm households' participation in the adoption of crop-livestock enterprise combination, the next step is to investigate the impact of the adoption on crop productivity. This was achieved by computing the probability of participation for all sampled households so as to prevent biasing the estimate. The probability is obtained from the estimated Probit model for the two zones and for the total number of observations. The decision whether farmers' participation in crop-livestock enterprise combination will influence the farmers' crop productivity is the required hypothesis to be tested. The explicit form of this model is stated below:

Yields =f (Input expenses, PTLU, Labour)* .....(7.2)

Equation 7.2 means that the yields of crops are a function of the expenses on inputs used, the probability of a farmer possessing livestock and the labour expended on crop production by the farmer. The decision to look at the impact of the adoption on crop productivity is born out of the belief that the farmers are rational decision makers who will only participate in adoption if the practice in question has a positive influence on their crop productivity and income (see equation 7.2).

7.3.1 Impact of the adoption of crop-livestock enterprise combination on crop productivity in Dumburum-Shamushalle

As shown in Table 7.5, all three variables in the estimate play very important roles in crop yield and productivity. Two of the three variables, labour and the probability of the farmer participating in crop-livestock enterprise combination are positively associated with crop yields. This means that these variables were instrumental to yield increase of crops among the agropastoralist group in the study area. The variable, expenses on inputs, has a negative sign. The observed coefficient is contrary to intuition implying that the more a farmer spends on inputs, the lower are the crop yields. A negative sign for this variable might be attributed to the fact that certain inputs were used in quantities above the agronomical optimal required level. It means that instead of additional input expenditure contributing to production, it rather leads to yield decreases. It can be concluded that production expenses were used beyond the threshold levels and hence diminishing returns to expenses have resulted. However, the participation of the farm household in crop-livestock enterprise combination is significant at the 1% level of probability, showing the importance of this particular variable to increase sustainable crop productivity. The keeping of animals alongside with crops has become a usual way of securing manure for crop production. The variable labour is significant at the 10% level of probability and reinforces the conviction that a labour increase improves yields.

Table 7.5: Results showing the impact of crop-livestock enterprise combination on crop productivity in the Dumburum-Shamushalle zone

Dependent Variable	Mean	Standard deviation	
Yields of crops in grain equivalents	*1916.4*	*1102.61*	
Explanatory Variables	Coefficients	St. error	t-statistic
Constant	0.73	0.29	2.54*
Input expenses	-0.02	0.033	-0.47
Probability of crop-livestock	1.08	0.21	5.27***
Labour used	1.09	0.43	2.54*
R-square = 0.22 R-adjusted =0.20 F-statistic =9.84 *** N = 109			

*, **, *** = Significant at 10%, 5% and 1% respectively
Source: own data, 2002.

7.3.2 Impact of the adoption of crop-livestock enterprise combination on crop productivity in Ajja-Tsabre

The estimates from the Ajja-Tsabre zone equally show that two out of the three variables in the regression play an important role in farm households' crop yields. Whereas the estimated coefficient for input expenses is negative in Dumburum-Shamushalle, it is positive for Ajja-Tsabre as shown in the table. Table 7.6 shows that productivity is a function of input expenses and as one uses more expenses on inputs, the productivity, all things being equal, increases progressively. The probability of farm households' participation in crop-livestock enterprise combination was also positively associated with crop productivity and shows that the participation of farm households in this practice increased soil fertility and hence crop yields. The coefficients of both input expenses and farm household's participation in crop-livestock enterprise combination were significant at the 1% and 10% level of probability respectively. This means these variables are important to the production levels of farmers in the study area. In contrast to the Dumburum-Shamushalle zone however, labour was found to have a non-significant negative coefficient. In this zone, motorways are located very far away and the likelihood of labour migrating to bigger towns is remote. The supply of labour is much higher in the Dumburum-Shamushalle zone in comparison to the Ajja-Tsabre zone where labour might have been over-utilized.

Table 7.6: Results showing the impact of crop-livestock enterprise combination on crop productivity in the Ajja-Tsabre zone

Dependent Variable	Mean	Standard deviation
Yields of crops in grain equivalents	*1549*	*912.24*

Explanatory Variables	Coefficients	St. error	t-statistic
Constant	1.08	0.28	3.88***
Input expenses	0.20	0.038	5.14***
Probability of crop-livestock	0.35	0.18	1.99*
Labour used	-0.25	0.47	-0.53
R-square = 0.21 R-adjusted = 0.18 F-statistic = 9.88*** N = 119			

*, **, *** = Significant at 10%, 5% and 1% respectively
Source: own data, 2002.

7.3.3 Impact of the adoption of crop-livestock enterprise combination on crop productivity among all agropastoralists in the study area

The overall impact of farm households' adoption of enterprise combination on crop yields and productivity is estimated by pooling all data for the two zones. It is found that all the three variables play an important role in farm household crop yields and productivity. All three variables, input expenses, adoption of crop-livestock enterprise combination and labour expended on crop production are positively associated with an increase in crop yields. All estimated coefficients are also equally significant. While input expenses and labour coefficients are significant at the 10% level of probability, it is very interesting to note that the probability of crop-livestock enterprise combination, which is the main subject of our investigation, is highly significant at the 1% level of probability. It shows without doubt that crop-livestock enterprise combination is an important means of generating manure for the purpose of soil fertility maintenance in the Zamfara grazing reserve.

Table 7.7: Results showing the impact of crop-livestock enterprise combination on crop productivity for all agropastoralists in the study area

Dependent Variable Yields of crops in grain equivalents		Mean 1724.7	Standard deviation 1022.18
Explanatory Variables	Coefficients	St. error	t- statistic
Constant	0.78	0.21	3.74***
Input expenses	0.06	0.03	2.33*
Probability of crop-livestock	0.74	0.14	5.25***
Labour used	0.83	0.33	2.51*
R-square = 0.13 R-adjusted = 0.12 F-statistic = 11.33*** N = 228			

*, **, *** = Significant at 10%, 5% and 1% respectively
Source: own data, 2002.

7.4 Summary

In this chapter, various variables that were used in the estimation of the adoption of crop-livestock enterprise combination as well as the impact of the adoption on crop productivity were presented. The results showed that out of the seven variables estimated for crop-livestock enterprise combination under single management in the Dumburum-Shamushalle zone, five coefficients were statistically significant meaning that these variables are instrumental in explaining the adoption behaviour of farmers in adopting crop-livestock enterprise combination. These variables include: the household size, the tradition of the farmers, the availability of manure for cropping, the availability of traction power for farming and higher income generation for the household.

The results from Ajja-Tsabre showed that the size of the farm household, tradition, the availability of more food and the availability of traction power for farming activities are the four main driving forces motivating farmers to adopt crop-livestock enterprise combination. Even though manure is not significant, it is positively correlated with adoption probability and income generation for the farm household. However, when the entire data was pooled together, it was found that all the variables are important in explaining farmers' adoption behaviour.

On the impact of the adoption on crop productivity, it was found that the adoption of crop-livestock enterprise combination is an important factor in farm productivity in the Zamfara grazing reserve. It was also observed that the three variables: adoption of crop-livestock, input expenses and labour, are important in crop productivity. The bottom line of these results underscores the importance of manure as a soil fertility maintenance medium in the study area.

8 THE FARM LEVEL BIO-ECONOMIC (FLBEM) MATHEMATICAL PROGRAMMING MODEL

Econometric models which evaluated factors driving farmers' participation in the two soil fertility maintenance practices adopted by farmers in the Zamfara grazing reserve have been presented in chapter six and seven. In this chapter, a farm level bio-economic model is introduced. The model is presented in GAMS format. In the GAMS format, the objective function and the associated constraints underlying the approach are presented. The mean values of the parameters estimated in the previous statistical analyses will serve as empirical components of the objective function and the model is based on outlined constraints. As a general principle in most programming modelling, four basic feature elements can be identified with the model. They are: the objective function, the various activities, the constraints of the optimized problem, and a matrix of technical coefficients. In this chapter, the four elements are presented in line with GAMS code formulation.

8.1 Overview of key variables and parameters in the model

All variables, parameters and scalars are presented as basic components of the mathematical programming model. Before a detailed discussion of the modelling process, we first proceed to clarify all variables in relation to the model. The detail explanations of the variables used are stated in Table 8.1 and expressed in GAMS code format. The variables are accordingly categorised into their respective endogenous and exogenous components. The endogenous variables of the model include:

- The crop revenue and the net revenues per year and per household.
- The total area presently cropped, assuming all farmers are croppers in the reserve area.
- The total area presently cropped, assuming that all farmers are agro-pastoralists
- The monetary values of gifts given to the herders for manure voided by their herd during contract participation.

In the case of agropastoralism, additional endogenous variables included are:

- The labour available for livestock
- The manure produced by own animals within the farm enterprise
- The costs expended on livestock production.
- The quantity of manure obtained by croppers from manure contract participation

- The sustainability of manure contracting as a means of soil fertility management
- The extra revenue gained by croppers for participating in manure contracting
- The total biomass produced by the pastures in dry matter (DM)
- The number of contracts that could possibly be based on the livestock-croppers ratio.

The farm level bio-economic model is essentially a static model, based on one off-time period. However, some dynamism is introduced to ascertain what will happen if an expansion of the farming area and with that the consequent deforestation over a period of ten years occurs. Two farm practices for soil fertility maintenance based on agropastoralism and a manure contract exchange system are introduced. The time "t" is appended to some endogenous variables as well as some parameters, which shows the implications of an annual variation of these variables over a period of ten years.

Parameters, matrixes, and scalars that are exogenous are given special notation in the model. They have been derived principally from the field study database and from the averages of statistical analyses. Such parameters included the crop yields, the quantity of crop residues, the prices of outputs and of labours, the amount of land available; the minimum manure needed for crop production; the prices of seeds, the livestock numbers needed for contract, the total pasture area and the total livestock population in the grazing reserve.

Most of the scalars are exogenous to the model, and they have been obtained from the results of the field study in addition to figures adopted from relevant literature.

Table 8.1: List of variables, parameters and scalars in the model

GAMS code	Interpretation	Unit of measure	Status in model
Variables			
CROPREV	Crop revenue	Naira/household	Endogenous
CROPNET	Crop net revenue	Naira/household	Endogenous
RESIDP	Crop residues production	Kg	Endogenous
AREACROP	Area presently cropped	ha	Endogenous
WORKSOLD	Work done outside farm	Naira	Endogenous
VALUEGT	Value gift to herder for manure	Naira	Endogenous
MANUCONT	Manure gained from contract	Kg (DM/FM)	Endogenous
RCMANUST	Sustainability of manure contract	ha	Endogenous
TBIOMAS	Biomass produced by the pastures	Kg	Endogenous
STOCKN	Livestock stocking rate	TLU/ha	Endogenous
CATTLU	Livestock after taxation	TLU	Endogenous
STOCKNT	Stocking rate change due to tax	TLU	Endogenous
LAND(t)	Change in land expansion over time	ha	Endogenous
PATCONS	Pasture consumed in dry matter	Kg	Endogenous
CONTOPP	Number of contract possible	-	Endogenous
Parameters			
Yields(c)	Crop yields with manure	Kg	Exogenous
Residuy(c)	Crop residues yields	Kg	Exogenous
Pout(c)	Prices of crop output	Naira	Exogenous
Labourc(c)	Labour requirement for crops	Man/hour/ha	Exogenous
Land(c)	Land available for croppers	ha	Exogenous
Dung(c)	Minimum manure required	Kg	Exogenous
Linum(mc)	Livestock number for contract		Exogenous
Dungv(mc)	manure voided per day	Kg	Exogenous
Pastur(mc)	daily pasture need per TLU	Kg	Exogenous
Pastutes	total pasture area	ha	Exogenous
Tax	Amount of tax imposed per TLU	Naira	Exogenous
Taxation	coefficient showing tax effect		Exogenous
Scalars			
Amlabour	labour available for activities	Man/hour	Exogenous
Labcost	labour cost	Naira/hour	Exogenous
Livpo	total livestock population	TLU	Exogenous
Pastarea	total pasture area	ha	Exogenous
Landh	land available to household	ha	Exogenous
Cggift	grain gift for contract	Kg	Exogenous
Avdcont	average day for contract	days	Exogenous
Housp	household population	person	Exogenous
Wksold	work done for money	Naira	Exogenous
Tohoush	total household in the reserve		Exogenous
Beta 1	annual population increase	%	Exogenous
Beta 2	annual rate of livestock growth	%	Exogenous
Beta 3	annual rate of livestock off-take	%	Exogenous
Inrla	annual pasture encroachment	%	Exogenous

8.2 The objective function of the farm level bio-economic model

8.2.1 General presentation of the objective function

The objective function of the farm level bio-economic model involves the maximization of the household farm net income. Emphasis is also placed on the sustainability of the production practice farmers engage in and the long-term sustainability of the grazing reserve as a biodiversity bank subject to the relevant constraints. The net revenue is expressed as the gross revenues from the farm minus the main variable input costs, such as seeds, fertilizers, labour and manure from a contract with herders. There is a special reference to some variables as regards their availability in sufficient quantities. Determining the scale of the production of crops by farmers in the study area is a separate exercise. Variables include labour and the manure obtained from the manure contracts between the croppers and the herders. This is relevant because we assume that every cropper in the grazing reserve will produce only crops and rely on manure contract for soil fertility maintenance. The quantity of manure needed by farmers to cultivate the land area available for farming will exceed the quantity generated from the current level of contracting. A generalised objective function for the model based on the HAZELL and NORTON (1986) framework is presented as follows:

$$Maximize \qquad NFR = \sum_{j=1}^{n} c_j X_j \qquad \text{.....eq 8.1}$$

Subject to constraints:

$$\sum_{j=1}^{n} a_{ij} X_j \leq b_i \qquad I = 1, 2, \text{.....m}$$

$$X_j \geq 0$$

Where:

a_{ij} input and output coefficients
X_j level of cropping activities
b_i level of resources
c_j gross margins.

Gross margins are the averages of the net revenue from each crop as gross revenues minus labour costs, and other input expenses. The gross margin is determined within the model given all the necessary parameters. Land rent is not considered since land is not purchased and is still regarded as a communal property.

In line with the generalised mathematical formulation shown above, the objective function of this study can be expressed as follows:

Max Net Farm revenue = Gross revenue – Labour cost – Input expenses – Value of gift for manure contract + wage of family labour-sold.....(8.2)

The model is mathematically expressed as follows:

$$MAX\ NFR = \sum_{c=1}^{C5} price * SELLCROP_c - Labour *$$

$$Labour\cos t - Input * Cost - Gift * gift\cos t +$$

$$Family\,Lbour\,sold * Wagerate \quad .....(8.3)$$

Where, NFR stands for the net farm revenues. However, two categories apply, the farm with only crops and the other combining an animal enterprise with cropping. These two are considered separately and the equation relating to the latter is specified later in equation 8.5. There are five major crops grown in the study area, accounting for the observed summation from 1 to 5. However, the model decides on the input-output relationships as regards the best crop or crop combinations that will maximize the net income of the farmer. The various costs associated with production are explanatory. Labour, inputs and the values of gift exchange for manure are the major considered factors. It could be in the form of cash, when the farmer has no grain to exchange. Family members who can, also work to earn money from other farms. Such money is utilised to meet some urgent family needs when crops are not mature. The objective function for farm enterprises combining crop and livestock is as shown as below:

Max Net Farm revenue = Gross revenue – Labour cost – Inputs expenses – Value of gift for manure contract + Pricelivstock*Selliv + Pricemilk*Milk – Vetcost –Livlabour –Feedcost + wage family labour-sold ..... (8.4)

$$Max\ NFR = \sum_{c=1}^{C5} price * SELLCROP_c - Labour$$

$$* Labour \cos t - Inputs * \cos t +$$

$$\sum_{l=1}^{L3} price * SELLIV + \Pr icemilk * MILK$$

$$- Vet \cos t - Livlabour - Feed \cos t$$

$$+ Family\ Labour\ sold * Wage\ rate \quad .....(8.5)$$

In equation 8.5, we observe revenues coming from the animal sub-sector assuming animals are sold. These animals are cattle, sheep and goats. Costs usually incurred by animal production result from veterinary services, labour and

supplementary feeding. In this study however, only crop revenues are considered for the purpose of ensuring uniform comparison between contract croppers and agropastoralist producers.

8.2.2 Further discussions of equations in the model

Additional equations in the model are further enumerated in this section. Manure from contracts is the sum of all animals multiplied by the dung voided per day and the average number of days that the animals were camped on the farm. It can be stated algebraically as follows:

$$\text{MANUREQNT} = \sum_{l=1}^{L3} LIVESTOCK*dungvoid*averagedaycont \quad \ldots\ldots\ldots\ldots\ldots\ldots(8.6)$$

Three types of animals are considered in the equation. They are: cattle, sheep and goats. On the average, livestock camps for seven days during contract before animals move away from the farm. Herders sometimes get a bag of grain millet for camping the animals for the stated time period. Immediate pre-harvest contracts exist when there is an abundance of residues. Herders may not be further compensated under this circumstance because residues on the fields are considered enough rewards for manure voided through contracts. Because the time of the contract is far away from the cropping season, croppers may not be pressed for the manure at this period of the year. The demand for manure is higher when fields lack manure and the new cropping season is fast approaching. Herders involved in contract within this period graze their animals in the nearby bush and later camp them on farmers' fields overnight to void manure and urine to fertilize farmers' fields.

The total area under crop production is the average sum of land under each crop type multiplied by that crop and multiplied by the total number of households in the reserve:

$$\text{AREACROP} = \sum_{c=1}^{C5} LAND*crops*tohoush \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8.7)$$

Manure available from contracts must be greater than the manure needed for crop production:

$$\text{MANUCONT} \geq \sum_{c=1}^{C5} DUNG*crops \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8.8)$$

Manure is in this case a vital constraint to the level of crop production and the number of hectares put under production will depend on the quantity of manure yielded from the manure contract participation.

The total biomass produced by a pasture is obtained by multiplying the pasture area by the dry matter produced per hectare of pasture:

$$\text{TBIOMASS} = PASTAREA*drmpasturha \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8.9)$$

Various studies have given an estimated quantity of the dry matter produced by one hectare of pasture in the various savannah pasture grasslands and particularly in the Zamfara grazing reserve (SHÄFER *et al*, 1998). The total biomass produced

must be in range of the livestock requirements for pastoralism in the grazing reserve to be sustainable:

$$TBIOMASS \geq \sum_{l=1}^{L3} LIVESTOCK * pastufeed \quad \text{.....(8.10)}$$

As an evidence of the sustainability of the grazing reserve based on the current stock level, the biomass produced must exceed what the current livestock population in the reserve consumes:

$$\sum_{l=1}^{L3} LIVP*pasturcomsumed \leq TBIOMASS \quad \text{.....(8.11)}$$

Next, the total labour available must be greater than the labour requirement for crop production :

$$AMLABOUR \geq \sum_{c=1}^{C5} CROPS*Labour \quad \text{.....(8.12)}$$

For the crop-livestock farm, the total labour available must be greater than the labour used for crops and livestock together:

$$AMLABOUR \geq \sum_{c=1}^{C5} CROPS*Labour + \sum_{l=1}^{L3} LIVESTOCK*Labour \quad \text{.....(8.13)}$$

The total livestock population in tropical livestock units divided by the pasture area defines stocking rates. It is a measure of the number of cattle per hectare of pasture area:

STOCKN=Livp0/Pastarea .....(8.14)

The population of livestock in the grazing reserve is bound to be reduced if a livestock tax is introduced as stated below:

CATTLU=Cattle + taxation*tax .....(8.15)

The stocking rate per hectare will consequently be higher prior to the introduction of a livestock tax, and will tend to decrease after introducing the tax. This is an indication that tax instruments could be used to control the population and the stocking level in the grazing reserve. Taxation could in this way be used to scare away pastoralists coming as free riders.

For the manure contract to be sustainable, there must be an average of 16 ha of grazing land to 1 ha of cropped land. In the study area, we evaluated this with the following equation:

RCMANUST=pastarea/landtc .....(8.16)

The quantity of manure available from contract depends on the optimum number of livestock that could be available to cropper households for contracts. It depends on the population of livestock in the grazing reserve:

OPTCATE=Livp0/tohoush .....(8.17)

8.3 Additional constraints of the model

The major constraints of the model comprise inputs needed for the production of the group of commodities in question. In this particular study, the constraints to crop production income optimisation are manure contracts, serving as means of soil fertility maintenance to a group of farmers.
Another equally important constraint is labour. Also, the available land cannot be expanded. It will, however, be seen later that the most limiting factor is manure since land and labour available to these farmers are sufficient for their current production level. Assuming we have equal land distribution, it cannot even be exhausted due to shortage of manure for soil fertility maintenance. It has been observed from the model that farmers can manage the available labour to have six hectares cropped. However, land availability in the model is later relaxed to allow the possibility of farmers clearing more land from the forest. That has always been the case. Land is cleared and then later legalised through association with public officials. This allowed for an evaluation of the best alternative of the two practices of manure acquisition. The wilful prior clearing of fresh land in the grazing reserve, before seeking approval, is an indication that laws are ignored and far from being enforced. There may therefore be a necessity to appraise the production practices with a view to identifying which particular one will be good enough in meeting the farmers' needs as well as the protection of the grazing reserve from further encroachment.

8.4 Operationalisation of the farm level bio-economic model

As already has been explained, the farm level bio-economic model is specified in a GAMS format and solved as a linear programming problem using the MINOS solver option. The structure of the model is basically the same both for contract croppers and agropastoralists except that animals' sub-activities are included for the agro-pastoralists. Samples of the full versions of the models in GAMS format are presented in the appendix 1a. Five sets of crops are considered in the model. Farmers in general make choices about which of these crops to produce to realise an optimum net income.
In the model, land, labour and manure arising from contracting or from own animals are treated as the factor constraining levels of crop production. The assumption is that there is equal distribution of land among farmers. Later, land as a constraint is relaxed to simulate what will happen if farmers are allowed free access to cut down more of the grazing reserve for crop production. This is an interesting development since it was revealed during the field survey that, even though farmers are barred from taking land that has not been allocated to them, most of them are in the habit of wilfully taking land from the grazing reserve. The logic is that farm practices that reduce taking over more land from the grazing reserve will help in sustaining the grazing reserve.

8.5 Scenarios for policy simulations

The simulation analysis examines the impact of policy and also provides details on how changes in certain variables will affect production and the sustainability of the grazing reserve. The sustainability of production and the grazing reserve as a natural resource and biodiversity bank of high value is recognised. The essence of the scenarios is to answer the question what will happen if certain parameters are varied in the model. The model simulates the effects of an increasing number of manure contracts. Of critical importance are income and the level of production. The sustainability of manure contracts is based on certain criteria, such as:

- The income gains accruing to households with an increasing number of manure contracts.
- The sustainability of the contract based on the cropped area compared with pasture areas.
- The sustainability of the grazing reserve based on the production practices.
- The pasture biomass production versus the current levels of livestock and their feed requirements.
- The long term effect of agropastoralism on the grazing reserve
- Livestock taxation as a policy measure to control pastoralists' livestock population and curtailing agropastoralism in the grazing reserve.

This is aimed at serving as a basis for policy recommendations on how best to use the reserve to enhance sustainability in its management. Several scenarios are considered as follows:

8.5.1 Scenarios on the effects of an increasing manure contract volume on household income

Under this scenario, the effect of increasing the volume of manure generated through manure contracts on farm household income is simulated. With the limitation posed by manure availability, i.e. if all farmers are croppers and have equal access to land, farmers will not be able to put the total area currently available under cultivation with higher yields. It is expected that increases in manure volume generated through contracts will enhance production and hence income for the households.

8.5.2 Effect of an increase in manure contracts on the level of manure production and cropping activities

Since manure major is a limiting factor for soil fertility maintenance and crop production, it is expected that a progressive increase in the volume of manure as the level of contracts is increased will enhance the ability of the farmers to increase the cultivated area. Efforts will therefore be focused on what will happen to areas put under crop production by croppers if additional contracts are engaged in to increase the quantity of manure available. It will also be investigated if more crops will enter the solution as manure quantities are made available through increased contract participation.

8.5.3 Sustainability of crop production by manure contracting based on livestock population and the number of households

For the contracting to be adequate in supporting crop production in the grazing reserve on a sustainable basis, there must be enough livestock in the reserve to facilitate the exchange of manure for cropping. This will be the focus of this scenario. If there are enough livestock in the reserve to support the households can they live in the grazing reserve?

8.5.4 Sustainability of manure contracting based on the cropped area versus the pasture area

Various studies have revealed that for manure production to be sufficient for crop production, a required ratio of the area of pasture available for grazing animals producing the manure to the area available for cropping is assumed to be important (BREMAN and TRAORE, 1990). This will be the indicator used for ascertaining if the ratio of the current grazing area is adequate to support grazing that will enhance the production of sufficient manure for the cropping area.

8.5.5 Sustainability of the grazing reserve based on production practices

There are two production practices that are modelled based on the mode of the acquisition of manure for crop production. So far, we want to know which of the two production practices would be ecologically friendlier to the survival of the grazing reserve. The assumption is that the production practice that will limit the acquisition of more fresh forest for cutting down for the purpose of cropping would be friendlier and sustainable to the grazing reserve. This is because taking more land from the grazing reserve will lead to further deforestation, thereby reducing the biodiversity of the flora and the fauna of the grazing reserve.

8.5.6 Pasture biomass and the current level of livestock and their feed needs

A usual major concern in the management of grazing reserves has been the issue of the appropriate carrying capacity. Even though it has been argued in earlier

studies (WARREN and KHOGALI, 1991) that this problem is not so serious in the case of African pastures, there is a need to assess the biomass production in a particular range versus the livestock population. To see if the pasture biomass is sufficient to ensure healthy livestock, the sustainability of the grazing reserve comes under consideration. If we have a situation where there are more livestock than a pasture can support, that will be injurious to the livestock and pose ecological damage to the pasture system. The purpose of this simulation is to see if the present animal and pasture biomass production is adequate for sustaining pasture management.

8.5.7 Long term effects of continued agropastoralism in the Zamfara grazing reserve

The aim of this scenario is to assess what would be the long-term effect of a continued agropastoralism practice in the Zamfara reserve. It is generally believed that livestock grazes around the same radius and causes permanent damage and degradation. Agropastoralists have two objectives in mind, namely the production of food and economic crops, as well as the objective of getting crop residues for their livestock during off-seasons. For this reason, they always desire to have bigger farm sizes. In the Zamfara reserve, this will elicit the cutting down of more forest. Since the objective is to have a production system that will demand less land of the forest, a simulation is done to project the effect of a long- term practice of agropastoralism on deforestation.

8.5.8 Scenarios on different levels of livestock taxation for herders as a policy for maintaining a livestock-pasture equilibrium

It has always been argued that pastoralists are irrational, and thus each of them adds more stock to grazing land. This is especially the case when the pasture they use is a property of the commons such as the Zamfara reserve (HARDIN, 1968). There is also the tendency for an influx of more pastoralists with their cattle if not checked. Even though the Zamfara reserve may not yet be overstretched or overpopulated by livestock, it is always good to envisage what would occur and consequently have a policy option for controlling a perceived eventuality. The purpose of this scenario is therefore to see if taxation could correct the livestock population in the reserve.

8.5.9 Scenarios on different levels of taxation as an instrument for curtailing agropastoralism

It has been widely asserted by many authors that agropastoralism is a major problem leading to overgrazing and permanent degradation of grazing land or forests (THOMAS and BARTON, 1994). This is because the settled nature of this group of farmers makes them immobile and hence their animals graze repeatedly around the same area. The essence of this scenario is to see if taxation as an

instrument could be used to curtail this practice. It is hoped that a cattle tax, if introduced on every head of cattle owned by an agropastoralist, will have profound effects and prevent farmers from practicing agropastoralism in the grazing reserve.

8.6 Review of the modelling approaches employed for the study

In chapter three of this work, the literature reviews pointed to the fact that farm level bio-economic models have recently become popular in modelling agricultural production and their associated environmental concerns. Chapter five and eight highlighted the structure and methodology of FLBEM. The econometric models presented in chapter six and seven evaluated the farm practices farmers engage in the study area and the factors driving the adoption of these practices as well as their impact on crop productivity. The objective here is to maximize the net farm revenues under the two practices of soil fertility maintenance, bearing in mind their sustainability as well as the long-term sustainability of the grazing reserve.

As earlier explained, the model was run on a one static basis but an element of dynamism is introduced to ascertain which of the two practices will be less injurious to the long-term sustainability of the grazing reserve. From farmers' point of view, not cutting down more forest for crop production in the nearest future is essential. This is based on the premise that a practice that does reduce further deforestation will lead to the sustainability of the grazing reserve. To sustain the livestock in turn, manure contracts are established to sustain crop production in the area.

8.7 Summary

This chapter focused on the presentation of the farm level bio-economic model using a GAMS formulation approach. Relevant variables and parameters were presented. The objective function and the associated constraints were equally highlighted in GAMS language and notations. Some of the limitations of the approach were equally reviewed. Based on the programming model discussed, the results of the modelling as well as some scenarios are presented in chapter nine.

9 MODEL RESULTS AND DISCUSSION

As stated earlier, one of the objectives of this study is to evaluate the extent to which the current production practices would be most sustainable, in terms of both meeting the farmers' needs for a crop production increase and for grazing within the reserve. The outlined modelling procedures are used to simulate the effects of various policy scenarios in this chapter.

A scenario or a sensitivity analysis is usually carried out to see what will happen if certain parameters are repeatedly varied in a solved model. That is why it is sometimes referred to as "if analysis". Because we are interested in what the results will be if and when a parameter used as the basis for the scenarios, is varied.

The selected scenarios are geared towards appraising the potential of manure contracts in farm income as well as the sustainability of the practice for soil fertility maintenance. It equally attempts to analyse what changes would take place with regards to land use increment and farmers' involvement in additional contracts to generate more manure for cropping. The selected scenarios were aimed at evaluating the effects of manure contracting on crop production and environmental sustainability in comparison with crop-livestock combination in the study area. The basis for selecting indicators for the results and scenario analyses are enumerated below:

- Scenarios on the effect of an increase in manure contracts on farm household income and cropping activities.
- The sustainability of crop production by manure contracting based on livestock population.
- The sustainability of manure contracts based on cropped area versus pasture area.
- The sustainability of the grazing reserve based on production practices.
- The sustainability of the grazing reserve based on pasture biomass production and the current stock of livestock and their feed needs.
- The sustainability of the grazing reserve by contract based production.
- The long-term effects of agropastoralism on the grazing reserve.
- Scenarios on different levels of livestock taxation as a means of controlling the stock level of pastoralists in the grazing reserve.
- Scenarios on different levels of livestock taxation as a means of curtailing agropastoralism.

Since there are two major practices farmers engage in for soil fertility maintenance in the study are, efforts will be geared towards evaluating the most sustainable option. The objective here is to evaluate the prevailing farm practices with a view to determining the best option that is compatible with the farming system of the households and the conservation of the environment.

9.1 Impact of increasing manure contract numbers on household income

As can be shown in the model results, manure is the most limiting constraint to crop production. The objective therefore is to make a comparison between agropastoralist based cropping and manure contract based cropping. This is grounded on the premise that, as more manure is made available through contract increases, the cropping levels and subsequently the income gap between these two farm practices decline gradually. It is shown in the model that the income of a household participating in one manure contract is N78,127. This translates into an income of N40,649 per hectare. On the other hand, the income per household for an agropastoralist is N346,200. This equally translates into an income of N56,293 per hectare. If we consider the two incomes on a per person basis, the contract farmer will have an initial per capita income of N8,681 for a nine member household. On the other hand, the agropastoralist will have a per capita income of N24,728 based on a 14 member household. There is a provision for the minimum coarse grain requirements for household consumption in the model. It is 1080 Kg for the manure contract farmer based on the household population, while a value of 1680 Kg was assigned for the agropastoralist for the same reason. The model calculations ensure that these requirements are met before any cash products are considered. Millet satisfies the requirements for both groups. It is the most cherished grain among the Hausa and Fulani farmers and it matures early enough before other crops. For the contract farmers, the model allocated 1.06 ha to the production of millet while for the agropastoralists, it was 2.35 ha. The remaining land for the agropastoralists out of the maximum 6.15 ha is used for the production of cotton. For the agropastoralists, land rather than manure is the most limiting factor of production. In the case of manure contract based cropping, manure is very limiting, and hence only 0.863 ha of cotton will be produced, making the initial total production level 1.922 ha. These initial incomes are based on the two practices used by farmers in the study area for soil fertility maintenance as presented in Table 9.1 and Figure 9.1.

Table 9.1: Results showing the scenario on the effect of one manure contract on farm household income

Farm practices	Income per household (N)	Income per ha (N)	Income per person (N)
Manure contract croppers	78,127	40,649	8,681
Agropastoralists	346,200	56,293	24,729

Source: own analysis. 1US$ = N133.

From the model results in Figure 9.1, it can be seen that there is a considerable difference between the income of agropastoralists and that of manure contract farmers. This is due mainly to the large quantities of manure generated that enable agropastoralist farmers to cultivate larger farm sizes. It will be seen subsequently that given more manure from increased contracting, the contract based farming could be as good as that of the agropastoralists in terms of manure availability and accrued farm income. It could even be a better alternative from the environmental point of view, since it is environmentally friendlier to the grazing reserve. Because this group of farmers have no animals grazing on the same area of the reserve, but rather depend on pastoralists whose animals are migratory in nature. The migratory livestock is thus less destructive to the grazing reserve's ecosystem.

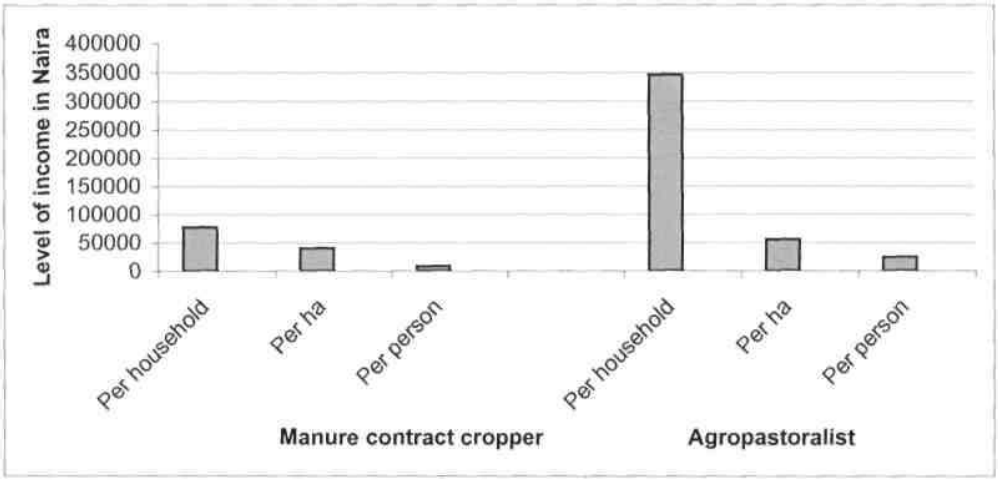


Figure 9.1: Income comparison between farming based on a single manure contract and agropastoralist farm practice

9.1.1 Scenario on the effect of croppers' participation in two manure contracts on household income

Using the income of croppers participating in one manure contract as a baseline scenario, three further increments in manure contract participation generating larger quantities of manure based on the overall population of livestock in the grazing reserve are considered. As seen in Table 9.2, farmers participating in two manure contracts will have a substantial increase in their income. The income level increased from the initial value of N78,127 for participation in one manure contract to N179,742 for participation in two manure contracts. The differences in income per person will also decrease considerably when compared with agropastoralists. It can be observed that there is a difference of just N4,757 between the income per person of manure contract participants and agropastoralists when the number of contracts is increased to two. The effect of this is that contract farmers have a good potential for crop production similar to

the practice of agropastoralists. They can participate in as many contracts to generate manure for cropping as they can afford. They have access to a larger number of animals than agropastoralists with smaller livestock sizes. Manure deposited *in situ* with urine is of better quality than manure that is spread out on the fields, containing no urine, which is common practice in agropastoralist systems. Therefore, participating in more than one manure contract is not only feasible but also of high benefit for the farmers. It probably needs some institutional arrangement such as a local legal framework that will formalise contracts, so that the default rate could be minimised. This would ensure the reliability and dependability of contracts as opposed to the prevailing informal arrangement, which is subject to flaws. There should also be a proper measurement of the volumes of the materials exchanged. Precisely, the exchange of a specified quantity of manure for a specified quantity of grain or cash should be based on verifiable calculated units of measurement. This will make manure contracting more attractive to both beneficiaries than it is presently.

Table 9.2: Results showing the scenario on the effect of two manure contracts on farm household income

Farm practices	Income per household (N)	Income per ha (N)	Income per person (N)
Manure contract croppers	179,742	46,723	19,971
Agropastoralists	346,200	56,293	24,729

Source: own analysis. 1US$ = N133.

Figure 9.2 shows that if croppers switch over to participating in two contracts, their income increases considerably. The gap between the income per person in the households of contract croppers and agropastoralists becomes so narrow that there is almost no difference in per capita household income for the two groups. It was also found that if the opportunity for contracts is adequately used in the study area, this could in particular help to satisfy the yearnings of these farmers for improved and sustainable production in the grazing reserve.

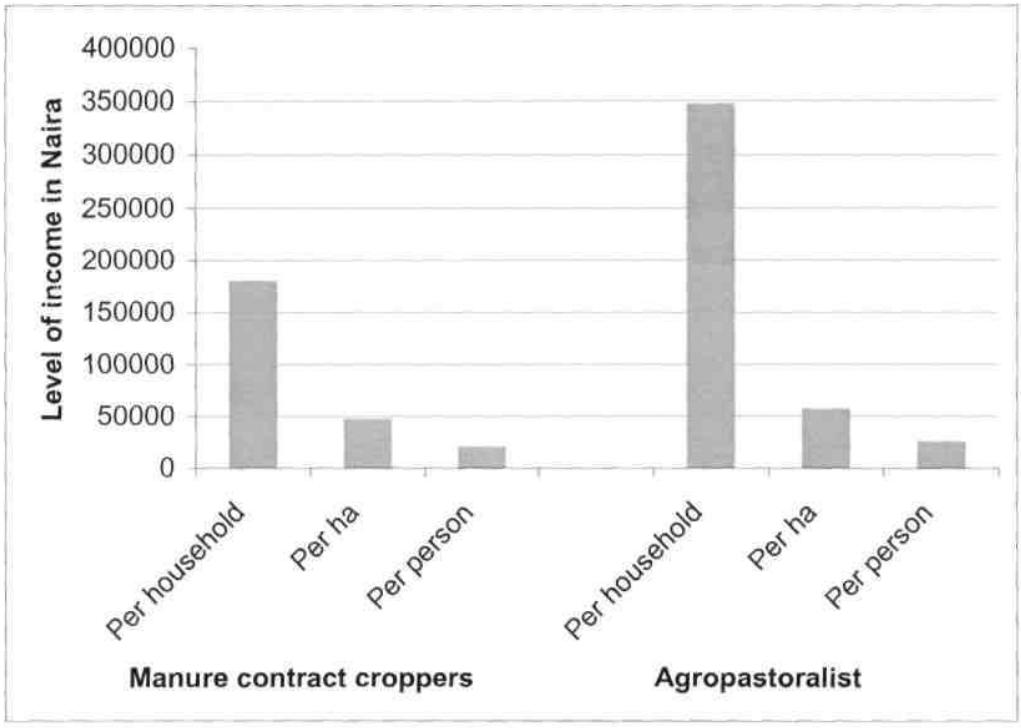


Figure 9.2: Income comparison between farming based on two manure contracts and agropastoralist farm practice

9.1.2 Scenario on the effect of croppers' participation in three manure contracts on household income

There is the possibility for farmers to participate in three manure contracts with the aim of securing more manure to fertilise their farms. This will further enhance the income of the croppers, which will increase from N179,742 per household for participation in two manure contracts to N218,356 if three manure contracts are engaged in. This is because the level of crop production will increase further, and consequently translates into higher income for the household. The income per person in the household, here, is higher at N31,262 when compared with that of agropastoralists, which is N24,729. It has been shown clearly that if the potential of manure is fully used, it could be a better alternative to agropastoralism. This is even so if contracts based on ecologically friendly grazing in the reserve are taken into consideration.

Table 9.3: Results showing the scenario on the effect of three manure contracts on farm household income

Farm practices	Income per household (N)	Income per ha (N)	Income per person (N)
Manure contract croppers	218,356	48,745	31,262
Agropastoralists	346,200	56,293	24,729

Source: own analysis. 1US$ = N133.

Looking at Figure 9.3, it is very clear that with the participation of croppers in three manure contracts, a farmer is able to rise his household income far above what would be obtained if engaged in only one contract. A contract also enhances the sustainability of the grazing reserve, since agropastoralism poses the danger of degradation to the grazing reserve. It will help eliminating farming without fertilization, which normally leads to frequent forest clearing and consequent degradation.

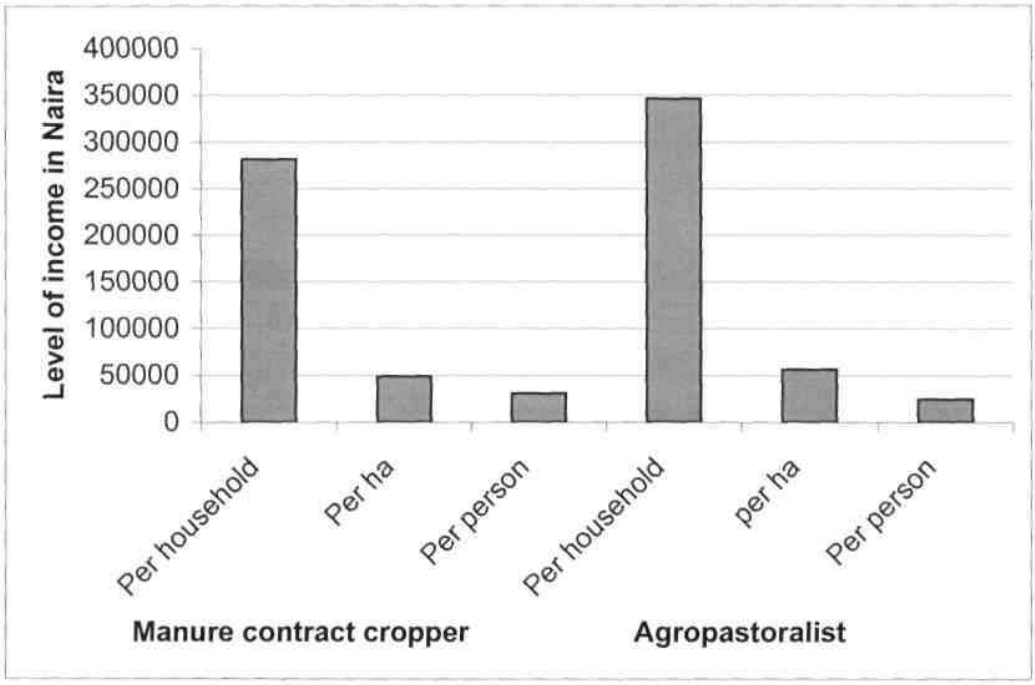


Figure 9.3: Income comparison between farming based on three manure contracts and agropastoralist farm practice

9.1.3 Scenario on the effect of croppers' participation in four manure contracts on household income

Finally, it can be deduced that farmers could have a maximum of four manure contracts, based on the total livestock number versus the total households within the grazing reserve. There is a potential of 210 tropical livestock units (TLU) for a farm household based on the total livestock population in the reserve. The question is what happens if a farmer picks a single herder each time he participates in four manure contracts? If a cropper is able and decides to use such an opportunity, he will be able to increase his income to the maximum possible under such arrangements. Then the household income will increase to N301,285. If the opportunity for contracting is used fully, it will have many positive impacts on production levels and income. For instance, household poverty will be reduced while also creating wealth for both the croppers and the herders in the grazing reserve.

Contracts could also be seen as a consequence of the availability of more manure for cropping. The gap between the income of croppers and agropastoralists becomes narrower. This shows that the practice could be an appropriate option for enhancing growth and alleviating poverty among farmers. Since the arrangement leads to substantial increases in soil fertility maintenance, land degradation could be greatly alleviated through the maximum utilization of grazing opportunities within the reserve. It is indeed the preferred option for intensifying production on the available land area as opposed to cutting more land from the grazing reserve, as is the case with agropastoralism. Manure contracting will help to restrict the undesirable situation of encroaching on the undisturbed lands within the grazing reserve.

Table 9.4: Results showing the scenario on the effect of four manure contracts on farm household income

Farm practices	Income per household (N)	Income per ha (N)	Income per person (N)
Manure contract croppers	301,285	48,989	33,476
Agropastoralists	346,200	56,293	24,729

Source: own analysis. 1US$ = N133.

The simulated results in Figure 9.4 further confirm that the income advantage accruing to the contract croppers becomes significant. The availability of more manure through multiple contracts will enable them to cultivate the maximum of 6.15 ha of land that could be available per household in the reserve, assuming all households utilise manure contract based farming.

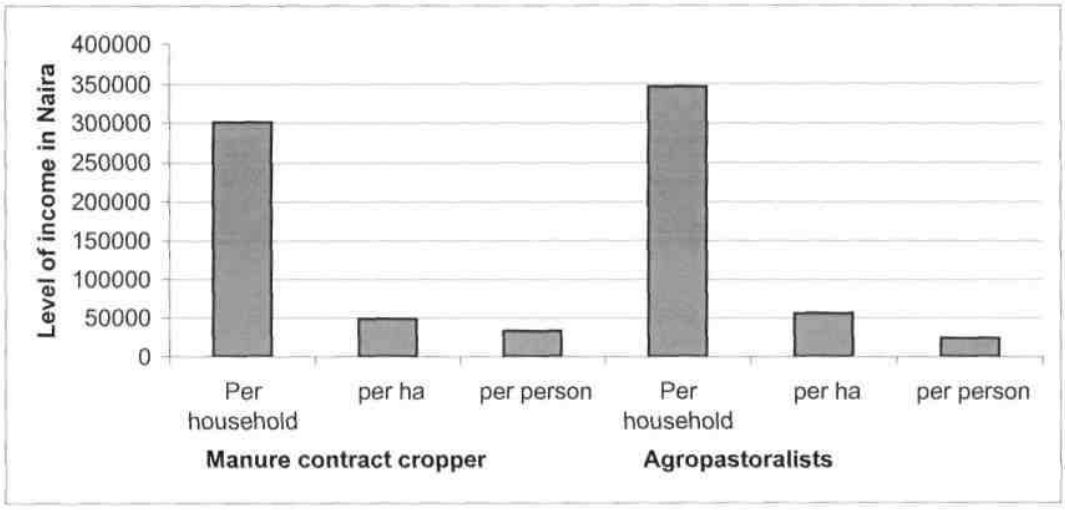


Figure 9.4: Income comparisons between farming based on four manure contracts and agropastoralist farm practice

9.1.4 Effect of manure contract increment on the level of crop cultivation

We have looked at the effect of increasing manure contracts and the subsequent increment on the inflow of manure on croppers' income. Subsequently, we proceed to assess the impact this increment has on the level of cropping. The impact is measured by the land area increment due to an increase in available manure to farmers. As earlier shown, the income increment was coming from the enhanced capacity of farmers to increase the current area under crop production with manure fertilization. Because the manure quantity available is the most critical and most limiting input for crop production in the study area, it is considered very important. As shown in Table 9.5, using the land area cultivated (when farmers participated in only one manure contract as the starting point), there is a progressive increment in the land area under cultivation. With only one contract, a farmer gets manure to cultivate 1.92 hectares and this could be increased to 3.85 hectares with two contracts. With three and four contracts, there will be an increase in the area of fertilized land up to 5.78 hectares and 6.15 hectares respectively. Farmers can fully exploit the opportunities for manure acquisition through contracts for crop production. It is to be noted that farmers will still be operating within the total available land that is already designated for farming activities and they will definitely not encroach on more lands from the grazing reserve.

We are assuming that the total land already designated for cropping is shared equally among all farmers. Provided that agropastoralism could be discouraged or reduced to the barest minimum as a production practice within the grazing reserve, the environmental situation may improve. That is why manure contract based crop production is suggested as the alternative pathway for intensification of the present cropping system in the area. It is the most viable way of enhancing

the sustainability of production as well as the sustainability of the grazing reserve. We can see in Table 9.5 the progressive increment in the quantity of manure that is generated, as the number of manure contracts increases from one to four. This will eventually lead to increments in the number of hectares cultivated by farmers and consequently to higher incomes for households. The results on Table 9.5 are also presented in Figure 9.5.

Table 9.5: Results showing the relationship between the number of contracts and the land area cultivated

Number of contracts	Hectares of land cultivated	Manure generated
1	1.92	1076.60
2	3.85	1615.60
3	5.78	2385.60
4	6.15	3155.60

Source: own analysis.
NB: The increment in the land added to the cultivated area with the fourth contract was less because the area designated for cultivation has been used up.

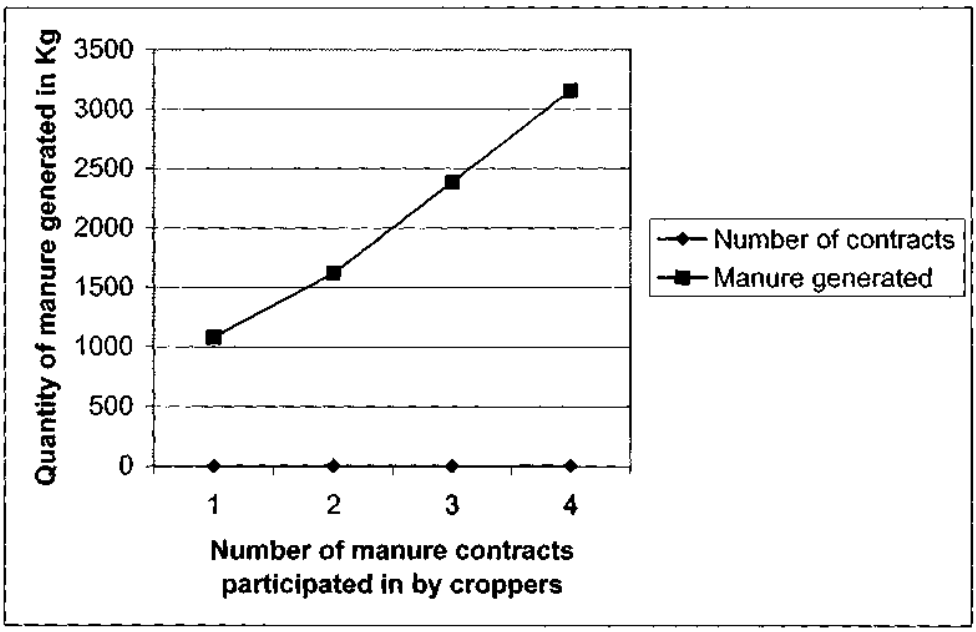


Figure 9.5: Relationship between the number of manure contracts and the manure quantity generated

9.2 Sustainability of crop production by manure contracting based on livestock population and the number of households in the grazing reserve

For manure contracts to become sustainable as a means of raising crop production in the grazing reserve, there must be enough cattle for contracting for cropper households in the reserve. The question here is, do we have enough livestock both resident and transiting through the reserve to sustain manure contracting for all croppers? Even though the present study was not aimed at providing an estimate of the livestock population in the grazing reserve, there are reports from previous studies that have been adopted for the purpose of our present study. In a study by SCHÄFER *et al.* (1998), the annual increment of livestock population was estimated to be around 41%, with an off-take of around 27%. It has been estimated that the current livestock population owned by herders will be around 250,928 in tropical livestock units (TLU). This figure is used in the model with the current household numbers in the grazing reserve. It is discovered that a household could have the opportunity of engaging in manure contracts with about four herders at the minimum rate of 50 TLU. This is considered adequate to generate enough manure for the average cropping of households in the grazing reserve. From the foregoing discussion, one can conclude that there is enough livestock in the grazing reserve to enhance sustainable crop production based on a manure contract arrangement. The above computations exclude the unaccounted quantity of urine voided during livestock camping on the farmers' fields. Urine is believed to have certain higher ammonium-based nutrients but is considered to be very volatile and could easily be lost. Nevertheless, Table 9.6 illustrates the sustainability of manure contracts for crop production in the study area.

Table 9.6: Results showing livestock population versus the croppers' household numbers in Zamfara

Livestock population in TLU	Household number	Livestock /household (TLU)	Minimum livestock for contract in TLU
250930	1190	211	50

Source: own analysis.

9.3 Sustainability of manure contracting based on the cropped versus the pasture area

It has been revealed by another study that there must be enough pasture area to enable livestock to consume and produce enough manure for cropping in a manure-based cropping system (BREMAN and TRAORE, 1990). BREMAN and TRAORE found in their study that for livestock being able to produce enough manure for sustainable cropping, a certain condition must be met. This requirement involves an average of 16 ha of pasture to 1 ha of cropland for the

Sahel area (BREMAN and TRAORE, 1990). For the northern Savannah, this is 10 ha of pasture to 1 ha of cropland, whereas 8 ha of pasture to 1 ha of cropland is the required ratio for the southern Savannah. The Zamfara grazing reserve is located in the Sudan and Sahel Savannah area of Nigeria and therefore the ratio of 16 ha of pasture to 1 ha of cropland is considered the applicable indicator. Using this criterion, it is found that whatever level the croppers are operating, there is more than enough pasture to serve the available cropping area. What these farmers need is tapping the available potential for production. The results for the pastureland versus the cropping area are presented in Table 9.7.

Table 9.7: Results showing the pasture and cropped area ratio in the Zamfara reserve

	Area in Hectares	Ratio pasture /cropland
Total pasture area	235500	
Area cropped	2287	103
Total Area available for cropping	7309.60	32
Normal pasture/cropland ratio for sustainable manure production (BREMAN and TRAORE, 1990).		16

Source: own analysis.

Our present study similarly uses the premise of BREMAN and TRAORE (1990), that a certain pasture-cropland ratio is required to enhance sustainability. As shown in Figure 9.6, the manure contract croppers are presently operating on 1 ha of cropland to 103 ha of pasture. This is more than six times the pasture area needed to generate sufficient manure for sustainable cropping. The implication is that, given enough livestock to graze and turn the biomass to manure, there is sufficient pasture to enhance the production of sufficient manure for cropping in Zamfara. It can, however, be seen in Table 9.8 that there are already enough livestock in the reserve to consume 76% of the biomass that is produced in the reserve. This is a very serious problem, since the pasture is not evenly grazed. That may be the reason for the substantial degradation that has occurred in the reserve in recent years. However, even if the total area currently allocated for farming is equally shared based on the manure contract practice, there is sufficient pastureland to successfully enhance manure contract based farming. Manure contract based farming is therefore preferred to agropastoralist based cropping since the herds under pastoralists used for manure contracts do not consistently graze on a portion of the reserve but rather around different portions. Such a situation will prevent the overgrazing of a particular portion that is always the case with agropastoralists. It should be noted that, since the animals of pastoralists migrate,

they also import nutrients from other locations such as the Runka forest to the Zamfara grazing reserve to further enrich its soil.

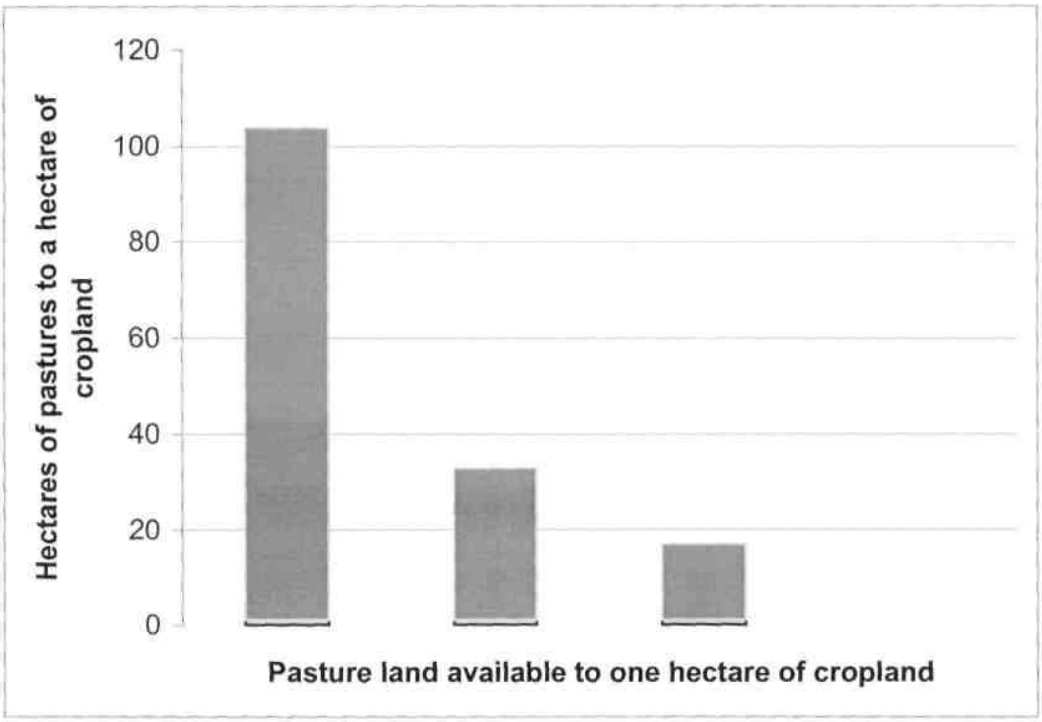


Figure 9.6: Pastureland area versus cropland area ratio in the Zamfara reserve

9.4 Sustainability of the Zamfara grazing reserve based on pasture biomass production and the current level of livestock

One of the major concerns of a grazing reserve is its ability to produce enough biomass to feed the animals that are kept in the reserve. The capacity to conveniently achieve this objective is not in doubt, since the grazing reserve has the ability to regenerate after a cycle of grazing. As shown in the model results, the Zamfara grazing reserve is producing very large quantities of biomass (Table 9.8). The current biomass production is far above the needs of the current livestock population. The livestock in the reserve is currently consuming about 686,921 tonnes of biomass out of the estimated 906,675 tonnes produced by the pasture in the reserve. This is based on the consumption of 7.5 Kg of dry matter pasture per animal per day. This shows that out of the substantial portion of the biomass produced annually, about 76% is consumed. Even though one could conclude that the current level of pastoralism in the Zamfara grazing reserve is still sustainable, the breakeven point is just about being attained. Increasing the stocking density of the grazing reserve must therefore be properly managed so as

to prevent overgrazing that could otherwise permanently damage the grazing reserve.

One can, however, infer from this result that there is presently sufficient pasture for pastoralists' herds in the grazing reserve. Enough pasture for grazing also means that the pasture situation can sustain manure contracting to generate the needed manure for cropping in the reserve. With sufficient pasture, it is expected that pastoralists' herds will be very productive from the viewpoint of manure production. More manure production will consequently enhance crop productivity in the grazing reserve. The fact that these animals migrate to feed at other locations also ensures that these animals import additional nutrients to the reserve. However, the stationary nature of agropastoralists' herds through their consistent grazing of pasture around homesteads is undesirable as they facilitate land degradation by rain and wind erosion. Degradation caused by animals in this category can consequently jeopardise the productivity of the reserve even in the short-run.

Woodcutting, on the other hand, is a very controversial issue in the Zamfara grazing reserve. The inhabitants of the enclaves in the Zamfara reserve depend on wood as an energy source for cooking and heating. As a rule, however, people are not allowed to cut down trees, except dead woods. Most of the respondents admitted that they get their fuel wood from dead woods in the grazing reserve. However, personal observations during the field work showed that some farmers indulge in cutting of trees for personal use. While the official of the forestry confirmed that there is heavy penalty for people caught cutting trees, he was unable to give an example of anybody that has been penalized in recent years for committing this offence. It could therefore be said that to curb degradation through the cutting of trees in the reserve, there is a need to properly monitor the activities of people within and around the grazing reserve.

Table 9.8: Results showing the total biomass produced versus the biomass consumed by livestock in the Zamfara grazing reserve

Total Biomass produced (ton) DM in the reserve	Total biomass consumed (ton) DM by all animals	Percent of total consumed
906675	686921	76

Source: own analysis.

Figure 9.7 shows the relationship between the biomass being currently produced in the grazing reserve versus the quantity consumed by livestock resident in the grazing reserve. From this result, we observe the need to control grazing and to ensure that a particular area is not overgrazed. The seasonal migration of livestock practised by pastoralists can further add some relief on the ability of grazed areas to regenerate and promote the sustainability of biomass production.

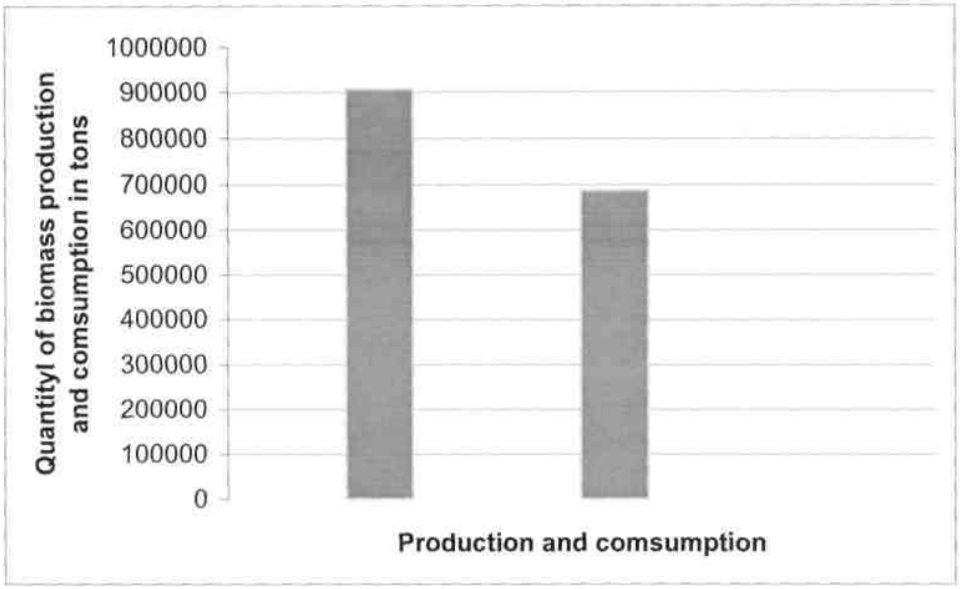


Figure 9.7: Biomass produced versus biomass consumed in the Zamfara grazing reserve

9.5 Sustainability of the grazing reserve based on production practices adopted

There are two practices adopted in the Zamfara grazing reserve to generate manure for the purpose of maintaining soil fertility. The indicator used here involves minimizing the extent to which new areas of the forest will be cut down for farming in the nearest future. That is given that any of the two practices adopted presently is chosen as the sole option for soil fertility maintenance. It has become common practice that, if these farmers are constrained by land resources, they wilfully cut more area of the forest before seeking approval from the concerned authority. So either of these two practices, manure contracts or agropastoralism, that will help in the minimization of the encroachment on the forest for cropping will be better appreciated for the grazing reserve. It will consequently be friendlier to the survival and sustainability of the Zamfara grazing reserve. The implication of each of these practices on the grazing reserve's sustainability was determined as follows:

The total area cropped presently available for all farmers in the grazing reserve, whether they are all contract croppers or all agropastoralist croppers, is:

$$AREACROP = \sum_{c=1}^{C5} LAND * crops * tohoush \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (9.1)$$

AREACROP = Area of land cultivated by all households which is first derived as a parameter within the model. This is the land devoted to crops cultivated multiplied by the total number of households.

Then, the yearly-cropped area over a ten-year horizon based on a certain annual increment using the RAMSEY (1928) growth model is given as:

*YAREACROP (t + 1) = AREACROP (t) + AREACROP (t)*pinrla.* ..... (9.2)
Where YAREACROP = the yearly land cultivated by contract farmers over a ten-year period

pinrla = the coefficient representing yearly land encroachment as a percentage of the current land cultivated, with a value of 0.03.
From equation 9.2, the RAMSEY model could be summarised in the following functional form:
$YAREACROP(t+1) = ARECROP(1.03)^t$ .....(9.3)
Where t = is the ten-year horizon under consideration (2001-2010).

9.5.1 Implication of manure contract based cropping on the sustainability of the grazing reserve

Using the RAMSEY growth model in a dynamic approach, we simulate what will happen as regards more land acquisition, assuming all farmers in the grazing reserve are manure contract croppers. For this purpose, we assume that farmers have equal access to land with manure contracts as a measure of soil fertility maintenance. We also assume that farmers expand their farm sizes by as much as 3% per annum. This is taking into consideration the extent of growth in land acquisition from the reserve over the past years. This growth in land acquisition also has a bearing on the annual growth of the population. It is discovered that if we use the level of land cultivated with just one contract opportunity, all households would have cultivated 2287 hectares of land available in 2001, translating into 1.922 hectares per household. Looking at this steady growth, the farmers would not have exhausted the land already designated for cropping by the year 2010. In fact, by 2010, only 2984.25 hectares of the 7310 hectares currently designated for cropping would have been put under use. It shows that the practice of manure contract based farming in the grazing reserve will put less pressure on the allocation of fresh land from the grazing reserve for cropping. The practice will equally enhance the gradual expansion of cropping in a sustainable way as the manure contracting expands gradually. That will consequently make sure that the increment in cultivated area is predicated on the availability of manure to maintain the farm. This practice will ensure that the degradation of land is greatly reduced to the barest minimum.

Table 9.9: Results showing the yearly progressive increment of land acquisition with manure contract based cropping

Years	Yearly land cultivated in ha	Yearly increment in ha
2001	2287.18	
2002	2355.80	68.62
2003	2426.47	70.67
2004	2499.26	72.79
2005	2574.24	74.98
2006	2651.47	77.23
2007	2731.01	79.54
2008	2812.94	81.93
2009	2897.33	84.39
2010	2984.25	86.92

Source: own analysis.

The question of what will happen if there is a gradual annual increment in farmers' land acquisition for farming is further depicted in Figure 9.8. It shows the change in land use between 2001 and 2010 in the grazing reserve. It further confirms that manure contract farmers will only add more land if there is more manure to fertilize such land.

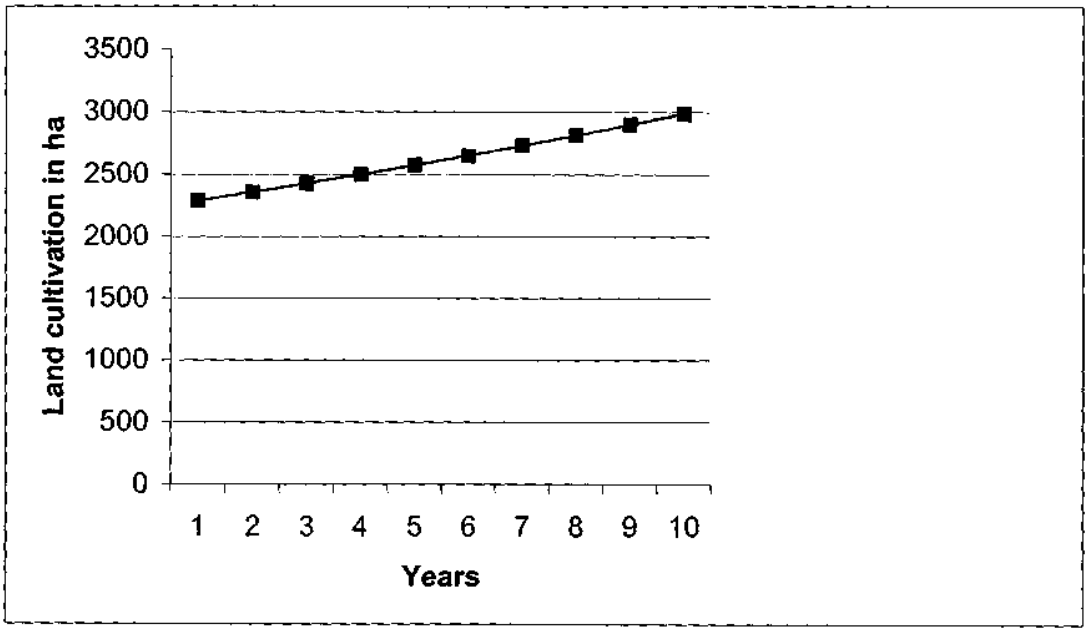


Figure 9.8: Simulated annual cropland increments under manure contract based cropping in the Zamfara grazing reserve

9.5.2 Implication of agropastoralism based farming on the sustainability of the grazing reserve

Also, using the RAMSEY growth model, the effects of agropastoralist farming systems have been examined with respect to the sustainability of the grazing reserve. The analysis is based on a period of ten years. Here again, it is assumed that every household practises agropastoralism and has equal access to land. We equally assume that the farm size of each household increases by 3% per annum. It should be recalled that this group of farmers have more access to resources like manure and labour that enable them to expand their farms from time to time. Consequently, their farm sizes are bigger than those of manure contract farmers. Larger farm sizes help them to meet the objectives of producing crops as well as crop residues for their animals. Looking at the land use changes of this group of farmers, and given their present scale of operation, all available land designated for cropping was exhausted by the year 2001. Subsequently, agropastoralists have started from 2002 to encroach on the grazing reserve to acquire more land for cropping. The rule that forbids taking more land for farming in the reserve is rarely obeyed. It has been alleged that people often wilfully take up land before seeking official endorsement, which is hardly refused.

Frequent land acquisition is a population driven problem and has also a lot to do with the farm practices adopted by the farmers. This phenomenon will continue as long as the population continues to increase and as long as the farmers continue to adopt some practices that encourage farm enlargement. The take-over of more land from the grazing reserve is much likely to be prevalent under agropastoralist practices. It will have a gradual damaging effect and eventually cause the obliteration of the grazing reserve. The implication is that at the end of the 10-year period, more than 30% of the current land under cultivation would have been added, to the detriment of the reserve. A perpetual deforestation and degradation of biodiversity is bound to continue as long as this practice is allowed to occur in the grazing reserve. Table 9.10 shows the progressive annual farming encroachment that will result if agropastoralism is allowed to be practised in the Zamfara grazing reserve.

Table 9.10: Results showing the yearly progressive increment of land acquisition for farming in an agropastoralist farming system

Years	Yearly land cultivated in ha	Yearly increment in ha
2001	7309.56	
2002	7528.85	219.29
2003	7754.71	225.86
2004	7987.35	232.64
2005	8226.97	239.62
2006	8473.78	246.81
2007	8728.00	254.22
2008	8989.84	261.84
2009	9259.53	269.69
2010	9537.32	277.79

Source: own analysis

In Figure 9.9, the simulation of the effect of annual farmland increments by agropastoralists is demonstrated. Farmers will begin to take more land from the grazing reserve, beginning from the year 2002. This implies that there will be more deforestation and degradation of the grazing reserve. If this is allowed, the forest will by and large become extinct. One could therefore infer that this type of farm practice will not ensure the sustainability of the Zamfara grazing reserve. It should therefore be discouraged as a production practice, so as to preserve the grazing reserve's biodiversity.

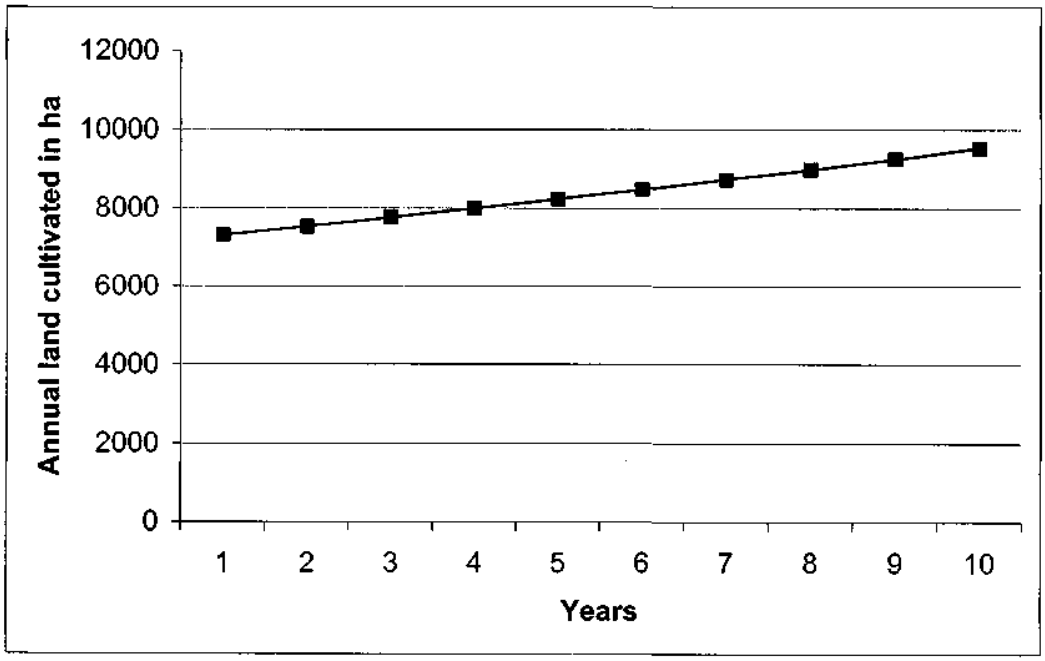


Figure 9.9: Simulated annual cropland increments under agropastoralism based cropping in the Zamfara grazing reserve

9.6 Consequences of allowing uncontrolled increase in livestock population in the Zamfara grazing reserve

There are many views about rural farmers being irrational in their behavioural approach to environmental issues, when it comes to an increase in the number of livestock on grazing land. The opinion is that herders in a common grazing land will continue to add to their flock, since they perceive that competitors will do likewise. It is reasoned that they will continue to do this until the pasture resources are overstretched (HARDIN, 1986, 1988). Some critics claim that this is an oversimplification, since the pastures in Africa are said to be resilient (SCOONES, 1995; TOULMIN, 1995; WARREN and KHOGALI, 1991).
However, it should be envisaged that overpopulation could occur if the stocking situation is not controlled. This perception will help us in visualising the development of a policy initiative that can be used in controlling such adverse situations as and when they occur. It is for this reason that we have projected into the future to see what happens if the livestock population is allowed to grow unfettered. Given the present annual increment and the off-take level of livestock in the Zamfara grazing reserve, problems are bound to occur. If we consider the present annual increment of 41% in livestock numbers and the sales of 27% per annum, a big growth in population is envisaged.
Using the estimated cattle population in the reserve, we equate:

$$Cattle = \sum_{l=1}^{L3} Livestock*(TLU)*tohoush \quad \ldots\ldots\ldots\

Table 9.11: Results showing the yearly natural growth in livestock population under uncontrolled growth conditions in the Zamfara grazing reserve

Years	Yearly stock population (TLU)	Yearly increment (TLU)
2001	250930	
2002	286060	35130
2003	326110	40050
2004	371760	45650
2005	423810	52050
2006	483140	59330
2007	550780	67640
2008	627890	77110
2009	715790	87900
2010	816000	100210

Source: own analysis

The simulation results of unfettered livestock growth in the grazing reserve are as shown in Figure 9.10. It confirms that there will be progressive growth in the population of livestock in the reserve through natural growth. This will lead to consequent overgrazing and degradation of the grazing reserve. The sustainability of the biodiversity bank of the flora and the fauna could be negatively affected. There is therefore the need to ensure a balance between the livestock population and the biomass production, so as to ensure the long-term sustainability of productive activities in the grazing reserve.

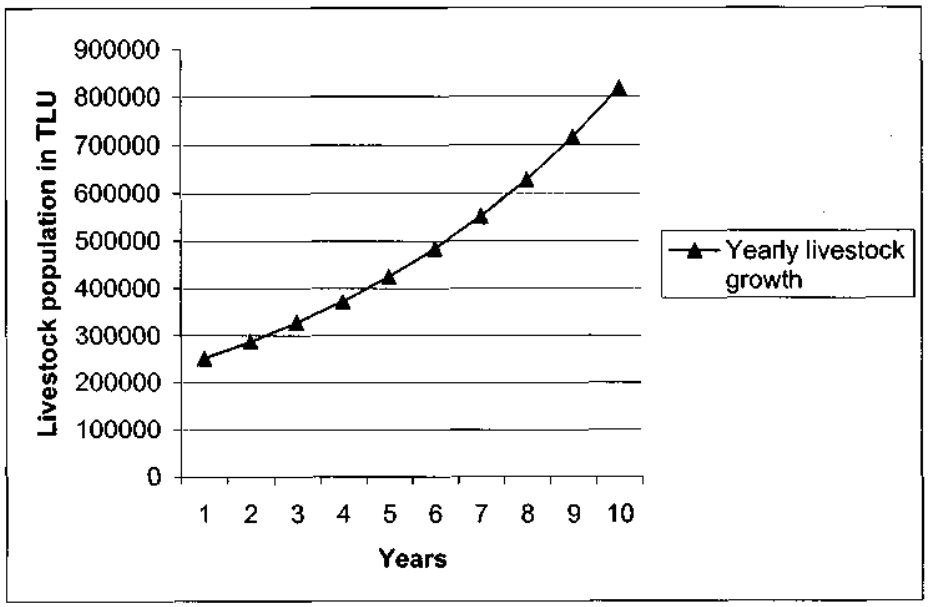


Figure 9.10: Projected yearly growth of livestock in the Zamfara grazing reserve

9.7 Scenarios on different levels of taxation as a policy measure to control overstocking and degradation in the Zamfara grazing reserve

Cattle taxation, popularly referred to in the Hausa language as "Jangali", is not new in Nigeria. What is really not clear is the motive for the collection (IRO, 2004). In most cases, the local governments collect taxes and the reason adduced is that these taxes are needed to provide market infrastructural facilities. There are a lot of resentments towards this taxation in most West African countries. The resentment is not really because the people hate paying taxes. But it is because tangible services and the maintenance or upgrading of marketing facilities are not provided, even if a substantial amount of money has been collected as taxes and levies. Some of the money is said to be ending up in the pockets of revenue collectors and the general municipal pool (HOLTZMAN and KULIBABA, 1996). As a result, livestock producers, traders and butchers resent these fees and evade paying them. The resultant effect is that private sector participants now view government agents as illegitimate extractors of fees or rents, rather than public agents committed to the servicing of private producers and traders. However, if tax revenues are returned to provide facilities that are physically feasible and have a positive impact on the life of producers, individuals would be willing to pay.

In the case of cattle taxation in a place like the Zamfara grazing reserve, herders should be educated in the protection of the reserve for sustainable livestock production. The purpose of educating herders in this policy is to create the awareness that the tax is not a punishment, but rather a regulatory measure aimed at preventing abuses in the use of the grazing reserve. It should be applied

because the degradation of pasture today will be a reduction in the future income of the herders. Since there are also intruders from other countries coming to the reserve as free riders, taxation as a policy instrument may help to keep such unwanted visitors away. Ensuring that important entry points to the reserve are properly controlled so that, herders coming from outside pay the required cattle head tax can be an alternative option. Enforcing the tax payment will keep free riders away from the grazing reserve. It could also help to curtail the practice of agropastoralism in the reserve.

An important question to be asked at this point is which categories of the actors in the reserve must be made liable to the cattle head tax? In effect, both pastoralist herders and agropastoralists must be made to pay cattle head tax since livestock from the two groups use the pasture resources in the grazing reserve. The herders coming from outside the reserve for periodic grazing should equally be made to pay for using the reserve as this will prevent unnecessary influx of herders from outside into the reserve. To demonstrate how effective this could be in checking cattle population within the reserve, the consequences of different levels of taxation scenarios on pastoralists' as well as agropastoralists' cattle populations are presented below.

Firstly, the total number of cattle belonging to all the agropastoralists is represented as:

$$Cattle = \sum_{l=1}^{L3} Livestock*(TLU)*tohoush \quad \ldots\ldots\ldots\

grazing reserve will also be in jeopardy if such growth is not checked. There may be a rapid influx of herders from other regions to the reserve. Bearing this in mind, taxation as a policy measure for stock level control has been simulated in the model. It is found that the stocking level, despite the high birth rate, could be regulated around the same level from year to year.

This will prevent overstocking and degradation that would result from it. From the model results, it is found that the stock level in TLU of herders' livestock decreases from 250930 to 244930, representing about 2.4% due to the introduction of a cattle head tax of N200. Consequently, there might be a decrease in the stocking rate from 1.07 TLU per hectare to 1.04 TLU per hectare due to the introduction of this tax. In fact, the amount of the tax could be varied to achieve the desired objectives. The various levels of tax scenarios are presented in Table 9.12. Cash proceeds realised from such taxation could be useful if utilized to provide watering points, road paths, market facilities and other infrastructure that may be of good use. This would help to improve the livelihood of inhabitants and producers in the grazing reserve. It could also help to achieve the objective of keeping the invading herders, particularly from the Niger Republic, away if strictly enforced. This is because herders from the Niger Republic might prefer sourcing from other grazing pastures than paying the tax to the Nigerian authorities for the use of the Zamfara grazing reserve. It will, above all, help in the protection of the grazing reserve's biodiversity. Since a tax will enforce a reduction of grazing, that could enhance the capacity of the pasture to regenerate and recover quickly after each cycle of grazing.

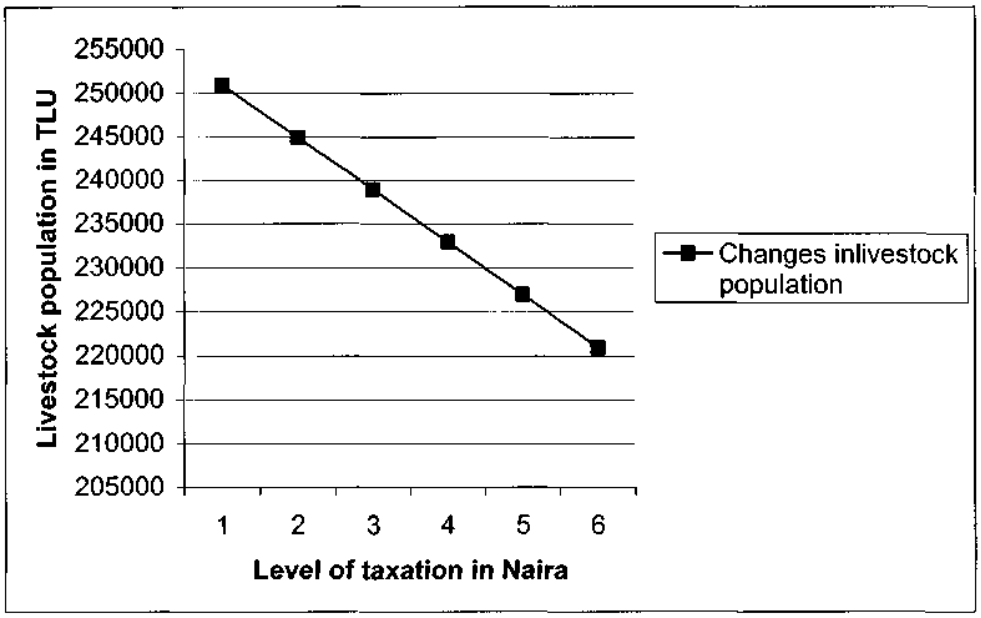
Table 9.12: Scenarios on the effects of different tax levels on herders' livestock population in the reserve

Different cattle tax regime	Effects on livestock population	Decrease in population	%Decrease
Population without cattle tax	250930		
Population with N200 tax	244930	6000	2.39
Population with N400 tax	238930	12000	4.78
Population with N600 tax	232930	18000	7.17
Population with N800 tax	226930	24000	9.56
Population with N1000 tax	220930	30000	11.96

Source: own analysis

Figure 9.11 shows that if a cattle tax is imposed on the pastoralists using the grazing reserve, there will only be a marginal drop in the population of livestock in the grazing reserve. This is because these pastoralists are already in the

business of tending animals and it will be difficult for them to abandon the business entirely. In fact, they see animal husbandry as a way of life.



NB: On the X axis, 1 = 0, 2 = 100, 3 =400, 4 = 600, 5 = 800 and 6 = 1000 naira respectively.
Figure 9.11: Effects on the scenarios of different taxation levels in regulating herders' livestock population in the reserve

9.7.2 Scenarios on different levels of taxation as a policy instrument for curtailing agropastoralism in the Zamfara grazing reserve

Agropastoralism has been viewed as a major problem in any grazing reserve set up. It is known to be responsible for patches of overgrazing and vegetation retrogression and consequent land degradation (THOMAS and BARTON, 1994). The major reason for this destructive tendency is the settled nature of the activities of this group of farmers. They tend to confine the grazing of their animals within a certain area. This is contrary to the activities of pastoralists who migrate to areas of greener pasture, thereby giving room for the recovery of grazed pastures. It is therefore viewed that, if this practice is allowed to gain prominence in the Zamfara grazing reserve, it will lead to the eventual destruction of the reserve. It is for this reason thought that taxation could be used as a viable instrument to reduce such an undesirable practice. While these farmers might still have animals, they may be forced to give up the keeping of their animals to the herders who are more knowledgeable in the act of animal husbandry. Their animals might then be integrated into the pool of transhumance animals, thereby checking the effect of their persistent grazing within the same area of the reserve. The effect of this taxation may even make some of them entirely give up animal rearing. Thus, taxation will be a disincentive for them because of the small size of their herd. The proposed tax used for the agropastoralists was simulated with a starting value

of N100. It is less than the one used for pastoralists. This is because the herd population for agropastoralists was considerably lower compared with those of the former. The result from the model is presented in Table 9.13 and Figure 9.12.

Table 9.13: Scenarios on the effects of different tax levels on agropastoralists' livestock population in the reserve

Different cattle tax regime	Effects on livestock population	Decrease in population	%Decrease
Population without cattle tax	13328		
Population with N100 tax	10328	3000	22.51
Population with N200 tax	7328	6000	45.00
Population with N300 tax	4328	9000	67.53
Population with N400 tax	1328	12000	90.04
Population with N440 tax	128	13200	99.04

Source: own analysis.

Figure 9.12 shows that the introduction of cattle taxation could serve as a good policy measure to reduce the practice of agropastoralism in the grazing reserve. The effect of taxation is seen as reducing the livestock numbers of agropastoralists rapidly if compared with those of pastoralists. This is because agropastoralists do not see animal husbandry as their major occupation. They see it rather as a subsidiary occupation, even though they seriously need livestock for manure production. They can, however, source manure from contracts if they are not able to keep their own livestock. The imposition of a tax on livestock could make agropastoralists reconsider their decision of keeping their own livestock. Those still willing to own livestock may now be forced to keep them with the pastoralists on a shared basis. This will be good for the grazing reserve since these animals will under such an arrangement be no longer confined to a restricted area. This will limit overgrazing within a particular area of the reserve, as pertains with most agropastoralist systems. Such taxation, if implemented, will help to ensure sanity in the use of the grazing reserve and consequently preserve the grazing reserve from eventual degradation.

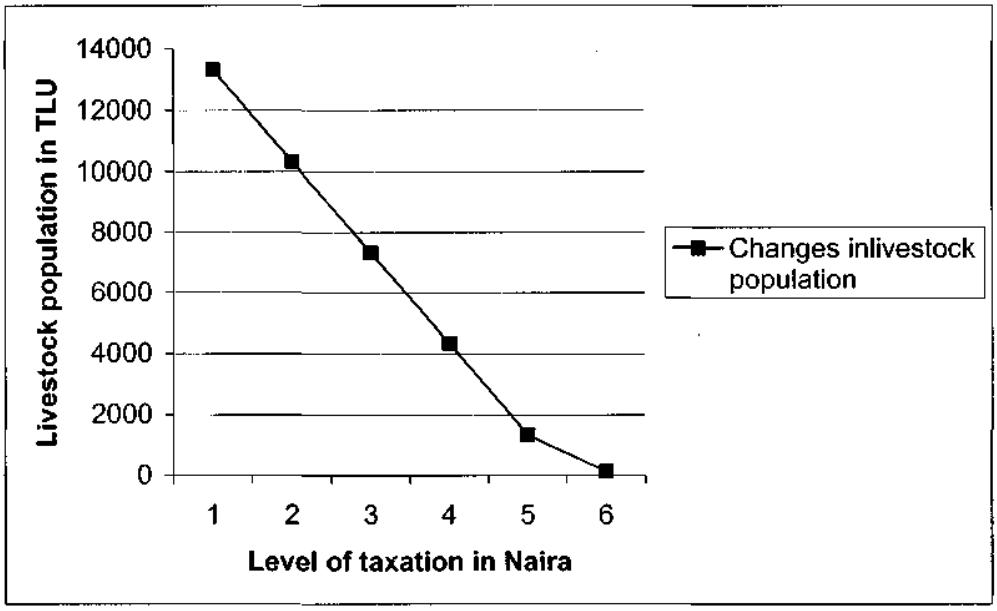


Figure 9.12: Effects on the scenarios of different taxation levels in curtailing agropastoralism in the reserve

9.8 Summary

In this chapter, comparisons were made between manure contracts and enterprises based on crop-livestock cropping. This is first with a view to identifying which option will increase farmers' incomes best. Secondly, which alternative would enhance the sustainability of productive activities such as cropping and pastoralism? Our study also took into consideration the preservation and sustainability of the grazing reserve as a natural resource of high value.

The model results presented in this chapter showed that manure contract based cropping can guarantee better income per person in the household than is possible for agropastoralism based cropping. Of utmost important consideration is the possibility of a farmer to participate in an increased number of manure contracts to generate sufficient manure for crop production. We equally took into consideration the totality of the land currently allowed for crop production in the grazing reserve. The result of higher incomes accrued from manure contract based farming has refuted the known excuse of high incomes from agropastoralism based cropping as a tenable option for soil fertility maintenance in the grazing reserve. This is hitherto justified when a thoughtful consideration is given to the negative impact of agropastoralism in a grazing reserve area.

The results showed that, based on the number of livestock resident in the grazing reserve and on a comparison of the cropland versus pasture area, the manure contract practice is practicable for sustainable production in the Zamfara grazing reserve. It was equally revealed by the model that livestock in the reserve is just sufficient to consume about 76% of the biomass being produced by the pasture.

As a result, the grazing reserve use must be properly planned against the backdrop of adding more stock, so as not to threaten its sustainability.

In analysing the sustainability of the grazing reserve based on the prevailing production practices, it was found that manure contract based production is more sustainable. This is because the widespread adoption of agropastoralism will in the nearest future not only lead to the take-over of more land from the grazing reserve but also to its eventual destruction. Agropastoralism will, beginning from 2002, lead to an encroachment on more land from the grazing reserve for crop production. Since the take-over of more grazing land will mean deforestation and subsequent degradation, agropastoralism will not help in the maintenance of the Zamfara grazing reserve, even in the short-run.

The effect of cattle taxation as a policy measure for controlling livestock population was examined. It was found that this instrument could be used to regulate and balance the livestock population in the ranch considering the current capacity of the pasture in the grazing reserve. It was found, however, that this measure would not adversely affect the production of cattle owned by pastoralists substantially. Since the population of pastoralists' cattle will not be seriously affected, the policy will not have much effect on the number of cattle available for manure contracts in the reserve. It was, however, found that it could help to reduce the practice of agropastoralism that is not too favourable for the sustainability of the grazing reserve.

Finally, it could be concluded that one of the keys to sustainable production among rural resource-poor farmers in northern Nigeria lies in the inward looking into the adoption of manure contracts as a production practice. That will enhance improvement in soil fertility maintenance and sustainable crop production. It will equally enhance the sustainability of the reserve use, since the take-over of more land will be minimised. One could therefore conclude that manure contract based cropping is a better pathway for the intensification of production in the grazing reserve than agropastoralism.

10 CONCLUSIONS AND RECOMMENDATIONS

This chapter summarises the main findings of the study, highlights the policy implications of the results, and offers recommendations for further research.

10.1 Summary of the main results

Forest reserves or grazing reserves are becoming endangered resources all over the world. This is particularly the case in developing countries, where their importance has been underestimated. The mismanagement of such reserves has led to deforestation and land degradation with the accompanying negative environmental consequences. The study is aimed at providing useful theoretical and quantitative information with which public forest reserves or grazing reserves could be managed. Such management practices will entail useful approaches to achieving production objectives of farming communities within such reserves, while, at the same time, enhancing the sustainability of the reserves. These desirable practices should aim at reducing deforestation and land degradation to the barest minimum, while at the same time enhancing sustainable production.

In order to achieve this, the various production practices farmers engage in the study area have been evaluated. This has been done with a view to identifying the best practice that can improve production activities in the Zamfara grazing reserve. It is also hoped that the recommendations coming out of the study could be useful in managing similar grazing reserves and other relevant public goods in the region.

To achieve the objectives of the study, a combination of econometric techniques and a farm household bio-economic model (FLBEM) was used. Using the above-mentioned analytical approaches, the study seeks specifically:

- To evaluate the factors driving farmers' adoption of manure contract practices in the Zamfara grazing reserve for the purpose of soil fertility maintenance,
- to evaluate the factors driving the adoption of crop-livestock enterprise practices among farmers in the Zamfara reserve as soil fertility maintenance,
- to evaluate the impact of these practices on crop productivity in the study area,
- to identify the best practice or intensification pathway for the utilization of resources for production in the reserve in a way that is consonant with the attainment of sustainable production. The sustainability of the grazing reserve as a natural resource of high value, rich in biodiversity, is equally considered.
- to make policy recommendations based on the findings of the study.

10.1.1 Major findings of the field survey

To fulfil the research objectives, a field survey was undertaken in the cropping season of 2001/2002 in the Zamfara grazing reserve, located in the Zamfara state of Nigeria. A total of 85 farmers, comprising manure contract adopters and non-adopters, were interviewed while another set of 228 farmers, comprising crop-livestock enterprise combination adopters and non-adopters, were equally interviewed. These farmers were interviewed using structured questionnaires. Questions were posed to them about their agricultural production, their socio-economic characteristics and the types of farm practices they engage in for the purpose of soil fertility maintenance as well as their reasons for adopting such practices. Apart from these groups of farmers, officials of the reserve as well as the village leaders and the opinion leaders in the study area were interviewed.

The results of the field survey described the major socio-economic situations of the farm households in terms of demography, resource endowments, education, production activities, credit markets, farm practices, soil fertility maintenance practices as well as the production activities of the people of the area.
The average household size ranged between 9 for croppers to 14 for agropastoralists in the survey area. The agropastoralists in Dumburum-Shamushalle have larger household sizes than their counterparts in Ajja-Tsabre. The mean difference of households for agropastoralists in the two zones was found to be statistically significant. It was also found that a statistically significant difference existed between the household sizes of croppers and agropstoralists in the study area, with agropastoralists having the largest numbers of household members. The average household farm size also varied from 1.7 hectare for croppers to 2.8 hectares for agropastoralists. It was equally found that agropastoralists have bigger farm sizes than manure contract farmers, with the mean difference of the farm sizes of the two groups being statistically significant. This is an evidence of the fact that agropastoralists will encroach more on the grazing reserve if given the opportunity to do so. It was discovered that the farm sizes for all groups ranged from 1 to 5 fields. Most farmers have at least two fields. Those having two fields mainly included croppers, representing about 27%. On the other hand, farmers having at least 3 fields were mainly agropstoralists representing about 25% of the total. The larger farm size of agropastoralists was mainly due to their manure endowments obtained directly from the animal sub-sector of their farm business.
However, it was later discovered in the study that manure contract based farmers have the ability to generate more manure from multiple contracting. This is because the livestock cropper ratio in the reserve could apparently ensure an arrangement that would favour farmers engaging in as much as four contracts with the herders in the grazing reserve.
Farmers' age ranged, on the average, from 43 years for croppers to 47 years for agropastoralists. The age of farmers may have a lot to do with material

endowments such as the possession of livestock. Since it takes a lot of years' savings to acquire livestock, old farmers are better off.

The majority of farmers are generally illiterate and the common education among the few that had education was religion-based education from Islamic schools in the area.

There are two major economic activities the households in the Zamfara grazing reserve are involved in. These activities are animal husbandry by pastoral Fulani and cropping by the Hausa as their principal economic activities respectively. However, there are some of the pastoral Fulani who combine cropping with their livestock husbandry, even though they do not regard themselves as farmers (ECKERT 1997). Some Hausa farmers also own animals as part of their farming enterprise. This is to enable them to generate manure for the maintenance of soil fertility. There are, however, croppers that do not own animals but mainly rely on manure contracts as an alternative way of generating manure for maintaining the fertility status of their soils. This practice of manure contracting is gradually becoming popular in the study area.

Labour is an important input in farming. It was, however, discovered that labour was not a limiting factor for production in the survey area. This can be justified if one matches the household size with the scale of farm operation. It was, however, discovered that croppers have surplus labour and could therefore afford to hire out more surplus labour than the agropastoralists' households could do, since their combined activities require more labour input. It was, however, found that agropastoralists in the Dumburum-Shamushalle zone used more labour on crop production than their counterparts at the Ajja-Tsabre zone, as the mean difference between the two zones was found to be statistically significant. This could be a result of the larger family sizes in the Dumburum-Shamushalle zone.

Regarding the credit market situation in the area, it was observed that there is currently no formal credit institution in the local government areas. Farmers in the area have no access to formal credit institutions. The only farmers with access to such credits are those located in Gusau, the Zamfara state capital. This can, however, be considered inadequate taking cognizance of the fact that the highest numbers of beneficiaries in credit schemes recorded is 308 people per year out of the over 2 million inhabitants of the state. The few beneficiaries of credit schemes are usually people affiliated with political power brokers. The farmers in the Zamfara grazing reserve, being predominantly rural, use self-savings for their farming activities. As such, they have difficulties in purchasing modern inputs like fertilizers for farming. They rely on local sources of inputs such as manure for production and seeds from previous harvests.

The manure contract participants have the following factors driving their participation in manure contracts:

- The number of days the herders are willing to allow their herds to stay on the farm,
- the prior relationship with the herder,
- the tribal closeness with the herder,

- the trust in the herder,
- the effect of seeing others getting involved as the motivating factor,
- other reasons not specifically stated.

On the other hand, crop-livestock adopters indicated that their motivations to adopt this production practice were driven by factors such as:

- More income generation,
- traction power availability,
- manure availability,
- livestock as means of savings,
- the availability of more food for the households,
- the fact that it is a traditional way of production,
- the size of the farmers' households.

The number of livestock owned by agropastoralists was equivalent to about 9 TLU in the Dumburum-Shamushalle zone. There were fewer animals in the Ajja-Tsabre zone, where the average number was around 5 TLU. The analysis revealed statistically significant differences in the average of livestock owned by households in both the Dumburum-Shamushalle and the Ajja-Tsabre zone.

However, the standard number of livestock required for successful manure contracts was found to be about 50 TLU in the Zamfara grazing reserve. This means for croppers showing willingness to participate in manure contracts, the participating herders must have at least 50 cattle in their herds.

The study also revealed that there is a statistically significant difference in the mean values of manure used by agropastoralists in the Dumburum-Shamushalle and the Ajja-Tsabre zone. This is attributed to the larger livestock size per household in Dumburum-Shamushalle. However, there was no significant difference in the quantity of manure used by agropastoralists and manure contract croppers in the area.

On the payment mode adopted for the contract, most of the participants stated that grain gift was the most common mode of payment. This category represented 18% of the respondents. Other gifts included crop residues, representing 15%, while about 45% of the respondents that engaged in contracts immediately after harvest did not list any gift. This must in most cases have coincided with periods when the residues on the fields were enough to compensate herders for the manure voided on the fields during the camping of the herders' animals.

Crop yields among the various groups of farmers based on soil fertility maintenance practices showed that there was no significant difference between the yields of agropastorlists and manure contract croppers, since farmers in both groups had higher yields when compared with farmers with neither manure contract or agropastoralism practice and consequently cultivated crop without manure. However, the analysis confirmed that non-contract farmers have the poorest yields and there were significant differences between the yields of manure contract croppers and non-contract croppers. This is because non-contract farmers

do not have access to manure and therefore cultivate poorer soils. This demonstrates the importance of manure in soil fertility maintenance and crop production in the area. The analysis also revealed the importance of cotton as an important cash crop for the agropastoralists and manure contract farmers in the study area.

10.1.2 Model and simulated results

Both econometric and mathematical programming modelling approaches were used for the evaluation of the various aspects of the study to achieve the diverse stated objectives. Econometric models were developed to evaluate factors propelling farmers to adopt manure contracts and crop-livestock enterprise combination practices as means of maintaining soil fertility. They were also used to evaluate the impact of the adoption of various practices on crop productivity in the Zamfara grazing reserve. In addition, a farm household bio-economic model was developed for the purpose of optimising farm revenues under the two practices of manure acquisition. The full version of the model is written in GAMS (General Algebraic Modelling System) using Linear Programming (LP). The GAMS/MINOS solver was applied to solve the model. Having developed a baseline model, several results and scenarios were generated using the following criteria to determine the sustainability of crop productivity:

- Scenarios on the effect of increasing manure contracts on farm household income.
- The sustainability of crop production by manure contracting based on livestock population.
- The sustainability of manure contract farming based on cropped versus pasture area.
- The sustainability of pastoralism in the grazing reserve based on biomass production and the current level of livestock and its feed requirements.
- The sustainability of the grazing reserve by manure contract based production.
- The long term effect of agropastoralism on the grazing reserve.
- Scenarios on different levels of livestock taxation as a means of controlling the livestock level in the grazing reserve.
- Scenarios on different levels of livestock taxation as a means of curtailing agropastoralism.

The results of the econometrics models have shown that factors driving farmers adoption of manure contracts are:

- The duration of time herders are prepared to camp their livestock on croppers' fields,
- prior contracts or a social relation with the herders,
- the tribal closeness to the herders,
- the trust reposed on the herder,

- the effect of croppers seeing other croppers participating in manure contracts.

These factors were found to be statistically significant in explaining farmers' adoption behaviours in the study area. The adoption of this practice along with labour input and production expenses was found to have positive impacts on crop productivity in the study area.

Moreover, there are seven factors driving the desire of other farmers to adopt crop-livestock enterprise combination as a practice for soil fertility maintenance. These factors are:

- The size of the farm household,
- the fact that it is a traditional way of production,
- because it increases food availability,
- because it is a means of saving,
- because it makes manure available,
- the provision of traction power,
- because it helps farmers to generate more income.

Of these seven factors, the household size, the traditional way of production, the availability of manure, the availability of traction power and more income were statistically significant in explaining farmers' adoption behaviour in the Dumburum-Shamushalle zone. In the Ajja-Tsabre zone, family size, traction power, food availability, and traditional way of life were statistically significant in explaining the farmers' adoption of crop-livestock enterprise combination under the same management in the area. However, when the zones were pooled together, all the factors were statistically significant in explaining farmers' adoption behaviour.

On the impact of the adoption of crop-livestock on crop productivity, it was found that the adoption of crop-livestock enterprise combination had positive impacts on crop productivity among farmers in the Zamfara grazing reserve.

The mathematical programming model results showed that manure is the most limiting factor for crop production in the area. This is because farmers cannot afford fertilizer. It was found that, using the participation of croppers in one manure contract as a baseline, the initial income from cropping activities was N78,127 while the income for agropastoralists was N346,200. These incomes were N40,649 and N56,293 per ha for contract farmers and agropastoralists respectively. A comparative analysis of the per capita income between manure contract and agropastoralist based cropping yielded N8,681 and N24,729 respectively. There is, however, room for a cultivation increment under manure contracts, since manure is always a limiting factor for crop production among croppers in the area, unlike agropastoralists that have already exhausted the land area designated for cropping in the reserve.

With two manure contracts, the contract based cropping would generate an income of N19,971 per person, which is almost at the same level of the income of N24,728 per person for agropastoralists. With three and four manure contracts,

the income per person in the household for manure contract based farming would be N31,261 and N33,476 respectively, which is far more than the income per person for agropastoralist households.

The increment in manure contracting shows that it is possible to increase the quantity of manure available for crop production through multiple manure contracts. This will consequently increase the area of land cultivated. It was shown that by the time a household participated in four manure contracts, it would have enough manure to cultivate 6.15 ha of land, as is the case currently with agropastoralists. It would, however, take a lot of extension enlightenment for these farmers to know that such a potential and opportunity exist.

Based on the livestock population versus the number of households of 1190 in the reserve, the manure contract practice was found to be sustainable in the Zamfara reserve. 50 TLU of livestock is the standard requirement for manure contract participation for a period of seven days. It was also found that, based on the population of livestock in the reserve, a household should have access to around 211 TLU. Based on this, one can say that the practice of manure contracting is still sustainable, and all farmers will have the opportunity to participate to benefit from the practice. What is needed is a good organisation to make the practice functional.

For sustainable manure-based cropping, there must be an average of 16 ha of pasture to 1 ha of cropland in the Sahel Savannah area. In the study area, the area cropped presently is 1 ha to 103 ha of available pastureland. It means we have more than enough pasture to enhance the transfer of nutrients from pasture to the cropping area. If the total area allocated for cropping is cropped under manure contracts, there will be an average of 1 ha of cropland to 32 ha of pastureland.

In terms of the time perspective, looking at the crop-livestock based cropping system, it was found that in the next 10 years, the land area needed for cultivation would exceed the current land capacity designated for farming. While in the case of manure contract based cropping, there will be less than 50% of such land capacity used. It means the incentives to take more land from the reserve for manure contract farmers are zero, at least for now. This is contrary to the case of agropastoralists, where all the land designated for cropping would already have been used up in 2002. Since these farmers will always want to take over new land, the incentive to take over more land from the grazing reserve for farming is very high under this practice. The survival and sustainability of the grazing reserve and the grazing reserve's environment will consequently be impaired.

Regarding the growth of livestock population in the grazing reserve, it was discovered from the model results that, if the present rate of growth was projected into the next 10 years, the population of livestock in the grazing reserve would increase by more than three times the present number. This already poses a serious threat, as the current livestock population consumes about 76% of the biomass produced by the pasture in the reserve. Uncontrolled stocking should therefore be prevented to avoid irreparable damage to the Zamfara grazing reserve.

The model also demonstrated the importance of livestock taxation as a viable instrument for regulating and maintaining a balance between pastures and the carrying capacity of the pasture. It was found that the level of livestock could be maintained almost at the same level from year to year if pastoralists in the reserve are taxed based on per heads of cattle. This way, the issue of overstretched and overgrazed pastures will not arise. It was found from the model results that the drop in livestock population for pastoralists would be marginal and this is because pastoralism is their main means of livelihood. It would be very difficult for them to abandon pastoralism, no matter what level of taxation is imposed. In contrast, taxing agropastoralists at even half the rate of pastoralists could totally drive them away from keeping animals in the reserve. This will force most of them to sell their animals while some will keep their animals on a sharing basis with the pastoralists. The taxation could also help to scare away intruding and straying pastoralists from the Niger Republic.
Finally, there is ample opportunity for farmers in the reserve to participate in manure contract adoption for increased production. Therefore, it is worthwhile to encourage farmers not currently involved to get involved in order to increase their productivity and consequently improve their livelihood status.

10.2 Policy recommendations from the study results

Based on empirical results from the present study, the following policy recommendations are suggested:
It has been shown in literature and reinforced by this study that any farm practice that does not involve soil fertilization will lead to soil fertility depletion, degradation and a loss of productivity. The authorities concerned with the management of the Zamfara reserve must encourage farmers to practice sustainable farming practices to embrace soil fertility maintenance, so as to prevent degradation and consequently deforestation of the grazing reserve.
They should encourage and motivate farmers to embrace manure contract based farming in order to get manure for the maintenance of their soil fertility.
A lot of extensive education is needed to enlighten farmers of the inherent potential benefits of manure contract farming. This particular enlightenment should be part of the activities of the Agricultural Development Project (ADP) assignment in the Zamfara grazing reserve. The staff of this organisation as well as the Ministry of Agriculture staff must carry out assignments to get the farmers in the Zamfara grazing reserve to embrace manure contract farming. To encourage farmers to take manure contracting as a serious practice, recognition by the local customary law is important for strengthening the institutional frameworks to handle problems that may arise from defaulters of manure contracting.

This study reinforced the importance of a tax as a viable policy instrument that could be used to control certain producer behavioural practices. Relevant

authorities should enforce livestock taxation to bring a halt to the practice of agropastoralism in the Zamfara grazing reserve. This is because it was shown that imposing a tax level on agropastoralists that is just half the level of that for pastoralists would force the former to give up livestock keeping.

Farmers and other inhabitants of the study area should be educated in the current and future benefits of a sound environment. This is because good management that preserves the environment today will enhance productivity in the nearest future for the inhabitants in and around the grazing reserve.

The local institutional framework should be strengthened to enforce management practices that are in consonance with practices that benefit the environment. There should also be devolution of the management of the reserve to the local and traditional authorities in the area. This will be a better alternative to the state ministry officials that are far away from the reserve in the state capital and are therefore unable to adequately monitor the activities going on in the reserve.

Finally, farmers should be assured of the property rights to the land they are currently cultivating. This is a way of giving them a sense of belonging that would motivate them to properly manage the land under their possession. If they were assured that they have long-term rights to the land they are using, they would be ready to commit resources to its management.

10.3 Research questions for future studies

The present study could not address all the important issues related to the management of the Zamfara grazing reserve due to some constraints. There is therefore more work for future research studies.

One limitation of this study is the use of cross-sectional data collected within a single cropping season due to time constraints and the absence of readily available data from the study area. Future research in the area should be tailored to obtain a stream of data colleted over a period of time. Such data would permit dynamic modelling of the productive activities and its effects on the grazing reserve.

Also, it appears from the current estimated households and the per-household land holding that there may be people cultivating crops in the reserve that are not residing in the reserve. Future study should take stock of such farmers that are urban based, but are currently cultivating crops in the grazing reserve. That will help to give a realistic view of situation about the number of households using the reserve.

Currently, the estimate of livestock population in the reserve is based on the pastoralists' and agropastoralists' population and the number of animals they

possess. A precise estimate of wandering pastoralists and their animals coming from the Niger Republic was not included in this study. This estimate would be very necessary to really reflect the livestock/pasture balance in the Zamfara grazing reserve. However, such estimation would require longer-term monitoring and a lot of financial resources to be accomplished. It may also require collaborative efforts between researchers from the Niger Republic and Nigeria working together across the two countries' border. Future research could be tailored to make room for such lengthy time periods needed as well as sufficient funds and the trans-border collaborative efforts needed to accomplish such tasks.

Finally, the effects of residues gained from manure contracts on the weight of participating livestock have not been quantitatively determined in the Zamfara grazing reserve. Obtaining such data will require a collaborative multidisciplinary approach between socio-economists and animals scientists. Future research in this area should explore such collaborative possibilities to generate the requisite data. This will provide more insights regarding the total benefits obtained by pastoralists from manure contracts in addition to the usual grain or money gifts that are presently involved in the manure contract exchange.

GERMAN SUMARRY (ZUSAMMENFASSUNG)

Problemstellung und Ziele der Arbeit

Das Zamfara Reservat wurde 1916 von der Britischen Kolonialregierung gegründet, um den Bedarf nach tropischen Hölzern zu verbessern, Jagd auf Wild zu gewährleisten und nicht zuletzt als Schutz gegen die von Norden her voranschreitende Desertifikation. Ursprünglich war es im Zamfara Reservat nicht erlaubt, landwirtschaftliche Tätigkeiten wie z. B. Ackerbau und Viehzucht zu betreiben oder Dämme an Flüssen im Reservat zu bauen. Man wollte durch dieses Verbot das ökologische Gleichgewicht nicht stören und wollte so die natürlichen Ressourcen und Habitate erhalten (THE FOREST ORDINANCE, 1938). In den ersten vier Jahrzehnten des Bestehens des Reservates wurden diese Verbote streng überwacht und so die Einhaltung gewährleistet. Nach der politischen Unabhängigkeit Nigerias 1960 nahm nach und nach die Viehhaltung in den Waldzonen des Reservates zu (HOFFMANN, 1998). Schließlich favorisierte die Politik Nigerias die Strategie, im ganzen Land sogenannte Weideland-Reservate einzurichten. Das Zamfara Reservat war eines von fünf Pilotgebieten im Norden Nigerias.

Es ist gut dokumentiert, dass menschliche Aktivitäten, vor allem umweltgefährdende, die Hauptursachen der Boden- und Umweltdegradation sind. SCHERR (1999) hat in einer Studie festgestellt, dass Überweidung für die Hälfte der Degradation im Afrika südlich der Sahara verantwortlich ist, gefolgt von anderen landwirtschaftlichen Aktivitäten, Waldrodung und Übernutzung anderer natürlicher Ressourcen. Die landwirtschaftlichen Produktionsmethoden werden zu einem Großteil davon bestimmt, wie viel in Bodenfruchtbarkeitsmanagement investiert werden kann. In ihrer Untersuchung Anfang der 1990er fanden STOORVOGEL und SMALLING (1993) heraus, dass die Verarmung des Bodens im Afrika südlich der Sahara hauptsächlich von Ernte und unsachgemäßer Anwendung von organischem und mineralischem Dünger herrührt. Noch dramatischere Produktionsrückgänge durch landwirtschaftliche Intensivierung wurden bei einer Untersuchung der „African farm-survey unit" und deren experimentellen Daten festgestellt. Die Studie zeigte einen Rückgang der Ernte von durchschnittlich 2-4 t auf unter 1 t pro Hektar, auf ursprünglich fruchtbaren Böden aufgrund dauerhaften Ackerbaus (Getreide) ohne Nährstoffzugaben (SANCHEZ et al., 1997). Die Ergebnisse dieser Studie sind äußerst relevant in Bezug auf die eingerichteten Reservate, da ein schlechtes Nährstoffmanagement zu einer Zerstörung des Reservats führen kann. Dies kommt daher, dass die üblichen Ackerbaumethoden, d. h. die Nutzung eines Stücks Land für mehrere Jahre ohne Düngung und danach Verlassen des Landes und Wechseln zu einem neuen Stück Land, dazu führt, dass nach und nach große Landstriche degradieren. Wenn das Zamfara Reservat zerstört würde, hätte dies auch Konsequenzen für den gesamten, von Savannen geprägten, nördlichen Teil Nigerias. Es ist daher

notwendig, Produktionsstrategien zu entwickeln, die die Bodenfruchtbarkeit erhalten und gleichzeitig muss einem weiteren Fortschreiten der Waldrodung entgegen gewirkt werden. Andernfalls wird die Zerstörung des Zamfara Reservates weiter fortschreiten und das ökologische Gleichgewicht empfindlich gestört.
Die Ziele dieser Arbeit sind aufgrund obiger Ausführungen wie folgt:

1. Es sollen verschiedene Produktionsmethoden beschrieben und untersucht werden, insbesondere Viehzucht und integrierte Ackerbau-Viehzucht-Betriebe wie sie im Zamfara Reservat weit verbreitet sind.
2. Es sollen Faktoren ermittelt werden, die hauptsächlich dafür verantwortlich sind, dass Landwirte an Maßnahmen teilnehmen und ihre Anbauweise auf eine gemischte (Feldfruchtanbau und Viehzucht) umstellen und die Auswirkungen dieser Umstellung auf die Ertragshöhe.
3. Es sollen wesentliche Faktoren ermittelt werden, die hauptsächlich dafür verantwortlich sind, dass Landwirte an Maßnahmen teilnehmen und ihre Anbauweise in der Weise umstellen, dass Ackerbauern Verträge mit Agropastoralisten abschließen, bei denen die Ackerbauern den Agropastoralisten erlauben, ihre Tiere auf die Stoppelfelder zu bringen und dafür den Dung der Tiere erhalten (Dung-Verträge). Desweiteren sollen die Auswirkungen dieser Umstellung auf die Ertragshöhe gemessen werden.
4. Es sollen optimierte Einkommen von reinen Ackerbaubetrieben und integrativen landwirtschaftlichen Betrieben verglichen werden. Des weiteren soll quantifiziert werden, wie sich Dung-Verträge auf das Einkommen aus Ackerbau im Untersuchungsgebiet auswirken.
5. Die beste Mischung der Produktionszweige (Feldfruchtanbau und Viehzucht) soll ermittelt werden, die die nachhaltigste Nutzung der natürlichen Ressourcen des Zamfara Weideland-Reservates gewährleistet
6. Empfehlungen sollen darüber gemacht werden, wie die identifizierte und ausgewählte Produktionsstrategie am Besten organisiert werden kann und damit nachhaltige landwirtschaftliche Produktion in diesem Gebiet gewährleistet werden kann

Untersuchungsmethoden

Um die Ziele zu erreichen wurden Feldforschungen in der Vegetationsperiode 2001/2002 im Zamfara Reservat im nördlichen Nigeria durchgeführt. Es wurde eine Gruppe von 85 Dung-Vetrags akzeptierenden und ablehnenden Landwirten befragt. Eine weitere Gruppe von 228 Landwirten, kombinierte Ackerbau-Viehzucht akzeptierende und ablehnende Landwirte, wurden befragt. Die Landwirte wurden mit einem strukturierten Fragebogen befragt. Es wurden ihnen Fragen gestellt über ihre landwirtschaftliche Produktion, sozioökonomische Charakteristika und über Maßnahmen, die sie zur Bodenfruchtbarkeitserhaltung anwenden und warum sie diese anwenden. Neben den Landwirten wurden

ebenfalls Offizielle des Reservats, Dorfälteste und Meinungsführer der Untersuchungsregion befragt.
Sowohl ökonometrische als auch mathematische Programmierungsansätze wurden benutzt, um die Daten auszuwerten und die Ziele der Arbeit erreichen. Ökonometrische Modelle wurden entwickelt, um die Faktoren zu untersuchen, die die Landwirte dazu veranlassen, Dung-Verträge oder Ackerbau-Viehzucht-Kombinationen anzuwenden, um die Bodenfruchtbarkeit zu erhalten. Desweiteren wurden diese Modelle genutzt, um die Auswirkungen der Anwendung auf die Feldfruchtproduktivität im Zamfara Reservat zu ermitteln. Der erste Schritt ist die Evaluation der Faktoren, die die Landwirte dazu bringen, Dung-Vertäge und Ackerbau-Viehzucht-Kombinationen anzuwenden, um so die Bodenfruchtbarkeit zu erhalten. Da die meisten Variablen binärer oder qualitativer Natur sind, wurde ein Probit-Modell benutzt. Weil die Zahl der Beobachtungen bezüglich der Dung-Vertragsanwendung nur 85 betrug, wurden die gesamten Daten der vier Enklaven im Reservat zusammen analysiert. Weiterhin wurden die vier Enklaven im Reservat in zwei Zonen eingeteilt, in die Dumburum-Shamushalle und die Ajja-Tsabre Zone, um bei der Gruppe der Ackerbau-Viehzucht-Kombination besser die Reaktion auf Annahme und die Auswirkung der Annahme beurteilen zu können. Desweiteren wurde eine Analyse des zusammengefassten Datenmaterials durchgeführt. Der zweite Teil der ökonometrischen Untersuchung befasste sich mit der Auswirkung dieser Bodenfruchtbarkeitsmaßnahmen auf die Feldfruchtproduktivität. Dazu wurde die Umsetzung dieser Maßnahmen geschätzt und als Variable zusammen mit anderen Produktionsfaktoren einer Regressionsanalyse unterzogen. Die beiden Regressionsgleichungen wurden rekursiv gelöst, um sowohl die Umsetzung der Maßnahmen als auch deren Auswirkung zu ermitteln.
Zusätzlich wurde ein bioökonomisches Modell auf der Haushaltsebene entwickelt, um das Einkommen unter Umsetzung der beiden oben aufgeführten Maßnahmen (Dung-Vertrag und Ackerbau-Viehzucht-Kombination) zu optimieren. Das Ziel des Modells ist, zu ermitteln, welche der beiden Maßnahmen nachhaltiger ist. Nachhaltigkeit bedeutet in diesem Zusammenhang, dass die Landwirte ein gesichertes Einkommen haben und gleichzeitig durch ihre landwirtschaftliche Tätigkeit nicht die Degradation oder die Entwaldung im Zamfara Reservat weiter voranschreitet. Es besteht daher die Notwendigkeit, das eine nachhaltige Bewirtschaftungsform eine weitere Landbeanspruchung des Weide-Reservates minimiert. Daten aus der eigenen Feldforschung, aus der Literatur und aus bereits abgeschlossenen Studien wurden als Input für die Modelle genutzt. Als endogene Variablen wurden im Modell festgelegt: Einkommen und Nettoeinkommen der Haushalte; die gesamte derzeit ackerbaulich genutzte Fläche (unter der Annahme, dass alle Landwirte Ackerbauern sind); die gesamte derzeit ackerbaulich genutzte Fläche (unter der Annahme, dass alle Landwirte Agropastoralisten sind); die Quantität an Dung, die die Ackerbauern über Dung-Verträge erhalten; die Nachhaltigkeit der Dung-Verträge in Bezug auf ihre Eigenschaften als Mittel der

Bodenfruchtbarkeitserhaltung; zusätzliches Einkommen durch die Teilnahme an Dung-Verträgen und auf der Weide produzierte Biomasse als Trockenmasse. Einige der exogenen Variablen sind: Gewinne aus Ackerbau unter verschiedenen Produktionstechniken; Arbeitsbedarf für die Produktionsaktivitäten; Tierbestand innerhalb der Dung-Verträge; gesamter Tierbestand des Reservates in TLU; gesamte Haushalte innerhalb des Reservates; den Haushalten verfügbares Land; gesamte Weidefläche innerhalb des Reservates; jährliche Rate der Landbeanspruchung und jährliche Wachstumsrate des Tierbestandes innerhalb des Reservates. Das Modell wurde in General Algebraic Modelling System (GAMS) als Lineare Programmierung (LP) erstellt. Innerhalb des GAMS Softwareprodukts wurde mit dem GAMS/MINOS Solver gearbeitet. Aufbauend auf das Grundmodell wurden zahlreiche Ergebnisse und Szenarien generiert, die anhand folgender Kriterien auf die Nachhaltigkeit der Feldfruchtanbauproduktion überprüft wurden:

- Szenarien zur Messung des Effekts von zunehmenden Dung-Verträgen auf Haushaltseinkommen
- Nachhaltigkeit des Feldfruchtanbaus mit Dung-Verträgen basierend auf dem Viehbestand
- Nachhaltigkeit von Landwirtschaft mit Dung-Verträgen basierend auf ackerbaulichen Flächen versus Weideflächen
- Nachhaltigkeit der Weidenutzung basierend auf der Biomasseproduktion, dem derzeitigen Viehbestand und dessen Futteransprüchen
- Nachhaltigkeit des Weide-Reservates durch landwirtschaftliche Nutzung mit Dung-Verträgen
- Langzeiteffekte des Agropastoralismus auf das Weide-Reservat
- Szenarien mit unterschiedlicher Besteuerung des Viehs zur Kontrolle des Viehbestandes innerhalb des Reservates
- Szenarien mit unterschiedlicher Besteuerung des Viehs zur Einschränkung des Agropastoralismus

Ergebnisse und Diskussion

Die Ergebnisse der Feldforschung beschreiben die sozioökonomische Situation der landwirtschaftlichen Haushalte bezüglich der Demographie, Ressourcenausstattung, Bildung, Produktionsaktivitäten, Kreditwesen, landwirtschaftlichen Produktionsmethoden und Bodenfruchtbarkeitserhaltung innerhalb des Zamfara Reservates.

Die durchschnittliche Haushaltsgröße reichte von 9 Personen bei Ackerbauern bis 14 bei Agropastoralisten. Die Agropastoralisten in Dumburum-Shamushalle hatten größere Haushalte als die in Ajja-Tsabre. Der durchschnittliche Unterschied bei dieser Gruppe zwischen den beiden genannten Gebieten ist statistisch signifikant, ebenso der Unterschied zwischen den Ackerbauern und Agropastoralisten. In derselben Art und Weise variierte die durchschnittliche Größe von 1,7 Hektar bei Ackerbauern bis zu 2,8 Hektar bei Agropastoralisten.

Desweiteren wurde herausgefunden, dass Agropastoralisten größere Betriebe haben als Landwirte mit Dung-Verträgen. Auch dies ist statistisch signifikant. Dies ist der Beweis dafür, dass Agropastoralisten eher mehr Land des Reservates neu in Anspruch nehmen werden, wenn ihnen die Möglichkeit dazu gegeben wird. Später wurde in der Untersuchung festgestellt, dass Dung-Vertrags-Landwirte die Menge an Dung erhöhen können, indem sie mehrere Verträge abschließen. Dies ist nur deshalb möglich, weil ein Verhältnis von Ackerbauern zu Agropastoralisten im Reservat von eins zu vier besteht.
Das durchschnittliche Alter der Landwirte reichte von 43 Jahren bei Ackerbauern bis zu 47 Jahren bei Agropastoralisten. Das Alter hat vermutlich Einfluss auf die Ressourcenausstattung, wie z. B. Anzahl der Tiere. Da für die Anschaffung von Tieren eine Zeit des Ansparens notwendig ist, haben ältere Landwirte mehr Tiere.
Im Zamfara Reservat wird hauptsächlich zwei wirtschaftlichen Tätigkeiten nachgegangen. Dies sind: Viehzucht (meist durch Angehörige des Fulani Stammes) und Ackerbau (meist durch Angehörige des Hausa Stammes). Nichtsdestotrotz gibt es auch einige Fulani, die Ackerbau und Viehzucht kombinieren, auch wenn sie sich nicht als Ackerbauern ansehen (ECKERT 1997). Einige Hausa besitzen im Gegenzug auch Tiere. Dies hauptsächlich deshalb, um Dung als Dünger für ihre Felder zu bekommen. Die anderen Ackerbauern haben keine eigenen Tiere und versuchen durch die schon erwähnten Dung-Verträge an Dünger zu kommen. Dies wurde in den letzten Jahren immer populärer.
Arbeit ist ein wichtiger Input in der Landwirtschaft. Es wurde jedoch festgestellt, dass Arbeit nicht der limitierende Faktor in der Untersuchungsregion ist. Dies kann begründet werden, indem man die Haushaltsgröße mit der Betriebsgröße vergleicht. Es wurde festgestellt, dass die Ackerbauerhaushalte einen Überschuss an Arbeit haben und diesen vermieten können, im Gegensatz zu den Agropastoralistenhaushalten. Statistisch signifikant konnte ermittelt werden, dass die Agropastoralisten in Dumburum-Shamushalle mehr Arbeit für Ackerbau einsetzen als ihre Kollegen in Ajja-Tsabre. Dies könnte mit den durchschnittlich größeren Familien in Dumburum-Shamushalle zusammenhängen.
Schaut man sich das Kreditwesen in der Region Zamfara an, so ist festzuhalten, dass es keine formalen Kreditanstalten auf lokaler Ebene gibt. Landwirte in diesen Regionen haben keine Möglichkeit, formal Kredite zu bekommen. Aufgrund dieses Mangels haben die Landwirte nur die Möglichkeit, selbst Erspartes (durch z.B. Dung- oder Saatverkauf) in ihren Betrieben einzusetzen.
Durchschnittlich besitzen die Agropastoralisten in Dumburum-Shamushalle Tiere äquivalent zu 9 TLU. In Ajja-Tsabre besitzen sie weniger Tiere, im Schnitt äquivalent zu 5 TLU. Um im Zamfara Weide-Reservat erfolgreich in das Geschäft mit Dung-Verträgen einzusteigen, sollte die Herdengröße allerdings bei 50 TLU liegen. Dies heißt, das ein Ackerbauer erst dann Verhandlungen mit einem Agropastoralisten aufnimmt, wenn seine Herde aus mindestens 50 Tieren besteht.
Die Studie ergab signifikante Unterschiede in der Dungnutzung der Agropastoralisten in Dumburum-Shamushalle und Ajja-Tsabre. Dies kommt von der durchschnittlich größeren Anzahl Tiere pro Haushalt in Dumburum-

Shamushalle. Dahingegen gab es keinen signifikanten Unterschied innerhalb einer der beiden Regionen zwischen der Dungnutzung von Agropastoralisten und Ackerbauern mit Dung-Verträgen. Die meisten Verträge zwischen Ackerbauern und Agropastoralisten werden mit Getreidegaben bezahlt (18%). Andere Geschenke inklusive Überlassung der Ernterückstände kommt in 15% der Verträge vor. Kommt der Vertrag direkt nach der Ernte zustande, so werden in 45% der Verträge keine Geschenke gemacht. Dies muss damit zusammenhängen, dass in diesem Zeitraum auf den abgeernteten Feldern genug Nahrung für die Tiere vorhanden ist, sodass die Agropastoralisten keine Ansprüche anmelden.
Gewinne aus Feldfruchtanbau waren unter den verschiedenen Gruppen von Landwirten, die Bodenfruchtbarkeitserhaltungsmaßnahmen durchgeführt haben, sowohl bei den Agropatoralisten als auch den Ackerbauern mit Dung-Vertrag, nicht signifikant unterschiedlich. Die Feldforschung hat ergeben, dass die Ackerbauern ohne Dung-Verträge die niedrigsten Gewinne haben und dass es signifikante Unterschiede zwischen Dung-Vertrags-Landwirten und Landwirten ohne Verträge gibt. Dies liegt wohl vor allen Dingen daran, dass ohne Dungzufuhr die Böden nach und nach verarmen. Durch diese Ergebnisse wird die Wichtigkeit des Einsatzes von Dung als Bodenfruchtbarkeitserhaltungsmaßnahme aufgezeigt. Ebenso hat die Analyse ergeben, dass der Baumwollanbau als cash crop eine bedeutende Rolle in dieser Region bei den Landwirten mit Zugang zu Dung spielt.
Die Ergebnisse des ökonometrischen Modells zeigen folgende signifikante Faktoren, die ein Zustandekommen von Dung-Verträgen erklären: der Zeitraum, wie lange ein Agropastoralist seine Tiere auf den Flächen des Ackerbauers belässt; vorherige Verträge mit dem gleichen Agropastoralisten oder gesellschaftliche Beziehungen mit ihm; Stammesverwandtschaft mit dem Agropastoralisten; Vertrauen zu ihm oder aber der Ackerbauer hat den Nutzen von Dung-Verträgen bei einem anderen Ackerbauern gesehen.
Die Anwendung dieser Technik, zusammen mit dem Arbeitsinput und den Ausgaben für die Produktion haben einen positiven Einfluss auf die Produktion von Feldfrüchten im Untersuchungsgebiet.
Aufgrund der Studie wurden sieben wichtige Faktoren ermittelt, die Landwirte dazu bringen, Ackerbau und Viehzucht zu kombinieren, um so die Bodenfruchtbarkeit zu erhalten. Diese sind: Größe des landwirtschaftlichen Haushalts, traditionelle Wirtschaftsweise, Erhöhung des Nahrungsangebots, größere Ersparnis, Produktion von Dung, Vorhandensein von Zugtieren und höheres Einkommen.
In Dumburum-Shamushalle waren von diesen sieben Faktoren Haushaltsgröße, traditionelle Wirtschaftsweise, Produktion von Dung, Vorhandensein von Zugtieren und höheres Einkommen statistisch signifikant. In Ajja-Tsabre waren dies Haushaltsgröße, Zugtiere, Nahrungsangebot und traditionelle Wirtschaftsweise. Bei einer gemeinsamen Betrachtung beider Regionen zusammen waren alle sieben Faktoren signifikant.

Die Ergebnisse aus der mathematischen Modellierung haben ergeben, dass Dung der am meisten limitierende Faktor für den Feldfruchtanbau im Zamfara Reservat ist. Dies kommt daher, dass sich Landwirte keinen mineralischen Dünger leisten können. Wenn man als Grundlage davon ausgeht, dass Ackerbauern mit einem Agropastoralisten einen Dungvertrag haben, so lag das Einkommen bei Ackerbauern bei 78,127 N und bei den Agropastoralisten bei 346,200 N. Dies sind 40,469 N pro Hektar bei den Ackerbauern mit einem Dung-Vertrag und 56,293 N bei den Agropastoralisten. Eine komparative Analyse des Pro-Kopf-Einkommens zwischen Landwirten mit Dung-Verträgen und Agropastoralisten auf Feldfruchtanbau bezogen ergab 8,681 N für die ersteren und 24,729 N für die letzteren. Es ist allerdings noch Raum für die Erweiterung der Kultivierung unter Dung-Verträgen, da Dung immer der limitierende Faktor beim Feldfruchtanbau ist.

Mit zwei Dung-Verträgen ergab die Untersuchung ein Pro-Kopf-Einkommen von 19,971 N bei Ackerbauern, was fast an das Pro-Kopf-Einkommen von 24,728 N bei den Agropastoralisten heranreicht. Mit drei (31,261 N) und vier Dung-Verträgen (33,476) übersteigt das Einkommen pro Person bei den Ackerbauern das Einkommen pro Kopf der Agropastoralisten deutlich.

Die Steigerung bei Dung-Verträgen zeigt, dass es möglich ist, die Menge an Dung, die für den Feldfruchtanbau zur Verfügung steht, durch Verträge mit mehreren Agropastoralisten zu erhöhen. Dies wird die Inkulturnahme von Land steigern. Bei vier Dung-Verträgen ist es durchschnittlich möglich, 6,15 ha Land unter Kultur zu nehmen, ebenso viel wie derzeit die Agropastoralisten. Es bedarf allerdings einer großangelegten Aufklärung, damit die Landwirte überhaupt feststellen, dass es dieses Potential gibt.

Basierend auf der Anzahl der Tiere versus der Anzahl der Haushalte von 1190 im Zamfara Reservat zeigt sich, dass Dung-Verträge nachhaltiges Wirtschaften gewährleisten. Hierfür müssen in der sogenannten Sudan-Savanne durchschnittlich 16 ha Weideland auf 1 ha Ackerland kommen. Im Untersuchungsgebiet ist dieses Verhältnis momentan 74 ha zu 1 ha. Dies zeigt, dass mehr als genug Weideland vorhanden ist, um einen Nährstofftransfer vom Weide- zum Ackerland zu ermöglichen. Wenn das gesamte Land, welches ackerbaulich genutzt werden könnte, auch genutzt wird, dann wäre das Verhältnis immer noch 32 ha zu 1 ha. Ein Blick in die Zukunft zeigt, dass in zehn Jahren das Land, welches zur Kultivation benötigt wird, das derzeitige zur Verfügung stehende Land übersteigt, wenn eine Ackerbau-Viehzucht-Kombination umgesetzt wird. Wird das System mit den Dung-Verträgen angewendet, dann wird nicht einmal 50% der vorhandenen Kapazität gebraucht. Dies bedeutet, dass bei einer konsequenten Umsetzung von Dung-Verträgen keine neue Landinanspruchnahme im Reservat erforderlich ist. Dies steht im Kontrast zu den Agropastoralisten, bei denen alles Land für den Feldfruchtanbau bereits 2002 aufgebraucht war. Dies bedeutet, dass diese Wirtschaftsweise einen großen Druck auf das Zamfara Reservat ausübt, in Bezug auf Nachhaltigkeit und ökologisches Gleichgewicht. Betrachtet man die Wachstumsrate der Tiere, so ergibt das

Modell, dass sich deren Anzahl in den nächsten zehn Jahren mehr als verdreifachen wird. Dies wird einen erheblichen Beweidungsdruck mit sich bringen, da bereits heute 76% der jährlich vorhandenen Biomasse von den Tieren als Futter benötigt wird. Unkontrollierte Beweidung sollte also möglichst vermieden werden, da dies dem Zamfara Weide-Reservat großen Schaden zufügen kann.
Das Modell zeigt desweiteren, dass Besteuerung von Tieren ein gutes Instrument ist, ein Gleichgewicht von vorhandenen Tieren und nutzbarer Weidefläche zu erreichen. Die Besteuerung könnte ebenfalls dazu führen, dass der Druck von Viehzüchtern aus dem Niger geringer wird, die immer wieder ihre Tiere in das Zamfara Reservat bringen.

Schlussfolgerungen und Empfehlungen und Vorschläge für weitere Studien

Basierend auf den empirischen Ergebnissen dieser Studie können folgende Politikempfehlungen gegeben werden. Es wurde in der Literatur gezeigt und mit dieser Studie belegt, dass Ackerbau ohne Maßnahmen zur Bodenfruchtbarkeitserhaltung zu Verarmung der Bodenfruchtbarkeit, Degradation und sinkender Produktivität führt. Daher muss die Staatsgewalt darauf drängen, dass solche Maßnahmen durchgeführt werden. Sie sollte auf jeden Fall die Landwirte auf die Möglichkeit der Dung-Verträge aufmerksam machen. Diese Aufklärung sollte vor allen Dingen in landwirtschaftliche Entwicklungsprojekte integriert werden. Die Mitarbeiter dieser Organisationen als auch die des Landwirtschaftsministeriums sollten Studien durchführen, um Landwirte im Zamfara Reservat dazu zu bringen, Dung-Verträge einzugehen. Um die Landwirte dazu zu ermutigen, müssen auf lokaler Ebene Institutionen geschaffen werden, die Hilfestellung bei Problemen in der Umstellungsphase auf Dung-Verträge leisten können.
Die Studie hat weiterhin gezeigt, dass Besteuerung von Tieren eine Möglichkeit ist, die stark ansteigende Zahl an Tieren in den Griff zu bekommen. Hierzu müssen die entsprechenden öffentlichen Stellen diese Steuer einführen und auch streng die Anwendung überwachen.
Weiterhin sollten die Landwirte und ebenso auch der Rest der Bevölkerung in öffentlichen Veranstaltungen darauf hingewiesen werden, wie wichtig eine intakte Umwelt für die Zukunft ist. So sollten lokale Institutionen gestärkt werden, um Landwirte dazu zu bringen, landwirtschaftliche Praktiken anzuwenden, die die Umwelt schützen bzw. eine nachhaltige Nutzung gewährleisten. Es sollte ebenfalls eine Übertragung des Managements des Reservates zu den lokalen und traditionellen Obrigkeiten in der Gegend stattfinden.
Auch müssen die Eigentumsrechte der Landwirte gesichert werden, denn wenn ihnen das Land langfristig gehört, dann sind sie auch bereit, Arbeitskapazität auf die nachhaltige Sicherung ihrer Ressourcen zu verwenden.

Eine Einschränkung dieser Studie ist sicherlich, dass die Daten nur aus einer Vegetationsperiode stammen und daher nur eine Querschnittsanalyse möglich war. Es wird daher empfohlen, weitere Studien in diesem Gebiet durchzuführen, um auch eine Zeitreihenanalyse anfertigen zu können. Solch ein Datensatz würde auch eine dynamische Modellierung möglich machen.

Zurzeit bestehen die Berechnungen der Wachstumsrate der Viehpopulation im Reservat nur aus den Angaben der dort sesshaften Viehzüchter und Agropastoralisten. Nomaden, die immer wieder mit ihren Tieren aus dem Niger in das Zamfara Reservat kommen, wurden nicht erfasst. Dies ist aber notwendig, um genauere Aussagen darüber zu machen, wie sich das Verhältnis zwischen Vieh und nutzbaren Weideflächen entwickelt. Dafür ist sicherlich ein längerer Beobachtungszeitraum und gesicherte Finanzierung nötig. Eine weitere Schwierigkeit, die dabei auftauchen könnte, wäre, dass eine grenzüberschreitende Zusammenarbeit von Forschern aus dem Niger und Nigeria notwendig ist.
Schlussendlich müssen auch noch der positive Effekt der Ernterückstände auf das Gewicht der teilnehmenden Tiere in den Dung-Verträgen quantifiziert werden. Hierfür ist eine Zusammenarbeit zwischen Sozioökonomen und Tierzüchtern sicherlich hilfreich. Dies kann helfen, um die tatsächlichen Vorteile zu messen, die ein Viehzüchter davon hat, an Dung-Verträgen teilzunehmen. In dieser Studie konnten nur Getreide- oder Geldzuwendungen erfasst werden.

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Appendix 1a:

$Title ZAMFARA MANURE CONTRACT MODEL
$OFFSYMXREF OFFSYMLIST

```
Sets c   Crops    / cowpea, cotton, gnut/
   fc  cropsc  /millet, sorghum/
   f   fertilization  /fert, dung/
   mc  fulani and his animals in manure contract activity /cattle, sheep, goat/
   t   time periods under consideration  /2001*2010/
   tfirst(t)  first year
   tlast(t)   last year;
   tfirst(t) = yes$(ord(t) eq 1);
   tlast(t) = yes$(ord(t) eq card(t));
Display tfirst, tlast;
```

Scalars

```
amlabour  amount of labour available for crops in hour                /1200/
labcost   labour cost per hour for activities in the area             /25.00 /
fertp     price of fertilizer in Naira per Kg                         /40 /
livp0     total number of livestock in the reserve in TLU             /250928/
Pastarea  total land area in the reserve for grazing (hectare)
/228190.44/
Landh     Land resource available to each household in ha             /6.15
/
Landt0    present total land area for cropping in the reserve
/7309.56/
Landtc    land area presently cropped based on croppers in the reserve
/3202.89/
cggift    grain given to the herders whose animals were camped on the field for
days  /100 /
avdcont   average day livestock camped on farm during contract        /7
/
beta2     annual rate of increase in livestock as percentage of herd  /.41
/
beta3     annual rate of livestock off-take through sales as percentage of herd
/.27/
inrla     annual pasture land encroachment for cropping activities in the reserve in
ha  /0.03/
housp     population per household in the reserve                     /9.00 /
wksoldh   number of man-hours of work sold out be the household members in
hours     /98  /
reservp0  population of people in the reserve in the base year        /
27000 /
```

beta1 annual increase in population as percentage of present
/0.03 /
tohoush total households in the reserve /1190 /
agrsize household farm size for agropastoralists in hectare /1.80
/
feacal manure released to pasture or farm as percent of feed in dry matter per TLU in Kg /.54 /
drmpastur dry matter generated per hectare of pasture in the study area per annum /3850 /
;

Parameters

Yields1(c) Yields of commercial crops (Kg per hectare)for contract croppers
/cowpea 487.46, cotton 1147.98 , gnut 226.38 /

Yields2(fc) Yields of grain crops grown for consumption
/millet 1019.12, sorghum 673.27/

Residuy1(c) Crop residues yields in (Kg per ha)
/ cowpea 2800, cotton 1600, gnut 1900/
Residuy2(fc) Crop residues yields of grain grown for consumption
/millet 2200, sorghum 2521/
consum(fc) food grain consumed per household member that must be produced
/ millet 90,sorghum 30 /
Pout1(c) prices of commercial crop outputs in Naira per Kg
/ cowpea 47.55, cotton 49.07, gnut 32.83/
laborc1(c) labour use (man hours per hectare) for commercial crops
/cowpea 100 ,cotton 112 ,gnut 90/
laborc2(fc) labour use (man-hours per hectare) for grain crops
/millet 94, sorghum 94/
land1(c) land use (hectares) for commercial crops
/ cowpea 1, cotton 1, gnut 1/
land2(fc) land use (ha) for grain crops
/ millet 1, sorghum 1/
seed1(c) seed input used per hectare for commercial crop production
/ cowpea 14, cotton 7, gnut 13/
seed2(fc) seed input used per hectare for grain grown for consumption
/millet 3, sorghum 5/
fert1(c) fertilizer used for each crop in Kg per ha
/ cowpea 5, cotton 12, gnut 5/
fert2(fc) fertilizer used for grain crops grown for household use
/millet 10, sorghum 10/
dung1(c) manure needed for commercial crop production
/ cowpea 372.30, cotton 400, gnut 372.30/

dung2(fc) manure needed for grain crops grown for home use
/millet 472.30, sorghum 472.30/
phcoms1(fc) prices of farm produce consumed by household
/millet 34.35, sorghum 32.55/
pseed1(c) prices of seeds for commercial crop inputs in Kg
/ cowpea 52.55, cotton 37.83, gnut 54.07/
pseed2(fc) prices of seeds for grain crops for home use
/ millet 39.35, sorghum 37.55/
linum(mc) number of livestock needed for manure contract
/cattle 50, sheep 10, goat 12/
dungv(mc) manure excreted per day in Kg dry matter during periods of camping on farm
/cattle 2.2, sheep 0.6, goat 0.4/
pastur(mc) daily pasture need of one TLU of livestock in dry matter Kg
/cattle 6, sheep 6, goat 6/
;

Parameters

pmill price of millet given to herders per Kg
pastures total pasture areas of the reserve
taxation the coefficient showing the effect of taxation on livestock population
tax the amount of tax in Naira imposed on cattle being grazed in the reserve
hfsize the highest farm size cultivated by households among the croppers involved in contract
thfsize0 total areas cropped by all the croppers' households in the area if all households were croppers
cattle the new cattle population due to the tax imposed;

pmill = 34.35;
pastures = 23500;
taxation = -30;
tax = 200;
hfsize = 1.922;
cattle = 250928;
thfsize0 = hfsize*tohoush;

Variables

Obj total net revenues from farm enterprise
hmgrainc minimum grain requirement of household that must be produced
mgrprod grain that must be produced by the farm household
hgrainb grain balance
tcropprd total commercial and grain crop production
ccroprev revenues from commercial crops
croprev revenues from crop production

laborc cost of labour expended on crop production
laborfc cost of labour for household grain production
tlaborc total cost of labour used by household
mbalc material balance crops
seedc Cost of seed for commercial crop production
seedfc cost of seed for grain production
fertcost cost of fertilizer used
tcroprev total crop gross revenues
cropc costs expended on crop production
cropnet total crop net revenues
residp quantity of residues produced by household
Crops1 level of cropping activities
Cropsc2 level of grain crops grown for home consumption
dungcont manure constraint for crop production
areacrop total area cropped in the reserve
worksold revenues from work done outside the household farm
valuegt values of grain given to the herder for seven days manure contract
manucont manure gained from the manure contract by the crop farmer
rmanust sustainability of manure production for cropping through contract
rcmanust sustainability of manure production for cropping through exchange based on area cropped by croppers
dungcont manure constraint for crop production
tbiomas quantity of biomass produced from the pasture yearly
stockn livestock stocking rate for the reserve
cattlu cattle population in TLU after tax introduction in the reserve
stockn1 stocking rate after tax introduction for grazing cattle in the reserve
Landt(t) changes in land expansion over the duration under consideration by agropastoralists
thfsize(t) changes in land expansion over the duration under consideration by croppers
livp(t) anticipated changes in livestock population over years
pastcont pasture dry matter constraint for livestock production in the reserve
pastcons pasture consumed in dry matter of the total biomass produced in the reserve
Croprd effects of organic manure application on crop yields
optcatc optimum numbers of cattle that could be available for contract based on cattle-household population
;
Positive variables hgrainc,
grprod,mbalc,croprd,tcropprd,ccroprev,croprev,laborc,laborfc,seedc,seedfc,fertcos
t,
cropc,cropnet,residp,dungcont,manucont,valuegt,worksold,areacrop,Crops1,crops
c2,residp,cropc,

tbiomas, Stockn, pastcont, pastcons, cattlu, stockn1, contopp, optcatc, rmanust,rcmanust,tlaborc,laborc;

Equations

QObj Objective function
Qhmgrainc equation of grain consumed by household
Qmgrprod equation of grain that must be produced by farm household
Qhgrainb equation of grain balance
Qccroprev equation of revenues from commercial crops
Qcroprev equation of revenues from crop production
Qtcropprd equation of total crop production
Qlaborc equation for crop labour cost
Qlaborfc equation of labour needed for grain production
Qtlaborc equation for total labour cost used by household
Qmbalc equation for material balance crops
Qseedc Costs of seed for crop production
Qseedfc equation of costs of seed for grain production
Qfertcost equation on the cost of fertilizer used
Qcroprev revenues from crop production
Qcropc costs incurred due to crop production
Qcropnet net revenues from crop production
Qresidp total crop residues produced by farmers that are needed for livestock production
Qlabcont labour constraint for crop production
Qlandcont land constraint for crop production
Qareacrop eqution of total area cropped in the reserve
Qdungcont manure constraint for crop production
Qworksold equation of revenues from work done outside the household farm
Qvaluegt values of grain given to herder for seven days manure contract
Qmanucont equation of manure gained from the manure contract by the crop farmer
Qrmanust equation of sustainability of manure production for cropping through exchange in the reserve
Qrcmanust equation of sustainability of manure production for cropping through exchange based on area cropped by croppers
Qdungcont equation showing manure constraint for crop production
Qtbiomas equation showing quantity of biomass produced from the pasture yearly
Qstockn equation of stocking rate in the reserve
Qcattlu equation of cattle population in TLU after tax introduction for grazing in the reserve
Qstockn1 equation of stocking rate after tax introduction for grazing cattle in the reserve

QLandt equation of the changes in land use over the period under consideration by agropastoralists
Qthfsize(t) equation of the changes in land use over the period under consideration by croppers
Qlivp(t) equation showing anticipated changes in livestock population over years
Qpastcont equation of pasture dry matter constraint for livestock production in the reserve
Qpastcons equation of pasture consumed in dry matter of the total biomass produced in the reserve
QCroprd equation showing the effects of organic manure application on yields
Qoptcatc equation of optimum numbers of cattle that could be available per contract based on cattle-household population
;

```
Qhmgrainc.. hgrainc =e= Sum(fc,consum(fc))*housp;
Qmgrprod .. grprod =e= Sum(fc,yields2(fc)*cropsc2(fc));
Qhgrainb.. grprod =g= Sum(fc,consum(fc))*housp;
Qmbalc .. mbalc =g= sum(c,yields1(c)*crops1(c)) +
Sum(fc,consum(fc))*housp;
QCroprd.. Croprd =e= Sum(c,yields1(c)*crops1(c));
Qtcropprd.. tcropprd=e= grprod + croprd;
Qccroprev.. ccroprev =e= Sum(c,yields1(c)*crops1(c)*pout1(c));
Qcroprev.. croprev =e= ccroprev + Sum(fc,consum(fc)*phcoms1(fc))*housp;
Qlaborc.. laborc =e= Sum(c,laborc1(c)*crops1(c))*labcost;
Qlaborfc.. laborfc =e= Sum(fc,laborc2(fc)*cropsc2(fc))*labcost;
Qtlaborc.. tlaborc =e= laborc + laborfc;
Qseedc.. seedc =e= Sum(c,seed1(c)*crops1(c)*Pseed1(c));
Qseedfc.. seedfc =e= Sum(fc,seed2(fc)*cropsc2(fc)*pseed2(fc));
Qfertcost.. fertcost =e= Sum(c,fert1(c)*crops1(c))*fertp +
Sum(fc,fert2(fc)*cropsc2(fc))*fertp;
Qcropc.. cropc =e= fertcost + seedfc + seedc + tlaborc + valuegt;
Qcropnet.. Cropnet =e= Croprev - cropc;
Qresidp.. residp =e= Sum(c,Residuy1(c)*crops1(c)) +
Sum(fc,Residuy2(fc)*cropsc2(fc));
Qlabcont.. Sum(c,laborc1(c)*crops1(c))+ Sum(fc,laborc2(fc)*cropsc2(fc)) =l=
amlabour;
Qworksold .. worksold =e= wksoldh*labcost;
Qlandcont.. Sum(c,land1(c)*crops1(c))+ Sum(fc,land2(fc)*cropsc2(fc)) =l=
Landh;
Qareacrop.. areacrop =e= Sum(c,land1(c)*crops1(c))
+Sum(fc,land2(fc)*cropsc2(fc));
Qvaluegt.. valuegt =e= cggift*pmill;
Qmanucont.. manucont =e= Sum(mc,linum(mc)*dungv(mc))*avdcont;
Qrmanust.. rmanust =e= Pastarea/Landt0;
```

```
Qrcmanust..  rcmanust =e= Pastarea/Landtc;
Qdungcont..  manucont =g= Sum(c,dung1(c)*crops1(c))+
Sum(fc,dung2(fc)*cropsc2(fc));
Qtbiomas..   tbiomas =e= Pastarea*drmpastur;
Qcattlu..    cattlu =e= cattle + taxation*tax;
Qstockn1..   stockn1 =e= Cattlu/Pastures;
Qpastcont..  tbiomas =g= Sum(mc,pastur(mc))*livp0;
Qpastcons..  pastcons =e= Sum(mc,pastur(mc))*livp0;
Qstockn..    Stockn =e= livp0/Pastarea;
Qoptcatc..   optcatc =e= livp0/tohoush;
QLandt(t + 1).. Landt(t + 1) =e= Landt(t) + Landt(t)*inrla ;
Qthfsize(t + 1).. thfsize(t + 1) =e= thfsize(t) + thfsize(t)*inrla ;
Qlivp(t + 1)..   livp(t + 1) =e= livp(t) + livp(t)* beta2 - livp(t)*beta3;
QObj ..    Obj =e= Cropnet + worksold ;

Model  Manure /all/;
Landt.lo(t) = Landt0; Landt.fx(tfirst) = Landt.lo(tfirst);
thfsize.lo(t) = thfsize0; thfsize.fx(tfirst)=thfsize.lo(tfirst);
livp.lo(t) = livp0; livp.fx(tfirst)= livp.lo(tfirst);

Option LIMROW = 0;
Option LIMCOL = 0;
Option RESLIM = 5000;
Solve manure using LP maximizing Obj;
```

Appendix 1b:

```
$Title ZAMFARA MIXED FARMING MODEL-a1
$OFFSYMXREF  OFFSYMLIST
Sets    c  Crops   / cowpea, cotton, gnut/
        fc  cropsc  /millet, sorghum/
        f  fertilization  /fert, dung/
        l  livestock      /cattle, sheep, goat/
        lv  livestock veterinary
          /Vetcattle, vetsheep ,vetgoat/
       li  livestock inputs / ration, pasture, residue/
       t  time periods under consideration  /2001*2010/
     tfirst(t)  first year
     tlast(t)   last year;
    tfirst(t) = yes$(ord(t) eq 1);
    tlast(t) = yes$(ord(t) eq card(t));
Display tfirst, tlast;
```

Scalars

amlabour amount of labour available for crops in hours /800/
amlabourl amount of family labour available for livestock in hours /2300/
labcost labour cost per hour for activities in the area /25.00 /
fertp price of fertilizer in Naira per Kg /40 /
livp0 total number of livestock in the reserve in TLU /250928/
Aliv total livestock owned by agropastoralists in TLU /13328/
Alivh Numbers of livestock owned by agropastoralist in TLU /11.20/
adungp recovable annual dung production in Kg per annum per TLU /200.75/
Pasture total land area in the reserve for grazing (hectare) /228190.44/
tration total ration available for livestock production per household /2680 /
rationp price of feed ration per Kg /10.00/
dration daily ration need by TLU in Kg dry matter / 5 /
Landh Land resource available to each household in ha /6.15 /
Landt0 present total land area for cropping in the reserve /7309.56/
beta2 annual rate of increase in livestock as percentage of herd /.41 /
beta3 annual rate of livestock off-take through sales as percentage of herd /.27/
inrla annual pasture land encroachment for cropping activities in the reserve in ha /0.03/
housp population per household in the reserve /14 /
Hoffrev average household off-farm revenue /234.63/
reservp0 population of people in the reserve in the base year / 27000 /
beta1 annual increase in population as percentage of present /0.03 /
wsoldh number of man-hours of work sold out be the household members in hours /10 /
tohoush total households in the reserve /1190 /
agrsize household farm size for agropastoralists in hectare /2.80/
feacal manure released to pasture or farm as percent of feed in dry matter per TLU in Kg /.54 /
milksold total money realised from the sales of milk in Naira per household /7136.71/
drmpastur dry matter generated per hectare of pasture in the study area per annum /3850 /
;

Parameters

Yields1(c) Yields from crops (Kg per hectare) for agropastoralists
/ cowpea 635.53, cotton 459.23 , gnut 127.33 /
Yields2(fc) Yields of grain crops grown for consumption
/millet 715.95, sorghum 627.90/
Residuy1(c) Crops residues yields in (Kg per ha)
/ cowpea 2800, cotton 1600, gnut 1900/
Residuy2(fc) Crop residues yields of grain grown for consumption
/millet 2200, sorghum 2521/
consum(fc) food requirement per family member per annum in Kg
/ millet 70, sorghum 30/
pout1(c) prices of commercial crop outputs per Kg
/ cowpea 47.55, cotton 49.07, gnut 32.83/
pout2(fc) price of home consumed grain in Kg
/millet 34.35, sorghum 32.55/
seed1(c) seed input used per hectare for crop production
/ cowpea 14, cotton 7, gnut 13/
seed2(fc) seed input used for grain for household
/millet 3, sorghum 5/
laborc1(c) labour use (man-hours per hectare for crop production)
/ cowpea 90, cotton 88, gnut 87/
laborc2(fc) labour use (man-hours for household grain production)
/ millet 85, sorghum 85/
fert1(c) fertilizer required for each crop in Kg per ha
/ cowpea 6, cotton 15, gnut 6/
fert2(fc) fertilizer used for household grain production
/millet 13, sorghum 13/
dung1(c) manure needed for crop production
/ cowpea 450.30, cotton 550, gnut 472.30/
dung2(fc) manure needed for household grain production
/millet 492.30, sorghum 492.30/
land1(c) land required for crop production in ha
/ cowpea 1, cotton 1, gnut 1/
land2(fc) land requirement for household grain production
/millet 1, sorghum 1/
Pseed1(c) price of seed inputs in Kg
/ cowpea 52.55, cotton 37.83, gnut 54.07/
pseed2(fc) price of seed inputs for household grain production
/millet 39.35, sorghum 37.55/
Phcoms1(fc) prices of farm produce consumed by the household use
/millet 34.35, sorghum 32.55/
rlinum(l) total number of each type of livestock in the reserve in TLU by types
/cattle 302400, sheep 17360, goat 12880/

linum(l) number of each type of livestock owned in TLU by agropastoralist
/cattle 9.40, sheep .8, goat 1.0 /
livet(l) Veterinary cost expenses on livestock in TLU expended by the agropastoralist
/cattle 300, sheep 300, goat 300/
labourl(l) Labour use per TLU (man hours per livestock) per annum
/cattle 175, sheep 175,goat 175 /

lisold(l) number of livestock heads sold by type
/ cattle 2, sheep 4 , goat 6/
pliv (l) prices of livestock per head
/cattle 30000 , sheep 5000 , goat 3000 /

resid(l) daily crop residues need for one TLU of livestock in Kg dry matter
/cattle 6, sheep 6, goat 6/
pastur(l) daily pasture need of one TLU of livestock in dry matter Kg
/cattle 6, sheep 6, goat 6/

Parameters

taxation the coefficient showing the effect of taxation on livestock population
tax the amount of tax in Naira imposed on cattle being grazed in the reserve;

taxation = -30;
tax = 440;

Variables

Obj total net revenues from farm enterprise
hgrainc minimum grain requirement of household that must be produced
grprod grain that must be produced by the farm household
tcropprd total commercial and grain crop production
tcroprd total commercial crop production
ccroprev revenues from commercial crops
Croprd crop production
laborc cost of labour expended on crop production
laborfc cost of labour for household grain production
tlaborc total cost of labour used by household
mbalc material balance crops
seedc cost of seed for commercial crop production
seedfc cost of seed for home consumed grain production
fertcost cost of fertilizer for crop production
croprev crops gross revenues
cropc costs expended on crop production
landcont land constraint for crop production
cropnet crop net revenues

residp quantity of residues produced by household
crops1 level of commercial crops cropping activities in ha
cropsc2 level of grain crops grown for home consumption in ha
dungcont manure constraint for crop production
areacrop total area cropped in the reserve
worksold revenues from work done outside the household farm
livrev revenues from livestock and milk sales
laborl cost of labour expended on livestock production
livrcost costs expended on ration for livestock production
livvetc cost of veterinary expended on livestock
totlivc total expenses incurred on livestock production
livnet livestock net revenues
agcattlu population of agropastoralists herd after tax
dungb total quantity of manure produced by household animals
dungh manure quantity used per hectare for cropping
livlab labour constraints for livestock production
ratcont ration constraint for livestock production
livbal end of year livestock balance in the farmer's households
residcont crop residues constraint for livestock production
Landt(t) changes in land expansion over the duration under consideration
livp(t) anticipated changes in livestock population over years
astock livestock stocking rate within the agropastoralists farm
totrev total revenues from farm enterprise
;
Positive variables laborc,
seedc,seedfc,grprod,tcropprd,croprd,laborfc,tlaborc,mbalc, croprev,
cropc, cropnet, residp, dungcont, livrev,laborl, livrcost, livvetc,totlivc, livnet,
dungb,
dungh,areacrop, livlab,livbal, ratcont, residcont, dungcont,worksold, astock,
totrev, agcattlu,
seedfc,fertcost,hgrainc,crops1,cropsc2,ccroprev;

Equations

QObj Objective function
Qhmgrainc equation of minimum grain requirement for farm household
Qmgrprod equation of grain that must be produced for household need
Qhgrainb equation of grain balance
Qtcropprd total commercial and grain crop production
QCroprd equation showing the effects of organic manure application on yields
Qtcroprd equation for total commercial crop production
Qccroprev equation of revenues from commercial crops
Qlaborc equation for commercial crops labour cost
Qlaborfc equation for the grain production labour cost

Qtlaborc equation for total labour cost
Qmbalc equation of material balance
Qseedc eqution for costs of seed for commercial crop production
Qseedfc equation for cost of seed for home comsumed grain production
Qfertcost equation for cost of fertilizer for crop production
Qcroprev revenues from crop production
Qcropc costs incurred due to crop production
Qcropnet net revenues from crop production
Qresidp total crop residues produced by farmers that are needed for livestock production
Qlabcont labour constraint for crop production
Qlandcont land constraint for crop production
Qareacrop eqution of total area cropped in the reserve
Qdungcont manure constraint for crop production
Qworksold equation of revenues from work done outside the household farm
Qlivrev revenue from livestock production
Qlaborl cost of labour expended on livestock production
Qlivrcost cost incurred on ration due to livestock production
Qlivnet net revenues from livestock production
Qagcattlu equation of population of agropastoralists herd after tax
Qdungb total manure produced by household animals
Qdungha equation of manure quantity used per hectare
Qlivlab labour constraint for livestock production
Qlivvetc equation of veterinary expenses on livestock
Qtotlivc equation of total expenses incurred on livestock production
Qratcont ration availability constraint for livestock production
Qlivbal equation representing end of year livestock balance in the household
Qresidcont crop residues constraint for livestock production
QLandt(t) equation of the changes in land use over the period under consideration
Qlivp(t) equation showing anticipated changes in livestock population over years
Qastock equation of livestock stocking rate within the agropastoralists farm
Qtotrev total revenues from the farm enterprises

,

```
Qhmgrainc..  hgrainc =e= Sum(fc,consum(fc))*housp;
Qmgrprod ..  grprod =e= Sum(fc,yields2(fc)*cropsc2(fc));
Qhgrainb..   grprod =g= Sum(fc,consum(fc))*housp;
Qmbalc ..    mbalc =g= sum(c,yields1(c)*crops1(c)) +
Sum(fc,consum(fc))*housp;
QCroprd..    Croprd =e= Sum(c,yields1(c)*crops1(c));
Qtcroprd..   Sum(c,yields1(c)*crops1(c))=l= mbalc;
Qtcropprd..  tcropprd=e=  grprod + croprd;
Qccroprev..  ccroprev =e= Sum(c,yields1(c)*crops1(c)*pout1(c));
```

```
Qcroprev..   croprev =e= Sum(c,yields1(c)*crops1(c)*pout1(c) +
Sum(fc,consum(fc)*housp*phcoms1(fc)));
Qlaborc..    laborc =e= Sum(c,laborc1(c)*crops1(c))*labcost;
Qlaborfc..   laborfc =e= Sum(fc,laborc2(fc)*cropsc2(fc))*labcost;
Qtlaborc..   tlaborc =e= laborc + laborfc;
Qseedc..     seedc =e= Sum(c,seed1(c)*crops1(c)*Pseed1(c));
Qseedfc..    seedfc =e= Sum(fc,seed2(fc)*cropsc2(fc)*pseed2(fc));
Qfertcost..  fertcost =e= Sum(c,fert1(c)*crops1(c))*fertp +
Sum(fc,fert2(fc)*cropsc2(fc))*fertp;
Qcropc..     cropc =e= fertcost + seedfc + seedc + tlaborc;
Qcropnet..   Cropnet =e= Croprev - cropc;
Qresidp..    residp =e= Sum(c,Residuy1(c)*crops1(c)) +
Sum(fc,Residuy2(fc)*cropsc2(fc));
Qlabcont..   Sum(c,laborc1(c)*crops1(c))+ Sum(fc,laborc2(fc)*cropsc2(fc)) =l=
amlabour ;
Qworksold .. worksold =e= wsoldh*labcost;
Qlandcont..  Sum(c,land1(c)*crops1(c))+Sum(fc,land2(fc)*cropsc2(fc)) =l=
Landh;
Qareacrop..  areacrop =e= Sum(c,land1(c)*crops1(c))+
Sum(fc,land2(fc)*cropsc2(fc));
Qdungcont..  dungcont =g= Sum(c,dung1(c)*crops1(c))+
Sum(fc,dung2(fc)*cropsc2(fc));
Qlivrev..    livrev =e= Sum(l,lisold(l)*pliv(l)) +milksold;
Qlaborl..    laborl =e= Sum(l,labourl(l)*linum(l))*labcost;
Qlivrcost..  livrcost =e= Sum(l,linum(l))* dration *42*rationp;
Qlivvetc..   livvetc =e= Sum(l,linum(l)*livet(l));
Qtotlivc..   totlivc =e= laborl + livrcost + livvetc;
Qlivnet..    livnet =e= livrev - totlivc;
Qagcattlu..  agcattlu =e= Aliv + taxation * tax;
Qdungb..     dungb =e= Sum(l,linum(l))*adungp;
Qdungha..    dungh =e= Sum(l,linum(l))*adungp/Landh;
Qlivlab..    Sum(l,labourl(l)*linum(l)) =l= amlabourl ;
Qratcont..   Sum(l,linum(l))*dration*42 =l= tration;
Qresidcont.. residp =g= Sum(l,resid(l)* linum(l))*150;
Qlivbal..    livbal =e= Alivh + Alivh*beta2 -Alivh*beta3;
QLandt(t + 1).. Landt(t + 1) =e= Landt(t) + Landt(t)*inrla ;
Qlivp(t + 1)..  livp(t + 1) =e= livp(t) + livp(t)* beta2 - livp(t)*beta3;
Qtotrev ..   totrev =e= Croprev + livrev;
Qastock..    astock =e= Alivh/agrsize;
QObj ..      Obj =e= Cropnet + livnet + worksold ;
Model Zamfara /All/;
Landt.lo(t) = Landt0; Landt.fx(tfirst) = Landt.lo(tfirst);
livp.lo(t) = livp0; livp.fx(tfirst)= livp.lo(tfirst);
```

Option LIMROW = 0;
Option LIMCOL = 0;
Option RESLIM = 5000;
Solve Zamfara using LP maximizing Obj;

Appendix 2 Questionnaires

Appendix 2a. Croppers questionnaire.

Questionnaire for Croppers.

A. General.

1. Date.....
2. Number of questionnaire.....
3. State..... Community.....
4. Name of the farmer.....
5. Tribe of the farmer.....
6. Level of education attained a). No formal education. b). primary education. c). secondary education. d). post-secondary education.

Family members					
Wife.(1).					
(2).					
(3).					
Children:	Sex		Age		
	M	F	<15	>15	Which of these participate in farm works?
1).					
2).					
3).					
4).					
5).					
6).					
7).					
8).					
9).					
10).					
Others and state relatives living in your household:					
1).					
2).					
3).					
4).					

7. Other occupations engaged in by the farmer.....
8. Marital Status:(1). single.....(2). married.....(3). divorced.....(4).widowed.....
9. If married, fill in the table below.

10. How many members of your family have migrated this year to another community?.....
11. What are the reasons for their movement? 1).....
2).....3).....
....
12. How many people have joined your family this year from another community?.....
13. What are their reasons for joining you from another community?
1).....
2).....3).....
.....

B. Farm Resources/Assets.

1. How many fields do you have?..... Please, list them in the table below as well as the ownership system of these fields.

Fields	Crop(s) planted or fallow	Field size	Ownership system
1			
2			
3			
4			
5			
6			
7			
8			
9			

NB: Ownership systems could be (a). purchased (b). inherited (c). rented,(d). leased (5). Gift.
2. Do you have reasons for leaving those fields fallow? Yes..... No.....
3. If yes to the above, please, give those reasons below:
(a).....
(b).....
(c).....
(d).....

C. Sources and Items of Expenditures on Cropping Activities.

Items of Expenditures	Expenses in (N) on									
	Millet		Sorghum		Maize		Cowpeas		G/nut	
1. Seeds procurement										
2. Land clearing-family/hired labour?										
3. Ridging by hand-family/hired labour?										
Ridging by draft power.										
4. Planting-family/hired labour?										
5. First weeding-family/hired labour?										
6. Manure and application.-family/hired labour?										
7. Fertilizers and types										
8. Fertilizer application-family/hired labour?										
9. Second weeding/hand or draft power.-family/hired labour?										
10. Harvesting-family/hired labour?										
11. Shelling-family/hired labour?										
12. Transportation										

14. Are you involved in the production of other crops? Yes .....No.....
15. Can you list those crops?.....
.....
16. Do you have problems of fertilizer availability in your community? Yes.....No.....
17. If yes, what do you think is the solution?.....
.....
18. If no, do you have problems of getting money to buy the commodity?
Yes.....No.....
.....

D. Yields of the major crops grown by the farmers.

Year/Yield	Millet	Sorghum	Maize	Cowpeas	G/nut	Others
2000						
Yields						
Market price						
2001						
Yields						
Market price						

E. Manure Contract.

1. Are you aware of manure contracts between croppers and herders? Yes……..No……..
2. If yes to the above, have you been participating in the contract arrangement? Yes……No……
3. If you have been participating, is it you that normally invites the herders to camp in your field or does the herder approach you first?

……
……
….

4. Pease, fill the table below with respect to the manure contract you have participated in.

Types of animals	Number	Days stayed on field	Amount of residues received: 1.bundle;2.transported;3.bulk			Amount of grain received in bag(Kg)	Payment in cash and amount in (N).
			Quality 1	Quality 2	Transported residues		

5. If you invite him to stay on your farm, how many animals must the herder have to make the arrangement possible?
6. For how long must the animals stay on the farm?……
7. Do you think such a contract exchange is a profitable exercise? Yes……../No…….
8.Will you prefer buying with money to this practise? Yes……/No……

9.What motivates you to carry out a manure contract with a particular herders? (a). former contract relationship. (b).Tribal closeness. (c). Established trust. (d). Because other farmers do it (e). Other reasons
(specify).....
.....
10. How long have you been engaged in manure contracting?.....
11.When did you apply manure last on your present field?.....
12. How frequently do you apply manure on your field? (a).yearly. (b). every two years. (c). every three years.
13. Have you ever been involved in conflicts over the manure contract arrangement with the herders? Yes...../No.....
14. If yes, what was responsible?.....
.....
15. What was the nature of the conflict involved?.....
.....
16. Who helped to resolve such a conflict? (a). Elders. (b). Local chiefs. (c). Police
17. Was payment of compensation involved? Yes...../No.....
18. If yes, how much did you receive? (N).....

F. Stubble Grazing Contract.

1. Are you aware of stubble grazing contracts? Yes...../No.....
2. If yes, have you been involved in this contract arrangement with herders? Yes...../No.....
3. If yes, how do you choose the person to do the contract with?.....
.....
4. What factors determine the person to be chosen?(a).....(b).....
..
(c).....
.....
5. What time of the year do you normally get involved in this contract?.....
6. Do you remove parts of the crop residues before you do the contract ? Yes...../No.....
7. If yes, what percentage of the residues are left on the field for the contract?.....

7. How many types of crop residues are on the field when the contract takes place? (a).....(b).....(c).....(d).....

9. Please, fill the table below with respect to this contract and specify which of the options below have been adopted by the herder in paying you for the stubbles grazed on your field:

Types of animals	Numbers	Days stayed on field	Quantity and quality of residues on field	Size of field in ha	Mode of payment		
					Grain quantity in local weight	Payment by money and amount(N)	Other payment

10.What types of contract do you prefer?(a).Manure/residues. (b).Stubble/money. (c).Stubble/grain. (d)Manure/milk. (f).Others,
Specify.....
11.Why do you prefer the chosen contract above?.....
.....
.....
12. Has the stubble grazing arrangement helped to reduce conflicts between you and the herders operating in your area? Yes...../No.....
13. Is water availability an important factor in determining whether or not a contract will take place? Yes...../No.....
14. Are there obstacles to the smooth operation of this contract? Yes...../No.....
15. What could be done to remove such obstacles?.....
.....

G. Labour work done by family members outside the farm.

1. Do your family members engage in labour work outside the farm to earn wages? Yes...../No.....
2. If yes, please, fill in the table below:-

No	Family members	Types of work done	No of weeks	Amount earned in (N)
1				
2				
3				
4				

H. Credit Market.

1.Where do you get money for your production activities?

a). personal savings . b). formal financial institution. c). from friends. d). from informal money lenders. e). cooperative organisations .
2. If you have been obtaining credit to carry out your production activities, please, fill in the table below:

Credit Organisations	Nature of Credit*	Collateral needed?	Guarantor needed?	Animals needed?	Annual interest rate (%)
Commercial Banks					
Agric. Bank					
Money lender					
From relations					
Other:					

*Nature could be either money = 1, or inputs = 2.
3. Are there other conditionalities for obtaining credit? Yes...../No.....
4. If there are, what are they?
a).....b).....c).....
.....d).....
5. Has it always been easy for you to obtain credit ? Yes...../No.....
6. If no to the above, what are the problems? (no collateral=1, no guarantor=2, high interest rate =3, too much time wasted on application =4, no personal land =5, others =6).
7. When you obtain credit, what do you normally use such a credit for? a). production . b) consumption. c).festival. d). marry more wives. e). other family matters.

Appendix 2b: Questionnaire for Agropastoralists

A. Questionnaire for Livestock Farmers (Pastoralists).

1. State.....2. Community.....
3. Name of the farmer.....
4. Tribe of the farmer.....
5. Sex : Male .....Female.....
6. Level of education attained: (a) No formal education. (b). Koranic education. (c). Primary education. (d). Secondary education. (e). Post-secondary education.
7. Other occupations engaged in by the respondent:.....
8. Are the animals you tend your own ? Yes...../No.....
9. If not all are yours, how many belong to other people?.....
10. How do the people keeping animals with you pay you for your effort? (a) with animals. (b). with money. (c). with other
explain.....
11. If with animals, in what proportion of the animals you tend is the animals given to you? (I do not understand the
question).....
12. Marital status of the respondent. (a). single... (b). married....(c). divorced....(d). widow...
13. If married, please, fill in the table below:-

Family members					
Wife					
Wife					
Wife					
Children	Sex		Age		
	M	F	<15	>15	Which of these participate in farm works?
1.					
2.					
3.					
4.					
Others and relatives living in your household.					
1.					
2.					
3.					

14. How many people have left your household this year for another community?.....
15. What are their reasons for leaving for another community? 1).....

2).....3).....
...
16. How many people have joined your household this year from another community?.....
17. What are their reasons for joining your community?
1).....
2).....3).....

B. Farm Assets Possessed.

Please, list in the table below assets possessed for your farm operation.

Assets owned	Year purchased and amount (N)	How much does this asset cost now in the market?(N)	For how long can you use this asset in yrs. ?	How much do you spend to maintain this asset.?(N)

C. Types of farm animals possessed.

Please, give in the table below the types of farm animals you have.

Types		Number	Number Calf/year	Milk prod/day Bucket or (Lit)	Manure prod/day Bucket or (Kg)	Milk price/lit or Bucket (N)	Manure price/Kg or Bucket/bag/ Cart/ Donkey load/mangala (N)
Cattle	M						
	F						
Donkey	M						
	F						
Sheep	M						
	F						
Goats	M						
	F						
Camel	M						
	F						

Please, choose from below your reason for keeping animals with cropping.

a). I have a large family and so labour is available
b). It is our traditional way of production
c). Because it increases food availability
d). As a means of savings,

e). Because it makes manure available
f). It provides traction power
g). It helps me to generate more income

Please, give in the table below the types of farm animals sold this year.

Types		Number	Price / animal in (N) and sales at optimum price	Price in (N) and sales at the lower price period	Total no sold	Price/calf in (N) and sales at optimum price	Price/calf and sales at the lower price period	Total no of calf sold
Cattle	M							
	F							
Donkey	M							
	F							
Sheep	M							
	F							
Goats	M							
	F							
Camel	M							
	F							

D. Expenses expended on Animal production.

Please, fill in the table below the expenses on your animals.

Types of livestock	Number	Number of hrs expended on grazing per day						Amount paid to hired labour/day		Crop Residues purchased per/ week		Price of residues N/ Kg		Veterinary Expenses in (N)
		By self		Children		Hired labs		Or contract labour? How paid?		Typ 1	Typ 2	Typ 1	Typ 2	
		Rs	Ds	Rs	Ds	Rs	Ds	Rs	Ds					
Cattle														
Donkey														
Sheep														
Goats														
Camel														

E. MANURE CONTRACT

1. Are you aware of manure contracts? Yes...../No.....
2. In which periods of the year is manure contracting a common activity?.....
From.....to.....?
3. Have you ever been involved in manure contracts with croppers? Yes...../No.....
4. When was the last contract you participated in?.....
5. Please, fill in the table below in respect of the said contract:

Types of animal(s)	Number	Number of days stay on field	Amount of residues received in bundles, transport or bulk(field)? and types			Or amount of grain received in bags (Kg.)	Payment in cash and amount(N)
			Quality 1	Quality 2	Transport residues		

6. Did the animals stay on the farm day and night throughout .....Or only in the night.....?
7. Where were the animals grazing in the day when you were camping them on that field?.....

8. Is it you that approaches the farmer to request for the contract? Yes...../ No.....
9. Or does the farmer approach you mostly? Yes...../ No.....
10. Do you consider manure –residues/grain contract a profitable arrangement?
Yes...../No.....
11. If yes to the above question, can you give your reasons? (a).....
(b).....(c).....
12. If no, can you please give reasons? (a).....
(b).....(c)...
.....
.....
13. Will you prefer buying grain with money to this type of exchange?
Yes...../No.....

F. Stubble Feeding Contract

1. Are you aware of the stubble contract grazing? Yes...../No.....
2. Have you been grazing your animals on stubble? Yes...../No.....
3. If yes, do you have the right to freely graze your animals on farms in your areas?
Yes...../No.....
4. If no, how do you arrange with the farmers to have your animals grazed on their farm stubbles?.....
.....
.....
.....
5. If you have been involved in stubble grazing, how frequently are you involved?.....

6. If you are involved in such a contract , please, fill in the table below

Types of animals	Numbers	Number of days stayed on field	Quantity and quality of residues left on field	Size of field in acres/ha	Mode of payment		
					Manure(Kg) or Local Ms	Money(N)	Other methods
Cattle							
Camels							
Sheep							
Goats							

7. What time of the year did the stubble contract take place?.....
8. What is the quality of the crop residues on the field when the contract takes place?..... 9. How many types of crop residues were on the field when the contract takes place?..... ...
.....
.....

10. What type of contract do you prefer ? (a). Manure/residues (b). Stubble/money (c). Stubble/grain (d). Manure/money (e). Stubble/milk (f). Other specify.....
11. Why do you prefer the chosen contract above?.....
.....
.....
12. Has contracting between you and the croppers helped to reduce conflicts over the years? Yes...../No.....
13. Does water availability in an area play any role in contract arrangements? Yes...../No.....

14. Which crop residues are most attractive to you for contract?.....

G. Feeds and feedings.

1. Where do you normally graze your animals in the rainy season?.....
2. How distant away do you take the animals out for grazing?.....Km in the rainy season?
3. Where do you graze your animals in the dry season?.....
4. How distant away do you take your animals out for grazing in the dry season?.....
5. How would you score the quality and quantity of forage from which you graze your animals
   1) sufficient .....2) insufficient.....3) Don't know.....
6. Can you give a rough composition of the species of this forage?.
   .....
   .....
   .....

7. How do you get feed for your livestock in times of scarcity?.
   a). By supplementation with purchased concentrates
   b). By giving them crop residues
   c). Migration to other areas like.....
   d). combinations of all of the above....
8. If you give supplementary feeds to your animals, how much do you spend on such supplements per week?.....
9. Please, give the following information on feed supplementation:

Markets	Types of feeds	Quantity Local Unit	Amount (N)	For which animals	For how long	Total Qt.	Transport costs (N)	Total costs(N)

10. How far from the settlement do you take your animals out for grazing?.....Km(approx)
11. Is the herd split .....or are all of the animals grazed together?.....

12. Do you engage your family members in the grazing exercise? Yes.....No.....
13. If your family members are engaged, please, fill in the table below:

Family Members	Number	Task performed	Duration in Hr/day
Adult male			
Adult female			
Grown –up male			
Grown-up female			
Children			

14. For how long do you take your animals out for grazing in the dry season?.....hours – in the rainy season.....hours
15. Is getting labour to graze your animals a problem for you? Yes.....No.....
16. If yes to the above, in which part of the year?.....
17. And who does the grazing at this period?
    a. family members (state relationship).....
    b. hired labours.....
    c. Animals allowed to wander on their own.....
18. If hired labours are used, how do you pay them per hour or day?
    1. in cash.....
    2. in kind.....
19. If they are paid by cash, how much do you pay per day? N.....
20. If by kind, state articles of gift and quantities.....

H. Labour work done by family members outside the farm.

1.Do your family members engage in labour work outside the farm to earn wages?
Yes...../No.....

2.If yes, please, fill in the table below:-

No	Family members	Types of work done	No of weeks	Amount earned in (N)
1				
2				

I. Data on Animals Prices .

Types of Animals		Age of animal in years	Price per head (N)
Cattle	Bull		
	Cow		
Camel	Male		
	Female		
Sheep	Male		
	Female		
Goats	Male		
	Female		
Donkey	Male		
	Female		

J. Seasonal Migration with Livestock.

1. Do you normally move at any particular period of the year with your animals to other parts of the country? Yes...../No.....
2. If yes, what are your reasons for such a movement?
(a).....(b).....(c).....
.....(d).....
.....
3. In which month of the year do you migrate in the dry season?.....
4. How far do you move away from your present settlement?.....
5. What time do you come back to your present settlement?.....
6. What are your reasons for coming back?.....
7. Do you also migrate during the dry season? Yes...../No.....
8. If yes, why are you involved in such a migration?.....
9. Which month of the year do you migrate during the rainy season?.....
10. When do you normally come back from such a migration?.....
11. What are your reasons for coming back from such a migration?.....
.....
12. Do you consider migration to be of any advantage to your animals? Yes...../No.....
13. If yes, what are they?
(a).....
(b).....

K. Credit Market.

1. Where do you get money for your production activities?
a). personal savings. b). formal financial institutions. c). from friends. d). from informal money lenders. e). cooperative organisations .
2. If you have been obtaining credit to carry out your production activities, please, fill in the table below:

Credit Organisations	Nature of Credit*	Collateral needed?	Guarantor needed?	Animals needed?	Annual interest rate (%)
Commercial Banks					
Agric. Bank					
Money lender					
From relations					
Other:					

*Nature could be either money =1, or inputs =2.

3. Are there other conditionalities (institutions?) for obtaining credit? Yes...../No.....

4. If there are, what are they?

a).....b).....c).....

.....d).....

5. Has it always been easy for you to obtain credit ? Yes...../No.....

6. If no to the above, what are the problems? (no collateral=1, no guarantor=2, high interest rate =3, too many time wasted on application =4, no personal land =5, others =6).

7.When you obtain credit, what do you normally use such a credit for? a). production. b). consumption. c). festival. d). marry more wives (or "another wife", I suppose this is more usual). e). other family matters.