# FARM ORGANIZATION AND RESOURCE PRODUCTIVITY: ANALYSIS OF INTEGRATED CROP-LIVESTOCK FARMING SYSTEMS IN KATSINA STATE, NIGERIA

BY

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## DECLARATION

I hereby declare that this thesis now submitted for the doctor of philosophy degree (Agricultural Economics) of Ahmadu Bello University is the record of my own research work, except where reference is made to published literature and duly acknowledged. It had not been presented before in whole or in part for any other qualification.

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## CERTIFICATION

This thesis entitled "Farm organization and resource productivity: analysis of integrated crop-livestock farming systems in Katsina state" by Shukurat Adunni Sanni meets the requirements governing the award of the degree of doctor of philosophy of Ahmadu Bello University, Zaria, and approved for its contribution to scientific knowledge and literary presentation.

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## DEDICATION

This dissertation is dedicated to the LOPD GOD ALMIGHTY who is the giver of knowledge and wisdom.

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ABSTRACT

The purpose of this study is to assess ways of intensifying crop and livestock production in Katsina state through an examination of farm level reorganization of resources and activities in the integrated crop-livestock system. Data were collected from 120 households in six villages of the state using structured questionnaire. The tools of analysis used were simple descriptive statistics; farm business analysis, profit function and Linear and mixed programming models.

Households in the study area operated under a relatively secure tenurial arrangement as most of them owned the plot of land they cultivated, In terms of household labour supply, about 56%, 66% and 66% of the household members in zones 1, 2 and 3 respectively were capable of providing the family labour force. The farming systems in all the zones were still relatively traditional as most of the households relied heavily on work bulls and hand implements. Crops produced were predominantly cereal and legume based. Work bulls were kept mainly for cultivation purposes while sheep and goats were kept mainly for meeting household cash needs. Manure is becoming increasingly important for soil improvement in the study area due to the high cost of inorganic fertilizers.

There were about 59%, 17% and 46% increases in gross margins of the integrated systems over the crop-based production systems of zones 1, 2 and 3 respectively. Efficiency of resource utilization was higher for the integrated crop-livestock systems than the crop-based systems of zones 1 and 3 while the reverse was the case in zone 2. The crop-based production systems were relatively more capital intensive in production while the integrated systems

were relatively more labour intensive. The integrated farms in zones 1 and 3 were technically and economically more efficient than the corresponding crop-based farms.

The optimum farm plans of the basic models show that higher productivity and more revenue could be achieved by reorganizing resources and activities in the integrated crop-Avestock production systems. Crop was the major source of farm income in the integrated crop-livestock systems. Land was the most limiting resource in both production systems. Labour was a constraint to production in the peak labour demand periods of May-August and September-December.

When land was not limiting, but capital and labour were restricted, crop-based production systems were more favoured in terms of efficiency of land utilization. As labour became limiting at a given level of land, livestock size and capital, the livestock activities were reduced or eliminated from the optimum plan. The inference from the results of the sensitivity analysis is that integrated crop-livestock production systems favour a low-resource base situation. Policy choice should therefore be geared towards tackling the constraints that would militate against the achievement of optimum benefit from integrated crop-livestock production system.

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## CHAPTER I

# INTRODUCTION

### 1.1 Background

Nigeria has considerable potential for agricultural production in terms of resource endowment as well as prevailing ecological condition. It is generally believed that the available land in the country is more than adequate for the attainment of self sufficiency in both crop and livestock production. The available land area in Nigeria is estimated at 98.3 million hectares, out of which 72% is considered as potentially cultivable but only about 40% is currently under cultivation (World Bank, 1993). Despite this, agriculture still remains the main stay of the Nigerian economy providing a source of livelihood, directly or indirectly, to about 80% of the population. The task of achieving self-sufficiency in food production in Nigeria has been the concern of every Nigerian, particularly, now that it has been observed that the problem of revitalizing the nation's economy can be solved only if due recognition is given to the agricultural sector.

Nigerian agriculture has been experiencing a moderate growth rate for the past six years. It is estimated that growth of agricultural production rose from an average of 1.8 per cent to 2.9 per cent between 1992 to 1993 while between 1993 to 1996 the growth rate increased to 3.7 per cent (1984=100). However, the average growth rate between 1988-1992 and 1992-1996 declined from 6.4 per cent to 3.0 per cent respectively (CBN, 1992 - 1986). Agricultural production constituted 38.8 per cent of Gross Domestic Product (GDP) in 1996 as compared with the respective shares of 38.7 and 38.3 per

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cent in 1995 and 1994 respectively (CBN,1996). However these increases were low when compared with the estimated values under the 1996-1998 National Rolling Plan. Inability to attain the potential estimate can be attributed to certain endemic and imposed problems such as, inaccessibility to and rise in the cost of some farm inputs (agro-chemicals, farming implements, and labour). The constraints in the livestock sub-sector can be attributed to reduced volume and quality of feed, as well as thes escalating cost of feed ingredients, and the high cost of drugs.

**Table 1.1: Index of agricultural production by type of activity**

**(1984=100)**

| Sub-sector | Percentage change over preceeding year | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1988-1992 | 1992-1996 |
| Crops | 5.8 | 7.4 | 5.9 | 3.3 | 3.4 | 3.0 | 3.6 | 7.6 | 3.4 |
| a) Staples | 6.1 | 8.1 | 6.1 | 4.8 | 3.9 | 3.1 | 3.3 | 8.2 | 3.8 |
| b) Others | 4.3 | 5.4 | 3.2 | -5.5 | -0.1 | 2.6 | 5.5 | 5.0 | 0.6 |
| Livestock | 3.0 | -1.6 | 0.7 | 1.4 | 1.5 | 4.2 | 2.9 | 2.2 | 2.5 |
| Fishery | -13.2 | 4.8 | -20.6 | -25.4 | 6.7 | 10.3 | 20.8 | -6.2 | 3.1 |
| Forestry | 4.0 | 2.0 | 2.3 | 2.0 | 2.6 | 2.2 | 0.5 | 2.9 | 1.9 |
| **Aggregate** | 4.9 | 5.9 | 4.5 | 1.8 | 2.9 | 3.4 | 3.7 | 6.4 | 3.0 |

Source: Federal office of Statistics, Lagos. CBN Annual Report, 1992 and 1996.

The government is making efforts towards ensuring that the desired potential of the agricultural sector is attained. Various programmes were embarked upon by different governments. These include: Farm Training Institutions (FTI), Directorate for Food, Road and Rural Infrastructure (DFRRI), the establishment of agricultural research institutes, agricultural extension and training institutes, Agricultural Development Projects (ADP) and input

supply and delivery policies. The expected effects of these initiatives were substantially curtailed by lack of consistency and continuity in the policies adopted by successive administrations in the country and the fact that the actual farm level situation was not considered. These efforts can only yield a sustainable result if farm level planning, which is a basic necessity for high level agricultural production, is given the desired attention. There is the need to analyze the total resources available on the farm and design a system that combines activities that use these resources to improve productivity. The various sub-sectors of agriculture have to be synchronized to ensure balanced growth. Efforts at improving productivity in the various sub-sectors of agriculture would need to take account of the pronounced diversity of the natural and human resources, and how to optimally allocate these resources at the farm level.

Although livestock and crop farm systems are major components of agricultural production in Nigeria, they have not yet been efficiently integrated to make good use of slack resources in the two sub-sectors. When crop and livestock production activities are optimally integrated and synchronized, the resulting farming systems can generate complementary relationship without competing for farm resources. By integrating and using crop-livestock linkages, farmers can make more efficient use of their marginal land with less chemical fertilizer, while substantially improving their economic gains, thus achieving a more sustainable agricultural production system and an overall economic growth. The aim, scope and the restriction of this study are best summarized by considering it a framework useful for resource assessment, allocation of production factors, and the impact of

development efforts at the farm level. The study was designed to assess the potential role of integrated crop-livestock farming systems in the intensification of food and livestock production through an examination of farm level reorganization of resources and activities.

## 1.2 The Problem Statement

Agriculture has a very important role to play in the economic development of the country in terms of feeding the steadily growing population and providing the investible resources for national development. Despite the various efforts made by the government, returns to the economy from this sector have been very much below the potential. The major factors contributing to the generally low level of agricultural development in the country include: poor allocation and management of resources, low level of technology, low productivity, inadequate capital, poor economic infrastructure, lack of adequate incentives, among others. The combined weight of these drawbacks has led to the sub-optimal utilization of the available physical, personnel and financial resources

Another serious problem hampering the development of the agricultural sector in the country is the prevailing fragmented and micro holdings resulting from the increasing population pressure and the traditional land inheritance system. The intensification of land use has led to increased rate of soil degradation due to continuous cropping, depletion of grazing land, severe deforestation and environmental degradation reducing the potential for agricultural output (FAO, 1985). The limited land resources available to individual farmers reduce the scale advantage in tackling the fundamental problems of resource conservation and attaining technical efficiency. As rural

population pressure increases, both crop and livestock farmers need to intensify production. McIntire *et al.* (1992) showed that, as population pressure increases, the crop and livestock activities often become integrated. Traditional soil protection techniques, particularly the long fallow periods, which protect against erosion and allow soil nutrients to recharge are no longer possible. If farmers cannot resort to external inputs because of the costs, the integration of crop and livestock activities represents their main opportunity for intensification. In the face of the gravity of these problems, there is a felt need to create an environment for the optimum allocation and efficient utilization of the available resources to improve productivity within the agricultural sector of the economy.

Studies have shown that one of the most cost effective means of generating higher levels of agricultural production is through increased integration of crop and livestock enterprises (FAO, 1983; Nuru,1984; Speedy, 1991). A re-allocation of resources towards a higher level of crop-livestock integration can result in the intensification of both enterprises. The heterogeneity of physical resources and climate of the country greatly favours the diversification of both crop and livestock enterprises. However, crop as well as livestock developments are characterized by extremely low levels of productivity attributable mainly to the very low level of technological inputs and poor resource allocation within the production system. An in-depth analysis into the degree of integration of crop and livestock becomes critical in proposing improvement needed for attaining optimum integration of crop-livestock farming system. Günther (1993) reported that integration of livestock and crop enterprises have several advantages. These include:

economic benefit from two sources of income, enterprise diversification to guide against risk and uncertainty, farm yard manure that ensures maintenance of soil fertility, draught power for farm work and transportation, and the use of crop residue for feeding livestock. Combining crops and livestock also has the potential to maintain ecosystem function and help *prevents agricultural system from becoming over connected by promoting greater biodiversity, and therefore increased capability to absorb shocks to* the natural resource base (Holling, 1995).

Despite these theoretical benefits of crop-livestock integration, crop and livestock production systems are not efficiently integrated in developing countries, Nigeria inclusive. This is evident from the low contribution of the agricultural sector to the gross domestic product. Observed benefits in terms of crop and animal productivity are few and improved soil fertility is limited by low output response to such inputs as manure, crop residue and animal power. The existing form of crop-livestock integration largely reflects the association or mere fusion of crop and livestock enterprises under one management unit (Assefa, 1989). The interactions in terms of input and output functions are limited. This form of integration can best be described as a horizontal integration where the expansion of the crop production is not seriously contingent upon the number of draught animals, nor is the number of livestock a function of crop residue availability. In an ideal integrated crop-livestock farming situation where a systematic symbiotic relationship, rather than the spontaneous type of relationship prevails, a vertical relationship is expected (Nasir, 1989).

Research and project activities for the sustainable development of integrated crop-livestock production systems should aim at understanding and strengthening the existing link between the two sub-sectors through assessment of the present state of their interaction within the traditional land use system. This study is designed to assess ways of intensifying crop and livestock production in Northern Nigeria through efficient integration of the two enterprises. It is anticipated that the study would throw some light on the following issues: (a) feasible interactions between crop and livestock systems, (b) the potential roles of crop and livestock production in the system, (c) pattern of resource allocation within the system, (d) farm-level reorganization required to provide an efficient integrated system, (e) Socio-economic and technical constraints in the existing modes of production and (f) policy implication and institutional support towards adoption of integration activities.

### 1.3 Objectives of the Study

The broad objective of the study is to determine resource productivity and optimum farm plan in an integrated crop-livestock production system. The specific objectives are to:

1. describe the existing farming systems of the study area and identify factors influencing farmers' priority in decision making within the system;
2. determine the profitability and efficiency of resource utilization in integrated crop-livestock farming systems;
3. determine optimum combination of enterprises under the existing practices for crop production and integrated crop-livestock systems;

4. assess the effect of imposing variations and restrictions of some limiting resource on farm productivity, and
5. identify the socio-economic and technical constraints to effective crop-livestock integration in the existing mode of production.

## 1.4 Justification for the study

It is presumed that resource allocation could be optimized with less difficulty where the environment is conducive to crop-livestock integration, simply because the by-product from both enterprises that would be otherwise unused could be efficiently utilized. Katsina State is most suited for both crop and livestock farming in the country. Crop and livestock production in the area are not mutually exclusive but intimately bound with the emphasis on each component varying among households. Despite the fact that crop-livestock integration is deeply entrenched in the traditional farming system of the state the efficiency of integration is still very low. Research efforts towards an improved integrated system that would effectively utilize slack resources will enhance sustainable agricultural production in Katsina State.

The design of a guideline for effective integration of crop and livestock in the traditional farming system will require farm level information on the existing farming systems and the socio-economic factors influencing decision making within the system. A lot of research work has been carried out on the interactive effects and integration of crop and livestock within the traditional farming systems. However, there is not much empirical data on the socio-economic advantages and constraints associated with such integration in the study area.

The study deals with the economic analysis at the micro level, addressing specifically the basic economic issues of the farm-household. It is hoped that this study will provide the much needed baseline economic information necessary for evaluating integrated crop-livestock system as a means of maximizing the efficiency of resource utilization. The study would also help in strengthening the development of research efforts towards improving the productivity of the agricultural sector in Nigeria.

## 1.5 Organization of the Study

This thesis is organized into six chapters. The first chapter is essentially the introduction to the study, it looks at the background of the research, the statement of the problem, the objectives as well as the justification of the research. The review of relevant literature is in chapter 2. It covers the area of concepts and theoretical framework of crop-livestock integration, empirical studies and review of analytical techniques. Chapter 3 is the research methodology involving the description of the study area, sampling techniques, data collection and analytical techniques. The descriptions of model specifications were also given in this chapter.

Chapter 4 describes the farm-household system by looking at the socio-economic characteristics of the household as well as resource allocation within the farming systems. It also looks into the input-output relationships in terms of profitability and efficiency of resource use. The presentation and discussion of the result of the linear/mixed integer programming are the focus of the fifth chapter. Attention is paid to the optimum farm organization of the models and their variants and the sensitivities of the optimum farm plan to adjustments in some limiting resources. Chapter 6 is the concluding chapter. It covers the summaries of major findings, policy implications and suggestions for further studies.

**CHAPTER 2**

# LITERATURE REVIEW

## 2.1 Conceptual Framework for Crop-livestock Integration

The various definitions of crop-livestock integration in literature always emphasize the positive effects of the integration and their advantages for the agricultural sector. Crop-livestock integration as defined by Delgado (1979) refers to a situation in which crop farmers as a group and livestock rearers as another group exchange product for their mutual benefits. This system involves the exchange of crops like grain, vegetable and crop residues for livestock product such as meat, milk, butter etc. This indicates that there is a purely symbiotic relationship between herders and crop farmers with mutual benefit to both parties. This definition of crop-livestock integration assumes that the two components are separated and only interact in the area of exchanging product.

Jahnke, (1982) defined crop-livestock production system as a situation whereby crop and livestock husbandry are practiced in association. He indicated that this association may be close and complex or the crop and livestock enterprises may be parallel activities without interaction, possibly not even belonging to the same management unit. In this case the association is reduced to geographical proximity. An efficient crop-livestock integrated farm therefore was referred to as a crop-livestock production system that displays pronounced and mutually beneficial interaction within the farm.

ILCA (1983) described crop-livestock integration as a well-defined proportion between arable farming and livestock farming. The livestock



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enterprise is complementary to crop production programme so as to provide a balanced and productive farming system. This system ensures a full utilization of the by-product of crops and their conversion into valuable animal product. Farm yard manure also becomes available and the spare time of the cultivator and his family is fully utilized. Thus crop-livestock integration can be analyzed on the basis of a complementary interaction between the two enterprises for the mutual benefit of both. This concept of crop-livestock relationship was supported by Günther (1993). He conceptualized an effectively integrated system to be the effects resulting from the inter-relationship and complementarities between crops and livestock production. The crop system contributes to livestock production by the provision of feed such as fodder crops, crop residues and by-products, and other primary products. Livestock provides, in many cases, essential inputs to crop production in the form of draught power and manure. These interactions have been of increasing importance for sustainable agricultural production. For an integrated crop-livestock system, farm families allocate certain quantities and qualities of basic type of resources to crop, livestock and off-farm enterprises. Allocation is usually in a manner that, given the knowledge they possess will maximize the attainment of the goals they are aiming at (Okon, 1989). The above concepts of crop-livestock integration view the system as a complementary interaction for the mutual benefit of both enterprises.

The aim of crop-livestock integration is to render a farm more productive. This is achieved through certain effects resulting directly from the realization of the respective flows of products between crop and livestock enterprises. The integrative functions of crop-livestock system according to



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Tesfaye, (1989) include: animal power for crop production and transport; manure for improving soil fertility; crop residue for animal feed; risk minimization, in terms of product diversification and marketing; sources of food and income; productive use of labour during slack periods; and yield increasing effect of fodder crops in the rotation system (Gryseels and Anderson, 1983).

The possible integrative function of crop- livestock could be schematically presented as shown in Fig. 2.1 Livestock enterprises produce meat, milk, manure and power. This output will have two major functions: (1) the meat, milk and manure retained for home consumption and also destined for market are taken as a direct source of food, energy and income. In this respect they are considered to have output function, and (2) the power and manure used as an intermediate input in the crop production, through which complementary relationship between crop and livestock enterprises would be established, would have input functions.

The *crop enterprises produce food crops, crop residues and fodder* crops. Similarly, these outputs will have two major functions: (1) the food crops consumed on the farm and sold to generate income are recognized to have output function; and (2) the crop residues and fodder crops used as intermediate inputs in the livestock production, through which complementary relationship between the two enterprises are established, are recognized to have input functions. The resource pool, consisting of land, labour, capital and management, is common to both enterprises. Depending on the resource input requirements, supplementary and competitive relationships between the two enterprises can be established. Supplementary relationships could be realized in many ways:

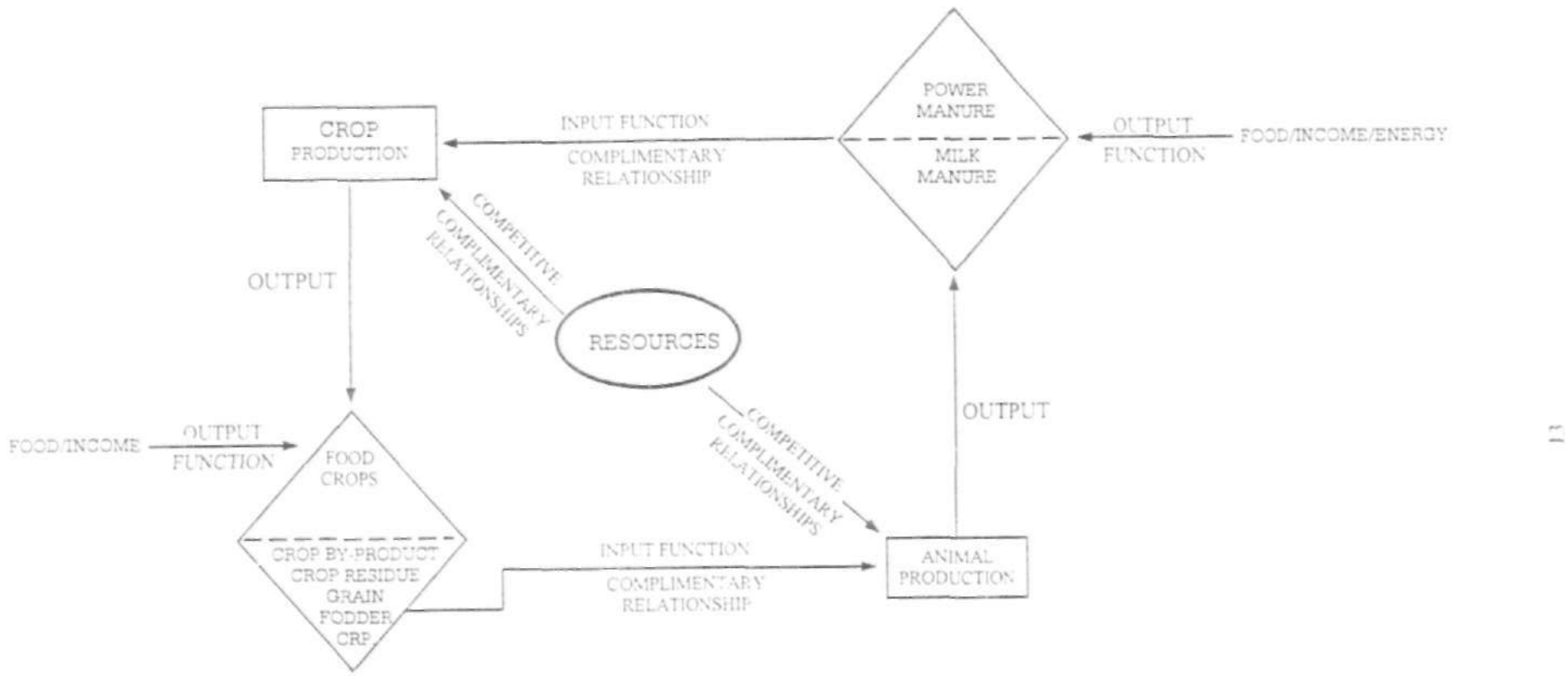



Fig. 2.1 Conceptual crop and livestock integration chart

Source: Assefa (1989)

1. when the pasture land is for grazing alone and crop production has no demand for it;
2. When fallow land is used for grazing;
3. When labour and management resources are fully employed by livestock and other activities during the slack period of crop production;
4. when the grain storage facility is used for storing animal feed during low level of grain inventory, and so forth.

The competitive relationship for scarce resources is unavoidable. During the critical periods of crop production (weeding and harvesting), there would be stiff competition for labour. Also if extensive fodder production is introduced, then the competition for arable land would become pronounced. The decision as to which enterprise shou'd be given priority in the event of competitive situation depends on opportunity costs, the returns involved, as well as the objectives of the farmers.

Two major determinants of crop-livestock interactions are; agroclimate and population density (McIntire *et al.*, 1993). Differences in agroclimate are distinguished by the amount and distribution of rainfall, and by altitude, particularly as it affects temperature. Agroclimate affects the type of crop that can be grown successfully and their agronomic characteristics, such as productivity, cycle length, ease of mechanization, and susceptibility to insect pests, diseases and weeds. Agroclimate also influences livestock production in terms of species, breed, stocking capacity, susceptibility to diseases and individual productivity. Agroclimatic differences demarcate the mixture of crops and livestock species that can be integrated on a given production unit, taking into consideration the effects on land productivity, animal diseases and

on stocking capacity. McIntire *et. al.* (1993) ascertained that the potential of crop-livestock integration is higher in the highland zone. This was attributed to the fact that the zone has a cooler climate and longer growing season. Low incidence of diseases and two rainy seasons permits pasture that encourages large scale livestock production. Mixed large scale crop-livestock production system is therefore very common in this zone.

The definitions of Gunther (1993) and Okon (1989) were adopted in conceptualizing crop-livestock integration in this work. Thus, in the context of this study, crop-livestock integration would be viewed simply as the flow of product/ by-product between crop and livestock enterprises. This term implies that the flow between the two enterprises is complementary and of positive impact. The study will also attempt to consider other negative impact like diseconomies of scale and other unfavourable economic consequences of the interaction. The restricted definition of crop-livestock integration was chosen, in order to focus this study on the direct effects of the integration between crop and livestock enterprises. Nevertheless, other effects of the integration would be taken into consideration when analyzing the situation of the production systems in the study area.

## 2.2 The Impact of Crop-livestock Integration and Technological Interventions

The schematic diagram below (Fig. 2.2) will be used to demonstrate how the crop and the livestock enterprises could be optimally combined with the existing technology and resources and with the intervention of improved technology and better management. The horizontal axis represents the quantity of livestock products, and the vertical axis represents the quantity of crop production.

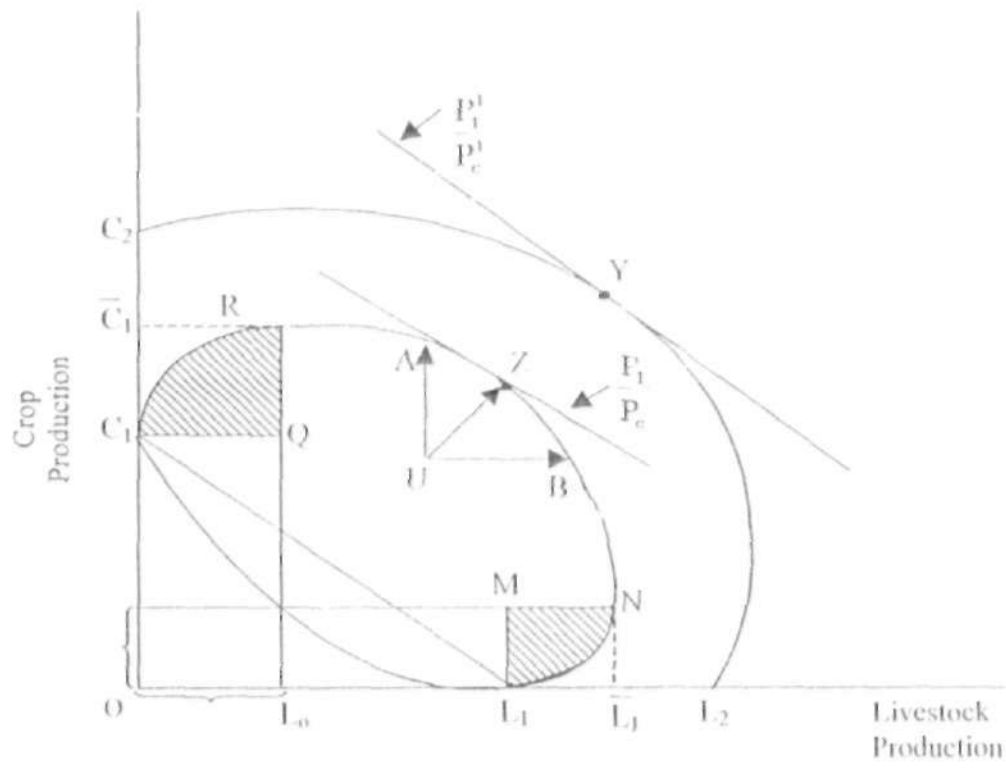



Fig. 2.2. The impact of crop livestock integration and improved technology on the production possibility curve.

Source: Adapted from Asefa, 1989.

Starting with the crop production, $C_1$ denotes the maximum crop production attainable utilizing all the resources with the available technology. The corresponding production for livestock is $L_1$. In this case, the production possibility curve ($C_1L_1$) could be either a straight line, signifying a constant rate of product transformation (constant returns to scale), or convex (from the origin), showing a decreasing rate of product transformation, associated with the advantages of economies of scale (increasing returns to scale)). Both of them depicts the possibility of specialization in either enterprise depending on their price ratio. Under this situation, there would be no complementary or supplementary relationship between the two enterprises. Rather the relationship is effectively competitive at all stages of product transformation (Upton, 1973). For an integrated crop-livestock production system, there is need for an effective complementary and supplementary relationship. However, this may eventually lead to competitive relationship depending on the scarcity of resources. The production possibility curve showing the impact of integration is represented by $C_1RNL_1$. The expansion of livestock activity by $L_0$ in a crop specialized farm will increase the crop production to $\overline{C_1}$ or R on the production possibly curve (ppc). $C_1R$ denote the complementary range, and the shaded area $C_1RQ$ is the incremental output resulting from the use of animal power, manure, etc. Likewise, the expansion of crop activity by $C_0$ in a livestock specialized farm will increase the livestock production to $\bar{L}_1$, or N on the ppc. $L_1N$ is the complementary range, and the incremental output is shown by the shaded area $L_1MN$ associated with the use of crop residue and fodder crops, etc. RN along the ppc represents the

region where the competitive relationship becomes effective and where the problem of resource allocation becomes relevant.

`U` inside the ppc exhibits under-utilization of resources (labour, storage facility, fallow land etc.). Production inside ppc generally reflects economic inefficiency, due either to unemployment of resources or inefficient organization or allocation of resources (Samuelson and Nordhaus, 1985). In this particular case `U` represents improper integration of crop and livestock, leading to the sub-optimal utilization of resources. If the resources were to be fully utilized, the farm would operate on the boundary of its ppc, where the competitive relationship becomes effective (i.e., R N). As shown in the diagram, `U` could be moved to the boundary of the ppc, viz; to A and B where the livestock production increases without affecting the crop production, demonstrating the effective supplementary relationship.

However, the frontier of the ppc (R N) is only the technically efficient region (including points A and B) where the scarce resources are fully employed and maximum output is obtained with the existing technology (Tisell, 1972; Samuelson and Nordhaus, 1985). But every point on the frontier (R N ) of the ppc is not necessarily economically optimum. It is generally agreed that technically efficient production functions help to attain the maximum output with the given input without paying much attention to the associated input and output prices and the social costs. (Upton, 1973).

In a product combination where several inputs and outputs are involved, the economic efficiency criteria of the equi-marginal return principle for each product can be applied. In the diagram, Z, on the ppc, represent the economically optimum combination of two enterprises. At this point, the marginal rate of product transformation of crop and livestock would be

inversely equal to their price ratio and the equi-marginal return principle holds. That means, at this point the technical and economic efficiencies converge and the social costs would be relatively minimized.

Further, through the application of improved technology- biological, chemical, mechanical etc. the land and the labour productivity will increase. With the application of improved technology, better organization and management, a higher production possibility curve ($C_2L_2$) could be attained. The economically optimum combination of the two enterprises at `Y` would therefore improve the aggregate farm income.

The next pertinent question concerns how to go about determining the best operating condition that satisfies both choices of the partial optimum production function and the economic optimum combination of crop and livestock. In other words, the central issue here is how to attain the technical and economic efficiencies simultaneously with the improved technology and given the resource constraints. This question demands an examination of the available planning techniques in general and the optimization models in particular. This study used the optimization models to determine how crop and livestock enterprises could be efficienty combined using the existing household resources.

### 2.3 Empirical Studies on Crop-Livestock Integration

The importance of crop-livestock integration as a means of increasing agricultural production has continued to receive considerable attention by both researchers and policy makers. Von Maufmann (1983) indicated that the promotion of integrated crop-livestock is not difficult to conceptualize given the vast amount of data on land area, ecology and livestock resources. He

asserted that the difficulty lies in developing innovations and system of management that are acceptable to the people involved. The increasing demand on land to produce more food means that cultivated area will expand and the conventional rangeland will diminish. This led Powell (1983) to conclude that a closer integration between crop and livestock will be necessary with animal becoming increasingly dependent on fodder from cropland. Eddy (1979) also conducted a linear programming study on integrated crop-livestock system in Niger Republic and came to the conclusion that farmers have developed a system of integrating cattle and goats rearing with grain production to minimize the risk posed by drought and fluctuating grain prices of the farm produce.

Commenting on the desirability of integrated crop-livestock system, Nuru (1984) indicated that the focus of attention of agriculture is on applied research that would make the integrated system economically viable enterprise for the farmer with a small capital base and often surplus family labour in the rural areas. He also observed that the concept of dual and tri-commodity integration has been practiced in Africa for centuries. According to him, integration of livestock into the cropping system has several advantages: effective utilization of natural resources, economic benefit from two sources of income, guide against risk and uncertainty, crop rotation and farm yard manure to maintain soil fertility thus increasing crop productivity.

Siewe, (1983) indicated that there is a high potential for increasing farm income when poultry enterprise is introduced into smallholder agricultural production without interfering with the cropping pattern. He observed that surplus family labour that exists during the slack farming period (January to

April and September to December) is more efficiently utilized with the introduction of livestock enterprise. The introduction of improved crop production technologies with the livestock enterprise greatly increased the profitability of the farm. The implication of this is that the adoption of improved crop production technologies in an integrated crop-livestock farming system improves the resource use efficiency. A similar study conducted by Okon (1989) revealed that mixed crop-livestock production system has some potential for achieving significant increase in farm income, resource use, and productivity through reorganization of the existing land, labour and livestock resources. The linear programming model with cattle integrated into crop production activities generated a higher gross margin. than the model with sheep production in the farm plan. The models without livestock production had the least gross margin. The contribution of cattle production to gross return could be attributed to its importance in farm power supply.

Bandara and Rajaguru, (1992) assessed the current level of crop-livestock integration in Sri Lanka and proposed that an improved crop-livestock integration system could raise annual gross farm profit by 62-72% over the current levels and also improve farmers living and nutritional standard. In a study to design new farming system with a crop and dairy using linear programming, Patil et al (1990) deduced that introduction of dairy cows in a crop farm increases the opportunity for employment and potentially adds to their income. They concluded that crop-livestock integration is more rewarding than is the system of cash crop only, provided that the animal productivity is adjusted to the feed quality so as to be able to utilize the available feed biomass.

In an attempt to examine the role of livestock on crop-livestock integrated farms in Ethiopia Highland between 1975 and 1985, Gryseel (1988) found out that livestock is of crucial importance to the farming system. He also asserted that there was a high level of crop-livestock integration with the livestock providing a dominant part of the farm's income and gross margin. The main output of cattle (draught power and manure) was intermediate products used as inputs for crop production enterprise. Livestock was observed to generate a substantial amount of employment, and was of prime importance in providing security and source of investment to the farm household. This result is consistent with the work of Powell and Mohammed, (1987) who ascertained that the use of manure on crop land and the grazing of crop residues and fallow lands is important interactions between cropping and cattle husbandry in seasonally dry West Africa. In central Nigeria, cattle spent 50% of their dry season grazing time on sorghum, pearl millet, rice and soybean residues as well as weeds remaining in fields after grain harvest. This resulted in nitrogen and phosphorus removals of approximately 25 and 40 kg per hectare respectively. The manure nitrogen and phosphorus return to crop land during this grazing period was 1.7 and 0.3 kg per hectare respectively. Herds camped on cropland for 2 to 3 consecutive nights deposited 40 to 104 kg of nitrogen per hectare and 10 to 15 kg phosphorus per hectare, depending on the season of confinement. Approximately, 18% and 33% of the manure Nitrogen and phosphorus were assimilated by maize crop: the remainder was taken up by weeds. As a dry season supplement, fallow lands sown to stylo provided a high protein diet supplement to cattle during the dry season. The fodder banks were more effective than the natural fallow

in restoring soil productivity. Maize grown after stylo produced up to 1.4 tonnes /hectare more grain than in areas of natural fallow, giving a net benefit of up to 80 kg Nitrogen per hectare.

Tajuddin, (1986) in his study of agroforestry approach of integrating animals in smallholder rubber plantation, observed that rotational system of broiler production under rubber was found to be technically, socially and economically feasible, providing a net return on family labour of M$370 to M$825 per consignment of rearing 500 birds. Sheep rearing under rubber also appeared to be very attractive and practical. Apart from producing meat for sale, it also serves as biological weed control measure. Cost of controlling the weeds commonly found under rubber plantations could be reduced by about 21% over the usual methods by using sheep grazing for weed control.The internal rate of return (IRR) from sheep rearing can be as high as 44%.

Thomson *et al.* (1995) used a model farm with integrated crop-sheep enterprises to study the benefits of improved crop-livestock integration. It was observed that integration improved farm profits and stocking rates. The model farm had twice the output of metabolizable energy and a higher stocking rate compared with the traditional rotation system. Apart from the adoption of improved crop technologies, by integrating and using crop-livestock farm linkages, farmers can make more efficient use of their marginal land with less chemical fertilizer, improve their income gains substantially, and achieve a more sustainable agricultural production system.

Static variant of linear programming model was used by Okaiyeto (1987) to provide empirical information on the economics of resource use by the agropastoralists when improved technology is introduced into their

farming system. The result indicates that the two important activities in the optimum farm plan are cattle production followed by milk and dairy products. Two products are sources of cash inflows with animals providing more cash. The study also showed that livestock is the predominant economic activity of the agropastoralists. However, crop production was also found to be important in their farming system. Though crop production does not contribute significantly to the net farm income, it allows for the rational utilization of the existing man-hour in the households. The results of such utilization are that cereals and other farm products that would otherwise have been purchased are now produced at no additional costs. These are thus means of attaining some of their stated objectives such as meeting subsistence consumption requirements, provision of employment channels to households members and augmentation of family -based wealth

Even though crop-livestock integration is considered a substantial improvement on traditional farming system, the actual rate of expansion had been very low. Norman (1979) reviewed some of the problems to include: population density; land tenure arrangement and acquisition of necessary capital. Some form of credit was therefore suggested in a situation where the capital needed to obtain animals and equipment are beyond the power of the farmers. Another problem of low adoption of the integrated system is lack of managerial knowledge and the economic implication of the integrated system. Efforts to eradicate these constraints will help in improving and sustaining the agricultural sector.

## 2.4 Review of Analytical Techniques

The most widely used techniques for assessing the efficiency of resource organization include; budgeting, programme planning, and mathematical programming. Budgeting as a farm planning technique has now been in use for a long time and proved very useful until the advent of linear programming. In most of the developing countries, including Nigeria,, budgeting is still widely used at farm and national level. The technique of budgeting is similar to system balance used at the national level in non-market economies. Both follow the same principle in defining input and output coefficient (Heady, 1971). Variants of budgeting comprise complete (whole farm) budgeting dealing with new organization or major adjustments and partial and break even (enterprise or activity level) budgeting dealing mainly with minor adjustments (Brown, 1979).

From a mathematical standpoint, budgeting and linear programming have several things in common: Linear objective function, additivity of activities and resources, divisibility of resources and activities etc. Both require the same type of basic information or input/output coefficients, price and cost parameters; both models are deterministic (Agrawal and Sharma, 1968). They also differ in many aspects: linear programming is more efficient than budgeting when alternative activities and restrictions are large and complex (Agrawal and Sharma, 1968; Baker, 1963 ). Budgeting does not provide optimal solution and shadow prices; budgeting does not identify resource constraints and has limited capacity in carrying out sensitivity analysis. According to Dorling, (1978) budgeting is less efficient in that its production possibility curve is implicitly linear and its choice usually leads to

specialization whereas, linear programming is flexible enough to allow for the combination of enterprises (Heady and Candler, 1958).

Programme planning has much similarity with linear programming. Its major difference from linear programming is that it is not an optimization model Upton (1973) defines programme planning as:

> "A method of whole farm planning which relies on gross margin other than the completely systematized method of linear programming."

It is a common approach employed in selecting enterprises on the basis of their gross margin per unit of restricting constraints. Despite its simplicity, it would be cumbersome to use in a situation with numerous activities and resource constraints because the whole approach is dictated by subjective judgment and trial and error. The classical optimization technique, using differential calculus, is a marginalists approach applied on a continuous and smooth non-linear production function. Notwithstanding its wide usage, it has a serious flaw as an optimization method. The initial attempt at dealing with unconstrained optimization could not ensure a global solution, and besides, it has been criticized for its very approach of optimization with no constraints, which is incompatible with the very premise of economic rationalization (Tisdell, 1972). Later, Lagrange devised a method for solving constrained optimization problems. But his assumptions of equality of constraints and negligence of non-negative restriction were the main drawbacks. The equality restriction necessitates that the constraint resource should be fully utilized and the absence of non-negative activity restriction allows the possibility of having negative activities. Following Lagrange, Khun Tuker introduced the inequality and non-negative restrictions that allow the

non use of resources and rules out negative activities. However, despite these refinements, the inherent drawbacks of classical optimization remain and so the difficulty of locating a unique global solution had not been solved (Tisdell, 1972). The problem of finding a global solution has finally been solved by linear programming, which is considered as a major breakthrough in the field of planning techniques.

The application of linear programming started in the early 1950s particularly in farm management related problems. In the United States, Heady and associates were the leading contributors in demonstrating the efficiency of this technique, both in micro and macro farm planning. The works of Heady and Candler (1958) and Beneke and Winterboer (1973), among others, are fundamental in the application of linear programming in the field of agriculture. In the United States, Japan, and Europe farm management planning services using linear programming (program planning) began in the early 1950s. In particular linear programming is well suited to solving the problems of optimum selection and the combination of crop and livestock enterprises throughout much of Europe and Japan (Baker, 1963). Since the early 1970s, the use of linear programming in the field of agriculture has gained much momentum.

Linear programming is also widely applied In African countries. This was first introduced in Kenya in 1963. Clayton and Heyer are regarded as pioneers in this breakthrough. It is only since the early 1970s that this technique has been used in other African countries. It is, nonetheless, limited to countries like Nigeria, Kenya, Tanzania; Uganda, Malawi, Cameroon, Mali and Burkina Faso, Kenya and Nigeria being the top on the list (Eicher and

Baker, 1982). Most of the contributions deal with the identification of constraints and the evaluation of the profitability of new technologies on smallholder farming systems with special emphasis on annual crops, livestock, and recently on optimizing crop-livestock combinations.

This study is a micro farm planning analysis focused on the use of linear/mixed integer programming techniques to solve the problem of optimum selection and combination of crop and livestock activities based on the existing farm-household resources.

**CHAPTER 3**

# METHODOLOGY

## 3.1 The Study Area

The study was conducted in Katsina state of Nigeria. The criterion for selecting the state is because of the popularity of mixed farming system among the farmers in the area. The state is located between latitudes 11°07' and 13°22' North and longtitudes 6°52' and 9°22' east. Katsina state is situated within three ecological zones namely; Sahel, Sudan and Northern Guinea Savannah. It occupies a total land area of about 2.4million hectares, out of which 1.64 million hectares is under both rainfed and irrigated farming (KTARDA, 1998).

The state is divided into three agricultural development zones (Fig 3.1). The headquarters of zone I is Ajiwa which is in the northern part bordering the Sahel, zone II has its headquarters in Funtua and lies in the south between the northern Guinea and southern Sudan Savanna zone, and zone III, with the headquarter in Duste-ma is in the center of the other two zones. (Ogunbile *et al.*, 1999). Each of the three zones was surveyed to covered the differences in the ecology, vegetation and prevailing farming systems of the state. The rain rainfall pattern in the state is unimodal with the peak in August. The annual rainfall ranges between 350 and 500mm in the sahel (zone I), 600 and 850 in the Sudan Savanna (zone III) and between 900 – 1000mm in the Northern Guinea Savanna, (zone II). The zonal annual rainfall data from 1994 to 1998 is presented in Table 3.1. The variations in rainfall in the zones contribute to major differences in agricultural production in terms of the choice of crop, input levels and average yield.

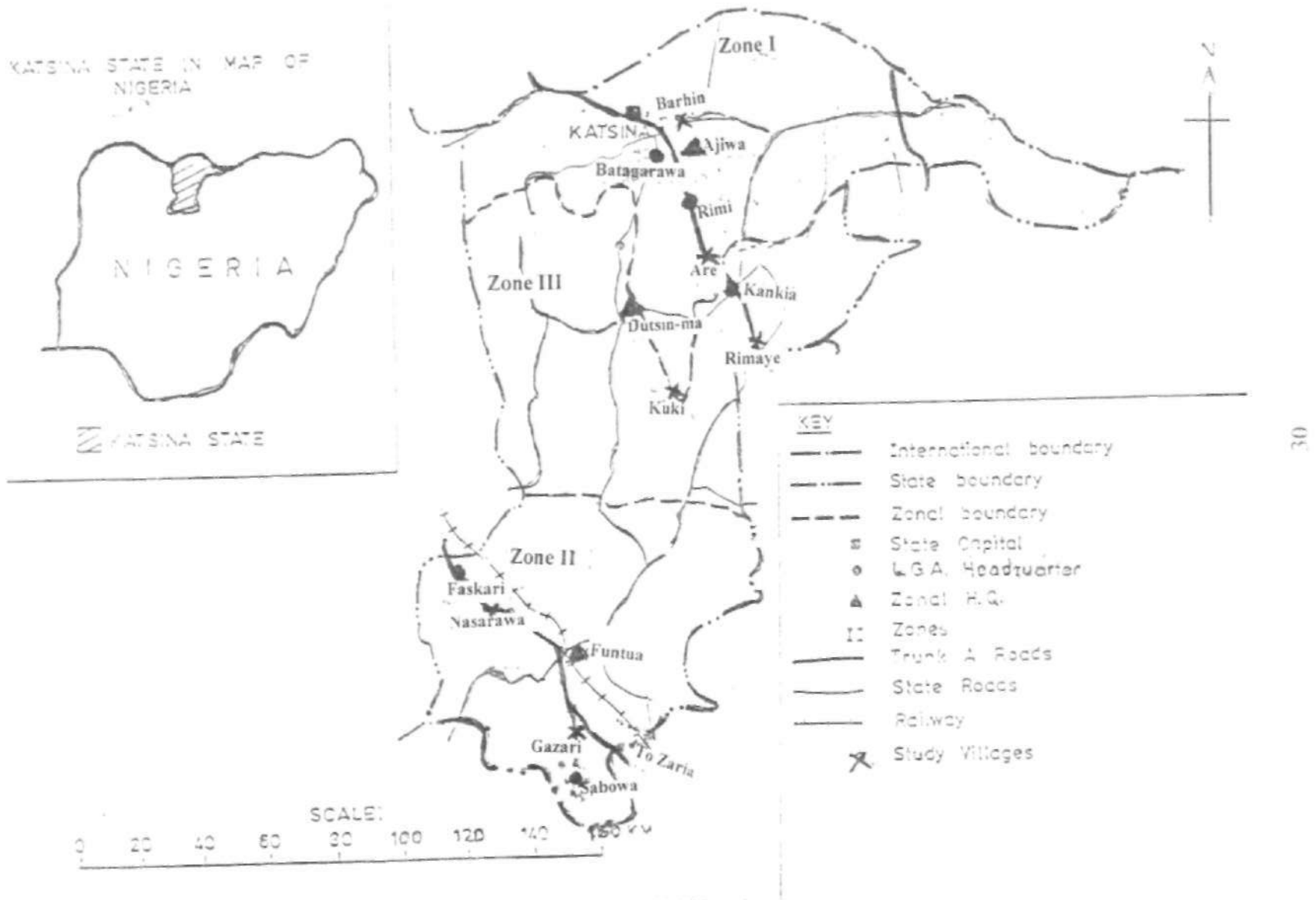



Fig 3.1: Map of Katsina State showing the research villages, their local government and zonal headquarters.

Table 3.1: Annual rainfall data, 1994-1998 (mm)

| Zone | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|
| 1 | 440.8 | 466.5 | 458.1 | 463.3 | 615.4 |
| 2 | 703.6 | 769.9 | 796.9 | 657.8 | 1369.2 |
| 3 | 1057.0 | 821.2 | 936.4 | 1174.4 | 1080.2 |

Source: KTARDA, 1994-1998 annual report.

The growing period of the major crops covers about 180 days. Although this is short, the distribution of annual rainfall is well suited to a number of crops. This, however, requires that all crop activities be done within a limited period. The importance of this cannot be over emphasized given the critical resource limitations of the average traditional farmer. The mean annual temperature is between 29 and 39 degrees Celsius. The relative humidity is constantly below 40% except in few wet months when it sometimes goes up to an average of 60%. The duration of dry season is about six to eight months. This starts from late September to April.

The agro-climatic condition of Katsina state, where the study was conducted is favorable for the cultivation of crops and livestock. Livestock such as cattle, sheep, goat, camel and donkey are very common in this zone. The major crops grown in the state are millet, sorghum, maize, groundnut, cotton, cowpea, rice, and soybean. They are grown either as sole crops or combinations of two to four crops. The relative importance of these crops vary according to the location. Sorghum, maize, rice, cotton and cowpea are the most important crops in the most humid southern parts of the state (zone II). As one moves northwards into the middle belt of the Sudan Savanna (zone

III), millet, sorghum, groundnut, cotton and cowpea become dominant. Millet, followed by sorghum, cowpea and groundnut are the most important crops in the northern part (zone II). The estimated total hectarage alloted to some of these crops together with the volume of total output is presented in Table 3.2. The major staple food crops in the zones as shown in Table 3.2 are sorghum, millet and maize while the major cash crop is cotton.

Table 3.2: Production estimates of major crops grown in Katsina State 1995-1998 ('000 units)

| | 1995 | | 1996 | | 1997 | | 1998 | |
|---|---|---|---|---|---|---|---|---|
| Crop | (ha) | (MT) | (ha) | (MT) | (ha) | (MT) | (ha) | (MT) |
| Millet | 309.5 | 247.6 | 259.6 | 181.1 | 249.9 | 179.4 | 261.9 | 235.7 |
| Sorghum | 359.1 | 323.2 | 259.1 | 207.3 | 240.0 | 165.8 | 303.6 | 258.0 |
| Maize | 123.8 | 185.7 | 23.8 | 35.7 | 178.9 | 289.8 | 126.8 | 291.7 |
| Cowpea | 99.1 | 49.5 | 90.1 | 45.0 | 97.3 | 66.9 | 96.6 | 115.9 |
| G'nut | 111.1 | 66.9 | 90.4 | 54.3 | 96.4 | 50.8 | 86.8 | 69.4 |
| Cotton | 156.2 | 93.7 | 130.2 | 104.2 | 110.7 | 90.0 | 103.8 | 93.4 |
| Rice | 24.8 | 37.1 | 14.8 | 23.1 | 17.0 | 25.5 | 19.8 | 31.7 |
| Cocoyam | 12.4 | 61.9 | - | - | - | | 3.5 | 56.8 |
| Soybean | 4.1 | 2.0 | 3.0 | 1.5 | 7.3 | | 8.3 | 6.5 |

Source: KTARDA Annual Report, 1995-1998.

The villages selected are; Barhim and Are in zone 1, Nasarawa and Gazari in zone 2 and Kuki and Rimaye in zone 3. The location of the villages in each zone and the distances from the zonal headquarters is presented in Table 3.3.

Table 3.3: Presentation of research villages

| Zone | Village | LGA | Zonal HQ | Dist to Zonal HQ |
|---|---|---|---|---|
| 1 | Barhim | Batagarawa | Ajiwa | 13 km |
| 1 | Are | Rimi | Ajiwa | 52 km |
| 2 | Gazari | Sabowa | Funtua | 70 km |
| 2 | Nasarawa | Faskari | Funtua | 40 km |
| 3 | Rimaye | Kankia | Dutse-ma | 54 km |
| 3 | Kuki | Dutse-ma | Dutse-ma | 08 km |

### 3.2 Sampling Technique

Each of the three ADP zones was used as case studies to arrive at a general overview of farming systems in the study area. Two villages were selected from each of the three zones making a total of 6 villages from the state. The villages were purposively selected in such a way as to ensure geographical spread of the zone. A total of twenty household heads were interviewed in each village. This gave a total sample size of 40 respondents per zone and 120 respondents for the state. Only farmers who are actively involved in crop-livestock integration were interviewed. Information for the crop-based farms were adapted from the data generated from the integrated farms. The households were selected using simple random sampling technique. The randomization process involved assigning numbers to the households in each village and randomly picking twenty numbers in the lot.

### 3.3 Sampling Unit

The household head was used as the sampling unit. This was to ensure that the various components of the farming systems in the area were effectively covered. The farming system of an area comprises the farm, the

household and off-farm activities. To be able to gather reliable information on these components, the household heads were chosen as the sampling unit. Where necessary, some key members of the household were also interviewed.

### 3.4 Data Collection

The study relied on both primary and secondary sources of data. Primary data were collected from 120 household heads through a single visit interview using structured questionnaire. The questionnaire was designed in such a way as to answer detailed questions on household characteristics such as: age, sex of the respondent, level of education, occupation, resource inventory, labour availability, on-farm and off-farm employment, household expenditure patterns, food consumption habits, economic and social constraints. Information collected on cropping activities include: cropping pattern, management practices (both technical and non-technical), types, amount, sources and costs of inputs used in the production process, level of technology, crop yield and production distribution. Information on livestock activities include: types and numbers of the different species of livestock at the beginning and end of the survey period, expenditure on livestock production, input-output data, livestock intake and offtake structure, marketing.

Secondary data were collected from the three zonal offices of Katsina State Agricultural Rural Development Authority (KTARDA), Institute for Agricultural Research (IAR) and National Animal Production Research Institute (NAPRI) both in Zaria. Information collected from KTARDA include baseline information about agricultural activities within the states. This organization is in constant contact with farmers in the state through its

extension network and it is therefore able to provide information about the general perspective of the farming systems in the state.

### 3.5 Analytical Framework

The analytical tools used in achieving the research objectives for the study include: simple descriptive statistics; farm business analysis, profit function and linear programming models.

1. Descriptive statistics was used in achieving objectives 1 and 2. Simple descriptive statistics such as averages, percentages, range and ratio were used to describe the general farming systems in the state and the Socio-Economic characteristics and decision making criteria within the households. It was also used to analyze the constraints to effective crop-livestock integration programme.

2. Farm business analysis was used to show the levels of costs and returns and net profits that accrue to farmers practicing integrated crop-livestock under the existing production system. This tool was used to determine the profitability of the integrated crop-livestock farming system by looking at the financial position of the farms. Farm business analysis measures the strength and weakness of the farm (Olukosi and Erhabor, 1987). The indicator used in this work is the gross margin. The gross margin is the difference between the total revenue and total variable cost of production. The items of revenue were: sales of crop produce and sales of livestock and livestock products. The variable costs considered were the costs of production inputs like: seed, fertilizer (both organic and inorganic), agro-chemicals, labour, supplementary feed, drugs and veterinary services.

The gross returns was estimated by multiplying the total quantity of produce or output by the prevailing market prices in the survey period. The value of livestock output was obtained by computing the average value of livestock intake and offtake during the year under study. The formula used in this analysis is (CARDI, 1989);

$$\text{Total value of livestock output} = \frac{(\text{End} + \text{Entry}) + (\text{Beginning} + \text{Exit})}{2}$$

Where:

End = Value of livestock at the end of the year under study

Entry = Value that entered the stock in the year e.g. bought, birth, inherited, given

Beggining = Value of livestock at the beginning of the year

Exit = Value of livestock that left the stock in the year e.g. Sold, died, consumed, gift.

The marginal rate of return (MRR) was used to compare the productivity of the two production systems. The MRR is computed as the ratio of the marginal net benefit to the marginal variable cost. It is the extra benefit that accrue to the household that practice integrated crop-livestock system instead of specialized crop production system. MRR can be specified as;

$$\text{MRR} = \frac{\text{Net benefit (Crop - livestock)} - \text{Net benefit (Crop)}}{\text{TVC (Crop - livestock)} - \text{TVC (Crop)}}$$

3. Profit function was used to determine the relative technical and economic efficiency of resource utilization (Objective 3). A profit function was developed within the framework of the Cobb-Douglas production function.

The profit function was developed by Lau-Yotopoulos in an attempt to measure economic efficiency using the log form of the power function. According to Yotopoulos (1971) the production function is the wrong trap for capturing relative economic efficiency. This is because of the omission of input-output prices from the analysis. The following advantages of profit function were observed over the average production function:

1. It accounts for firms that produce different quantities of output from a given set of production input.
2. It takes into account the fact that different firms succeed to varying degrees in maximizing profit
3. It also considers the fact that firms operate at different sets of market prices.

A fundamental assumption of the profit model is that firms are profit maximizers and price takers. These may not hold in real life because farmers may have other objectives as well. Other farmers' objective may include security maximization and risk aversion. This will not be a serious setback in this study because studies have shown that traditional farmers are profit maximisers.

The profit model is given as:

$$\ln P = b_0 + b_1 \ln W + b_2 \ln N + b_3 \ln K + e$$

Where

Ln = log form of the representative variables.

P = Profit in Naira (gross margin from all enterprises on the farm).

W = Money wage rate per man-hour (Naira).

N = Land input in hectare.

K = Capital inputs in Naira. (Sum of costs incurred on seed, agrochemical, fertilizer, livestock feed, drugs, vetenary services etc.).

E = Disturbance term.

b's = regression coefficients. They represent elasticity of profit generation, that is, percentage change in profit when a factor input is changed by one percent.

Production elasticities, which is a measure of relative economic efficiency will be derived from the regression coefficients:

Labour $= b_1/ (b_1 - 1)$

Capital $= b_2/ (1 - b_1)$

Land $= b_3/ (1 - b_1)$

4. Linear programming model was used to determine the optimum farm plan through re-organization of the existing resources and enterprises (objective 4). Parametric or sensitivity analysis was used to subject the optimum farm plan to changes in the mode of production by varying the level of resource use (objective 5).

Linear programming is quite efficient in handling a large number of linear constraints and activities at the same time. It uses a global objective function in finding optimal farm plan or strategy by putting together the best combination of activities or objectives (Thampapillai, 1978). The method is based on the premise that peasant farmers tend to behave in a way that optimize their objectives given the constraints within which they operate. The programming procedure provides a computational method of determining the best plan or best course of action among alternatives that are characterized by a specific objective, limited resources and competing means

of using resources provided these three requirements can be quantified (Heady, 1969). There are seven basic assumptions on which the conventional linear programming is based, and can be summarized a follows (Agrawal and Heady, 1972):

1. The objective function and the constraints' equations must be linear.
2. Activities and resources are assumed additive, implying the absence of any interaction among the activities or resource.
3. Activities and resources are assumed to be infinitely divisible.
4. The activities and decision variables must be non-negative.
5. The number of activities and quantities of resource are assumed finite to permit realistic programming.
6. Activities and resources have linear relationship implying constant resource productivity and constant return to scale.
7. Resource supplies, input-output coefficients, and prices of resources and products are known with certainty.

Linear programming has been recognized as a proven tool for micro as well as for macro planning for its simplicity, flexibility, efficiency, and versatility (Agrawal and Heady, 1972). The static linear and mixed integer programming methods were used in this study. The linear programming technique was used for the specialized crop systems while the mixed integer programming technique was used for the crop-livestock models. The mixed integer programming method was deemed appropriate for the crop-livestock models to ensure that the livestock enterprises take only integer or whole numbers. This is because livestock units are in actual situations not perfectively divisible.

Linear programming consists essentially of the objective function, the activities/resources and the linear constraint components. The complexity in ascertaining the objectives of traditional farmers make the definition of a meaningful and operational objective function a difficult problem in the application of a linear programming technique. There are different objectives that farmers pursue in their choice of enterprise. The two main goals of smallholder farmers identified in the study area are; maximization of food security and income maximization. Other objectives of peasant farmers identified in literature include: maximization of status (Wolf, 1966), maximization of flow of consumption (Upton,1974) and maximization of the number of people fed (Etuk, 1979). The maximization of gross income and household food security objectives were incorporated in the objective functions of this study. The two objectives are in different dimensions and as such the constraint optimization was used. This method known as the lexicographic approach has been used for similar optimization studies by Etuk (1979), Okorowa (1992) and Ahmed (1994). This approach involves optimizing the different objectives in a single decision criterion by employing a hierarchy of objectives and treating all but one as constraints. The income maximization objective was specified as the objective function while food security objective was treated as a constraint to force the production of necessary amount of staple food crops for meeting family consumption levels.

Activities included in the models include: crop production, livestock production, labour hiring (This was discussed under three periods January to April, May to August and September to December), selling activity and consumption activity. Two main types of restraints were employed: resource

restriction (land, labour and capital restrictions) and subjective restriction (food consumption restriction).

### 3.6 Limitations of Linear Programming

The major limitation of linear programming as a planning tool rest almost entirely on the assumptions underlying it. These assumptions are not always in accordance with reality. Linear programming offers little help in estimating input-output relationships; it is inadequate in treating activities that involve decreasing costs. The results from this tool depend entirely on the accuracy with which price expectations, input-output relationship, resource and other restrictions are formulated. Also linear programming treats all enterprises as if they were equally without risk, hence it becomes necessary for the programmer to exclude or limit the scale of enterprises that the farmer considers to be too risky by eliminating them from the range of activities offered or by restraining their level in the programme.

Usually, the nature and problems of agriculture impose limits to which the conventional linear programming technique can be employed as an effective tool to tackle all difficult situations in agriculture. Barnard and Nix (1979) ascertained that in situation where these assumptions are thought not to have a fair representation, some modifications can be made. The divisibility assumption can be tackled using integer programming. This is effective in constraining some variables to take up integer. The single value expectation assumption can be relaxed by employing sensitivity and parametric programming. This allows the variation of prices of one or more outputs or the variation of the levels of one or more resource restrictions to know how optimum farm plans should change. The analysis that involves variation in

prices is termed variable price programming while that which involves resource variation is termed variable resource programming.

### 3.7 Specification of the LP Models

There are two basic models formulated for achieving the objectives of the optimization process. The first model represents only specialized crop production systems using the representative average farm-household. Model 2 considered the integration of crop and livestock production under the existing system. This model was built on the first model. Besides all the crop production activities that were considered, livestock farming was introduced into the existing farming systems The model incorporated crop and livestock linkages. Crop residue was used to feed livestock and animal manure to improve soil nutrient for the benefit of the crop. Both crop residue and animal waste were considered as resources endowment at the farmer's disposal. The objective of this model is to determine the possibility of increasing farm income through the integration of crop and livestock programmes under the same management system.

Two variants of each of the models were formulated to assess the effect of land constraints on both production systems. The basic models consider the average farm size in each of the zones (8.93, 9.85 and 9.11 hectares in zones 1, 2, and 3 respectively). The first variant of the basic models depicts the optimum plan for household with five hectares of land. About 50% of the respondents belong to this category. In the second variant, the farm size was increased to 20 hectares to show the effect of relaxing the land resource constraint on the objective function. The basic models were used to to test the stability of the production systems to changes that might take place in

terms of resource use and returns to resource adjustments. The model runs were estimated by SLP88 student Demons. Version of LP88.

A linear programming problem has three components: an objective, alternative method or processes for obtaining the objective and the resources and other restrictions.

The problem here is to maximize an objective function (gross return) subject to the limitation of certain resources.

The model may be specified as:

Max. gross return $$Z = \sum_{j=1}^{n} C_j X_j \qquad (j = 1, 2, 3, \ldots\ldots\ldots\ldots n)$$

Subject to

$$b_i \geq \sum_{i=1}^{m} a_{ij} X_j \qquad (i = 1, 2, 3, \ldots\ldots\ldots m)$$

and

$$X_j \geq 0$$

Where:

Z = objective function (Gross Return);

$X_j$ = the quantity of the activities where there are n activities to be considered, (i.e. number of hectares of crop be produced or amount of labour to hire).

$C_j$ = net prices per unit of activity with n activities. It measures the marginal contribution of each decision variable. i.e. return over variable cost (gross margin) of one hectare of crop or one head of livestock produced.

$a_{ij}$ = resource requirement per unit of activity. It represents how much of a resource is required for each activity unit. That is the amount of labour required to produce one hectare of crop or one head of livestock.

$b_i$ = available productive resources in limited supply (constraints)

n = number of activities.

m = number of resources.

### 3.8 Activities in the LP Models

The following activities were identified as contributing to the objectives of the farm-households production systems in the study area; Model 1- crop production, labour hiring, selling activity and consumption activities. Besides these, livestock activities, and purchase of farmyard manure were included in model 2.

#### 3.8.1 Crop production

All the crop production activities identified in the various zones were retained for investigation in the optimization process. About 16 crop activities (five sole crops, six 2-crop and five 3-crop mixtures) were identified in zone 1 while 13 crop enterprises comprising of seven sole crops and six 2-crop mixtures were included in the representative farm of zone 2. A total of 20 crop enterprises were considered in zone 3. These include six sole crops, ten 2-crop and four 3-crop mixtures. The cropping pattern of these crop activities and the extent of cultivation are shown in Tables 4.3a, 4.3b and 4.3c for zones 1, 2 and 3 respectively. The unit of production of each crop activity is one hectare.

#### 3.8.2 Livestock activities

The livestock enterprises to be included in all the zones are cattle, sheep and goat. This is because these are the major livestock activities practiced by the households in the study area. Also these activities have been found to have positive linkages in the integration system. The unit of each livestock production activity is one head.

### 3.8.3 Labour hiring activity

Labour hiring activity was included in the model to ensure that shortage of family labour does not seriously constraint the capacity of farm-household to produce. The survey revealed that hiring of labour for farm work is limited to two periods in a year; May-August and September-December. Thus two labour hiring activities were included in the model to supplement family labour supply in these two periods. Labour could be hired at the prevailing wage rate in each zone. No restriction was imposed on the amount of labour that can be hired as long as it is within the capital restriction. Their coefficients in the family labour row are negative implying that if family labour constraint is decreased by one unit its value would increase by one unit. The activity level is one man-hour while the wage rate (naira per man-hour) is indicated in the capital row to be deducted from the available capital.

### 3.8.4 Selling activity

Although it is generally believed that the bulk of the agricultural products in traditional farm-household is destined for home consumption, farmers in the study area have been used, for quite a long time to the market economy. Food crops produced in excess of family requirements are sold. Besides, some households produced some cash crops to supplement their family cash needs. It is assumed that crops produced are immediately transferred into selling activities after deducting the minimum requirement for home consumption. The objective function values of each activity represent the unit selling price of the crop at harvest time.

### 3.8.5 Consumption activity

Subsistence food requirements are met by estimating the farm household consumption of carbohydrate and protein. It is assumed that the carbohydrate requirements are obtained from cereals (sorghum, millet maiwa) and (sorghum, maize and mawa) in zones 1 & 3 and zone 2 respectively. About 70% of protein requirement are assumed to be obtained from cowpea. The objective function values are zero while the row values are positive in both output allocation and food consumption constraint rows.

### 3.8.6 Purchase of farmyard manure

Farmyard manure is used extensively in the study area to augment the use of inorganic fertilizer that is becoming scarce and unaffordable to farmers. The study also revealed that besides the farmyard manure produced within the household, they also purchase from outside. Thus purchase of farmyard manure was incorporated into the model as an activity to ensure that the available farmyard manure within the household does not limit its use. No restriction was imposed on the amount of farmyard manure that can be purchased as long as it is within the capital restriction. The coefficient in the available farmyard manure row is negative implying that if the farmyard manure available within the household is decreased by one unit its value would increase by one unit. The activity level is 1 kg while the net price (0.5 naira per kg) is indicated in the capital row to be deducted from the available capital.

### 3.9 Constraints in the LP Models

The specification of the resources available in the farm-household is essential due to certain factors that become limiting. Two types of constraints were considered based on the resource situation in the household. These are the resource and subjective constraints. The resource constraints include; land, livestock number, labour, farmyard manure, crop residue and draught power supply and capital. The subjective restriction includes the minimum amount of food required to sustain the family. Output allocation constraint was also included to ensure that all that is produced is either consumed or transferred into selling activity.

#### 3.9.1 Land restriction

The average farm size observed in each zone was taken as the limit of land available for cultivation in the basic models. Thus the average land area available for cultivation in the basic models was restricted to 8.93, 9.85 and 9.11 hectares in zones 1, 2 and 3 respectively. The survey also revealed that more than 50% of the households had farm size between 0-5 hectares and less than 15% had farm size greater than 20 hectares. Thus the land constraint limit was reduced to 5hectares in the first variant of the models and increased to 20 hectares in the second variant. This was done to reflect the different farm situations with varying land resource base.

#### 3.9.2 Livestock restriction

The existing average livestock number for cattle sheep and goat was taken as the available livestock in the household. The respective size of cattle, sheep and goat used in the basic models are; 3, 7, 13 for zone 1, 5, 9, 12 for zone 2 and 4, 8, 12 for zone 3. The average number of livestock in the

household was obtained by finding the average of total offtake plus the number at the end of the year and total intake plus the number at the beginning of the year ((End + Exit) + (beginning + Entry))/2. The total offtake include the number sold, deaths, consumed while the intake includes the number given out, purchased and births during the year.

The study revealed that about 58% of the household surveyed had about half of the average holding in each zone. Thus these values were used in the first variant of the basic model 2. The livestock size was doubled for the household with larger holdings in the second variant. This was done to assess the effect of different livestock sizes to resource allocation in the integrated farming systems.

### 3.9.3 Labour restriction

Both hired and family labour were used for production activities in the study area. In the specialized crop systems, family labour accounted for about 70%, 72% and 73% of the total labour used in zones 1, 2 and 3 respectively. While the contribution of family labour in the integrated systems was about 77%, 80% and 79% in zones 1, 2 and 3 respectively. The level of restraint on the available family labour was determined based on the composition and size of the household. The average household was found to be made up of 5, 6 and 6 man-equivalents in zones 1, 2 and 3 respectively. Norman's' conversion factor (1972) was used to arrive at the available man-equivalent.

Labour restriction was separated into three periods. January - April, May - August and September - December. The first period is the dry season when farming activities are at their lowest stage. Period two is the peak labour demand period when farming activities are at their highest peak while

period three is the harvesting period. The potential labour supply was estimated by assuming that each man unit will work on the farm for about 70% of the total number of days in each period and for five hours a day. Thus for zone 1 the potential labour supply was 0.7 X 120 days X 5 hours X 5 man-equivalent to 2100 man-hours, while for zones 2 and 3 the labour supply was 0.7 X 120 days X 5 hours X 6 man-equivalent to 2520 man-hours. Thus each of the periods has a maximum family labour restriction of 2100, 2520 and 2520 man-hours for zones 1, 2 and 3 respectively. Additional labour required above these levels would be hired at the prevailing wage rate. The row values are the total labour (man-hours) per hectare used for the various production activities.

### 3.9.4 Capital restriction

The level of capital available to the average household was the constraint to the amount used to purchase seeds, fertilizer, agro-chemicals, farmyard manure and hired labour. No provision was made for capital borrowing in the models because none of the households interviewed borrowed capital for their production activities during the survey period. Capital was mainly generated from sales of crop and livestock in addition to the little income from off-farm activities. The row values in the matrix are the variable cost per hectare for the purchase of seeds, fertilizer, agro-chemicals, and farmyard manure used for the specified production activities. The cost of hired labour was excluded from these values in all the models because this was taken care of in the labour hiring activity. Besides this, the cost of purchasing farmyard manure was excluded in the integrated crop-livestock systems due to the same reason.

### 3.9.5 Farmyard manure restriction

Farmyard manure was used to supplement the use of inorganic fertilizer that is becoming unavailable and expensive. The potential supply of farmyard manure in the household would depend on the type and number of livestock in the household. Kallah and Adamu (1988) in their study on the importance of manure as fertilizer, found out that a livestock unit would produce about 1.5 kg of manure per day. A livestock unit was assumed to be equal to 250 kg that is equivalent to one bull or 10 sheep or goat (Jankhe, 1982). In estimating the potential supply of farmyard manure in the household, it was assumed that the animals would be out grazing on an average of 5 hours a day or about 38 days in the dry season (November - April) and 2 hours a day or about 15 days in the wet season (May - October). Thus for 53 days in a year the animals are out grazing and for the rest of the year they are tiltered in their barn. Using this assumption, the potential available manure in zone 1 is 312 days X 1.5 kg X 5 livestock unit = 2340 kg. Assuming the weight of other debris (left over feed, kitchen waste etc.) make up about 30% of the manure thus, the total available manure per household in zone 1 was estimated at 3042 kg. The total livestock unit for zones 2 and 3 are 7 and 6 respectively. Using the above procedure, the potential available manure was estimated at 4259 kg for zone 2 and 3650 kg for zone 3. To supplement these quantities, the programme allows for purchasing additional manure when required. The row values are the quantity (kg) of farmyard manure required to produce one hectare of each of the specified crop enterprises.



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### 3.9.6 Draught power restriction

All the households interviewed used animal traction for land preparation, weeding and/or transportation. The intensity of use however varies from zone to zone. This resource was not considered as a constraint in the real sense but its incorporation in the model helps to identify the level of usage in the optimum plan. The row values are the man-hours equivalent of draught power used for the production of one hectare each of the various crop enterprises. It is assumed that one draught-hour is equivqlent to 6 man-hours. The restriction was fixed at zero to ensure free use of this resource.

### 3.9.7 Crop residue restriction

Crop residue from the crop activities was used to feed livestock. The stover/straw content of each of the crops produced in the household was estimated using the ratio of 1:2 grain to stover ratio for maize, sorghum, millet, and maiwa and 1:1 grain to straw ratio for cowpea, groundnut, cotton and rice The total volume of each of the crops produced in the average household was estimated for each zone and using the above ratio, the maximum limit of crop residue available was obtained.

The study revealed that the available crop residue in the household lasted only for a period of about 6 months as a result of poor handling and storage facilities. Assuming that a livestock unit consumes about 6.25 kg dry matter per day, with 100% crop residue supplementation in the dry season, the total crop residue required by each livestock unit is 6.25 kg X 182.5 days = 1140.63 kg. (Jankhe 1982). This value was used to generate the coefficient for the row values in the matrix.

### 3.9.8 Output allocation restriction

These were introduced into the models to ensure that the total quantities of each crop produced were accounted for in the model. This restriction level is zero showing the condition that all that is produced is sold after deducting the quantities for home consumption. The row coefficients are the yield per hectare of the specified crop activities.

### 3.9.9 Consumption restriction

Consumption of staple foods in the household was specified in the matrix as constraint to force the production of necessary amount of food crops for meeting minimum family consumption level. It was assumed that all the energy required in the household was obtained from staple cereal crops (maize, millet, sorghum and *maiwa*) while about 70% of the protein was obtained from cowpea. Aduku, (1993) indicated that an average adult of about 65kg body weight would require a minimum energy of 2550 kcals and 56 g protein per day or 930750 kcal and 20.44 kg protein annually. Multiplying these values by the household size in man-equivalents give the annual minimum energy and protein required by the average household. A review by Momento de l'agronome (1984) revealed that sorghum, millet, maize, and *maiwa* will supply about 3,800, 3,555, 3,795, 3,680 kcal respectively while cowpea will supply about 25.1% protein. The survey revealed that the total consumption unit is about 10.21, 9.90 and 10.96 persons in zones 1, 2 and 3 respectively. The consumption level of the major staple food indicated in the study are that sorghum, millet and maiwa are consumed in the ratio of 0.40:0.38:0.22 and 0.33:0.46:0.21 in zones 1 and 3 respectively while sorghum, maize and maiwa were consumed in the ratio of 0.50:0.35:0.15 in zone 2.

Using these values, the respective minimum annual quantity of sorghum, millet, maiwa and protein required by the average household in zone 1 was calculated as follows:

930750 kcal x 10.21 persons x 0.40 (sorghum ratio)/3800 kcal = 1000 kg

930750 kcal x 10.21 persons x 0.38 (millet ratio)/3555 kcal = 1016 kg

930750 kcal x 10.21 persons x 0.22 (maiwa ratio)/3680 kcal = 568.kg

20.44 kg Protein x 10.21 persons x 0.7 (cowpea ratio)/0.2510 = 625 kg

Using the same procedure, the minimum annual requirements of the staple food crops were estimated for zones 2 and 3.

**CHAPTER 4**

# DESCRIPTION OF THE FARM-HOUSEHOLD SYSTEM

## 4.0 Introduction

Proper representation of an agricultural situation requires a good understanding of the farm-household characteristics. The aim of this chapter is to discuss the characteristics of the farm-household system and how they affect decision making in the household

## 4.1 Resource Allocation in the Study Area

### 4.1.1 Land resource and tenureship

Land is the most crucial factor of production in traditional agriculture. Land in the study area as in many parts of Nigeria is communally owned and individuals only possess the usufructuary right to the piece of land they occupy and these rights can be inherited (Ogungbile, 1980). The ownership of land is controlled at the local level by the village head. This implies that the individual residing in the community has no right to alienate the land he holds. The mode of land tenureship system in the three zones studied is presented in Table 4.1.

The study revealed that most of the household surveyed operated under a relatively secure tenurial arrangement, as most of the households owned the plot of land they cultivated. Out of the total number of plots cultivated, about 71%, 76% and 65% were acquired through inheritance in zones 1, 2 and 3 respectively while about 26%, 19% and 33% were purchased in the respective zones. Less than 10% of the plots in all the three zones were borrowed or rented.

Table 4.1 Mode of land tenure in the study area

| | Zone 1 | | Zone 2 | | Zone 3 | |
|---|---|---|---|---|---|---|
| Tenurial Status | No. of plots | % of total | No. of plots | % of total | No. of plots | % of total |
| Inherited | 135 | 71 | 149 | 76 | 115 | 65 |
| Purchased | 49 | 26 | 38 | 19 | 59 | 33 |
| Borrowed | 6 | 3 | 9 | 5 | 4 | 2 |
| TOTAL | 190 | 100 | 196 | 100 | 178 | 100 |

Land in the study area was used for continuous cultivation with little or no fallow. Fragmentation of land holding was typical in all the zones. The range of plot land per household varied from 2 to 11 with an average of about 5 plots in each of the zones. The fragmentation of land holdings in the study area could be attributed the tenurial systems operating in the area that precludes individual title to land.

The average farm sizes cultivated by the sampled households during the survey period were 8.93, 9.85 and 9.11 hectares in zones 1, 2 and 3 respectively. An analysis of variance test indicates that there were no significant differences ($P < 0.05$) in farm size between the three zones. One notable feature in the study area was the inequitable distribution of farmland among the sampled households. The graphical presentation of the farm size distribution in the study area is depicted by a pie chart (Fig 4.1).

In quantitative terms, about 50% of the households surveyed cultivated about 0.5-5 hectares of land, 35% cultivated between 5.1 to 20 hectares while about 15% cultivated above 20 hectares of land in all the zones. The implication of this is that majority of the households surveyed were smallholders who produce mainly for household subsistence with little surplus for the market.



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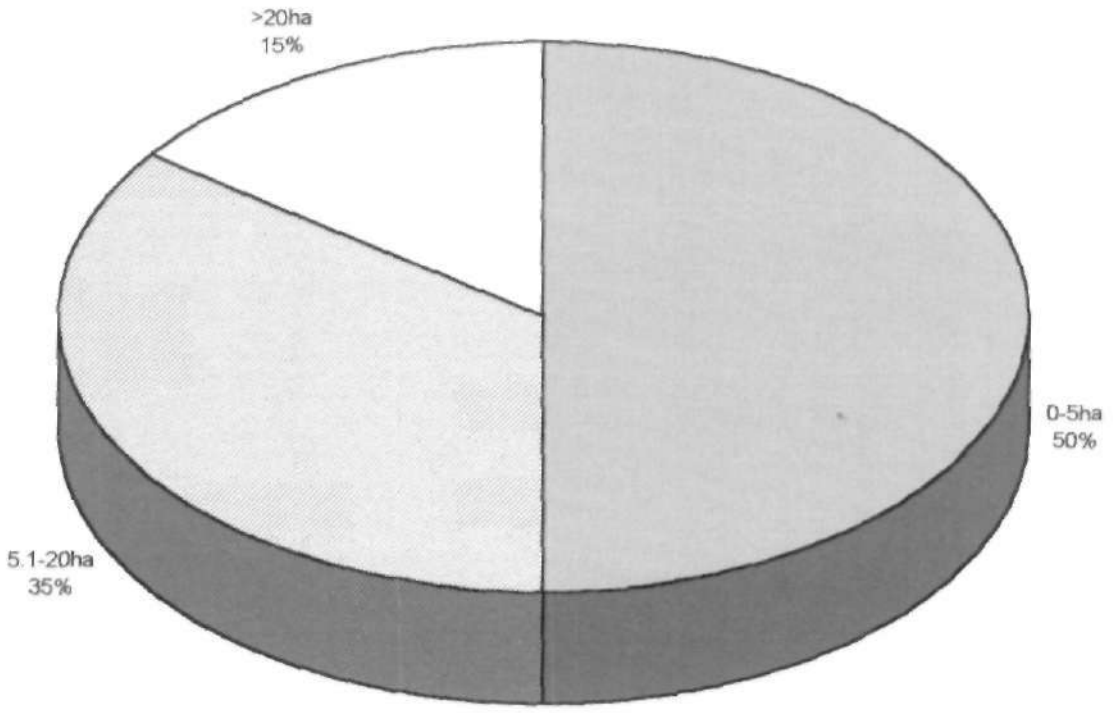



Fig 4.1: Farm size distribution among the households in the study area.

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### 4.1.2 Labour composition and size

Farm labour in the study area constitutes mainly of family labour as in most traditional agriculture. This means that the size and composition of the household in terms of age and gender is very important in determining the size of land cultivated and the intensity with which the farming activities are carried out. Hence potential family labour supply for farm activities will depend on the composition and quality of household members. Table 4.2 shows the size and composition of household size in the study area. Norman's (1973) weighing formula was used to convert household size into adult man-equivalent. Male youth, female youth, female adult, elderly persons and children were converted into man-equivalent using the factor; 1.00, 0.75, 0.75, 0.5 and 0.50 respectively.

Table 4.2 Household size and composition (man-equivalent)

| | Zone 1 | Zone 2 | Zone 3 |
|---|---|---|---|
| Male Adult | 2.60(2.60) | 2.71(2.71) | 2.68(2.68) |
| Female Adult | 2.32(3.09) | 2.04(2.72) | 2.23(2.97) |
| Male Youth | 1.85(1.85) | 2.76(2.76) | 2.94(2.94) |
| Female Youth | 1.24(1.65) | 1.08(1.42) | 1.58(2.11) |
| Children | 1.90(3.80) | 1.10(2.20) | 1.24(2.49) |
| Elderly Person | 0.30(0.60) | 0.21(0.42) | 0.29(0.58) |
| TOTAL | 10.21(13.59) | 9.90(12.23) | 10.96(13.77) |

Figures in bracket are the average number of persons in each category.

The household size in the study area consists of an average of 13 individuals with average consumption units of 10.21, 9.90 and 10.96, man-equivalent in zones 1, 2 and 3 respectively. The composition of household members in the different zones follow similar pattern. Adult male and female

members between 15 and 60 years comprise about 43% of the entire family size. Adolescents between 7-14 years were about 32% of the household population while elderly people above 60 years and children below 7 years comprise one fourth of the household size in the study area.

In terms of household labour supply, about 56%, 66% and 66% of the household members in zones 1, 2 and 3 respectively were capable of providing the family labour force. The relative proportions of the household labour force have serious implications on the potential labour capacity per household. The analysis further indicates that male labour accounted for about 80% of the potential labour capacity while female labour was insignificant. Women, though involved in threshing, winnowing and livestock feeding and watering were not actively involved in farm activities because of the *purdah* system where women are secluded. The household labour force were involved in such activities as land clearing, planting, weeding and harvesting. The households in the study area supplemented the family labour force by hiring labour for such activities as ridging, weeding and harvesting. Payment was mostly in cash depending on the prevailing wage rate in the locality at the period. The family labour force constituted about 71% of the total labour used for crop production in the study area while only family labour was used for all livestock activities in all the zones.

### 4.1.3 Capital input

Capital inputs are classified according to their productive life into fixed and operating capital. The fixed capital input consists of items such as machines, hand tools, land improvements and buildings with productive life that extend beyond one production cycle. Whereas the operating capital

inputs includes seed, fertilizer, herbicides, insecticides, drugs, vaccines and livestock feed. These inputs are used up in a single production cycle.

The level of fixed capital in the study area was relatively low. Various explanations have been given for this shortage. This range from low productivity, low income that result in low capacity to save for investment and unavailability of low-priced credit facilities. Most of the households in the study area relied heavily on work bulls and farm implements, such as hoe, cutlass, ox-plough (*garma*), weeder (*chakarkara*), and carts (*omolanke*). Less than 5% of the households surveyed owned tractor. It can thus be deduced that the mode of crop cultivation in the study area is still relatively traditional.

Operating capital items for crop activities such as fertilizer, agro-chemicals, seeds were inputs that usually involve cash expenditure. For the livestock activities, operating items include drugs, vaccines and supplementary feed such as *kaikei, dutsa, kanwa*. The levels of cash expenditure on crops and livestock are fully discussed in the section on cost-return analysis. Personal savings from sales of crop and livestock constituted the major source of capital for financing agricultural activities in the study area. Very few households borrowed money from informal sources like friends and relatives. None of the respondents borrowed money from institutional sources during the survey period. The major reason given was the inaccessibility to this source of credit

### 4.1.4 Cropping pattern

The ranges of possible cropping alternatives in any particular area are determined by the climate (rainfall and temperature), soil, personal taste, tradition, labour availability, available market, transport facilities and

available capital. The physical and socio-economic characteristics of Katsina state is very favourable for the production of varieties of crops ranging from cereal, grain legumes, starchy roots to vegetable crops. Most of these crops have become adapted to both the food habit of the households and the emerging economic incentives. Cereal crops and grain legumes were the predominant crops in the area. Considerable quantities of vegetables like tomatoes and pepper are also grown.

A total of 12 crops were grown in about 16, 13 and 20 combinations in zones 1, 2 and 3 respectively. These crops were grown either as sole stands or in mixture with two to three crops. The major crops grown include sorghum, millet, maize, cotton, *maiwa*, rice, groundnut, cowpea, soybean, *cocoyam* and tomato. Sorghum and millet were the major food crops in zones 1 and 3 while maize and sorghum were the major food crops in zone 2. In terms of area cultivated, sorghum ranked as the most important staple food crop in the state, and this is followed by millet and maize in that order. The major cash crops were, tomato and groundnut in zone 1, maize and cotton in zone 2 and cotton and groundnut in zone 3. Table 4.3a, 4.3b and 4.3c show the total farm size in hectares devoted to the various sole and mixed crops grown in zones 1, 2 and 3 respectively.

Table 4.3a: Distribution of farm size to crops grown in zone 1

| Crop | No. of Household | % of Household | Total farm size | % of farm size |
|---|---|---|---|---|
| Sorghum | 13 | 32.5 | 32.2 | 9.01 |
| Millet | 10 | 25.00 | 47.0 | 13.16 |
| Tomato | 14 | 35.00 | 32.1 | 8.99 |
| Groundnut | 1 | 2.50 | 2.0 | 0.56 |
| Rice | 1 | 2.50 | 1.2 | 0.34 |
| Mi-Cp | 25 | 62.50 | 70.7 | 19.79 |
| So-Gn | 14 | 35.00 | 43.4 | 12.15 |
| So-Cp | 14 | 35.00 | 53.4 | 14.95 |
| Ml-Gn | 9 | 22.50 | 25.6 | 7.17 |
| Mwa-Cp | 3 | 7.50 | 10.0 | 2.80 |
| So-Mwa | 1 | 2.50 | 1.6 | 0.45 |
| Ml-Gn-Cp | 2 | 5.00 | 7.2 | 2.01 |
| So-Gn-Cp | 3 | 7.50 | 18.0 | 5.04 |
| Ml-So-Cp | 2 | 5 00 | 6.8 | 1.90 |
| Mi-So-Gn | 1 | 2.50 | 4.0 | 1.12 |
| Ml-So-Mwa | 1 | 2.50 | 2.0 | 0.56 |
| Total | | | 357.2 | 100 |

Key:

Mi = Millet
Cp = Cowpea
Mwa = Maiwa
Ma = Maize
So = Sorghum
Gn = Groundnut
Ri = Rice

Table 4.3b: Distribution of farm size to crops grown in zone 2

| Crop | No. of Household | % of Household | Total farm size | % of farm size |
|---|---|---|---|---|
| Maize | 27 | 71.1 | 116.2 | 31.03 |
| Sorghum | 30 | 78.9 | 85.0 | 22.70 |
| Cotton | 13 | 34.2 | 63.1 | 16.95 |
| Cowpea | 6 | 15.8 | 9.4 | 2.51 |
| Rice | 5 | 13.2 | 5.8 | 1.55 |
| Groundnut | 1 | 2.6 | 4.8 | 1.28 |
| Maiwa | 1 | 2.6 | 0.4 | 0.11 |
| Ma-So | 18 | 47.4 | 45.5 | 12.15 |
| Co-Cp | 8 | 21.1 | 24.2 | 6.46 |
| So-Cp | 3 | 7.9 | 5.6 | 1.50 |
| So-Gn | 3 | 7.9 | 2.0 | 0.53 |
| So-Soy | 3 | 7.9 | 11.2 | 2.99 |
| Ma-Rice | 1 | 2.6 | 1.2 | 0.32 |
| Total | | | 374.4 | 100.0 |

Table 4.3c: Distribution of farm size to crops grown in zone 3

| Crop | No. of Household | % of Household | Total farm size | % of farm size |
|---|---|---|---|---|
| Sorghum | 16 | 43.2 | 65.3 | 19.37 |
| Cotton | 5 | 13.5 | 12.8 | 3.8 |
| Millet | 5 | 13.5 | 5.2 | 1.54 |
| Maiwa | 3 | 8.1 | 1.6 | 0.47 |
| Rice | 3 | 8.1 | 10.0 | 2.97 |
| Groundnut | 1 | 2.7 | 2.0 | 0.59 |
| Ml-Co | 22 | 59.5 | 81.6 | 24.20 |
| So-Co | 4 | 10.8 | 4.4 | 1.31 |
| So-Gn | 14 | 37.8 | 38.2 | 11.33 |
| Ml-Cp | 6 | 16.2 | 28.0 | 8.31 |
| So-Cp | 6 | 16.2 | 6.0 | 1.78 |
| Ma-Co | 6 | 16.2 | 15.6 | 4.63 |
| Co-Cp | 4 | 0.8 | 19.2 | 5.69 |
| Ml-Ma | 1 | 2.7 | 22.4 | 6.64 |
| Ml-Gn | 1 | 2.7 | 1.4 | 0.42 |
| Ml-So | 2 | 5.4 | 2.4 | 0.71 |
| Ml-Co-Cp | 3 | 8.1 | 9.6 | 2.85 |
| So-Co-Cp | 5 | 13.5 | 6.0 | 1.78 |
| So-Gn-Cp | 1 | 2.7 | 2.7 | 0.24 |
| Ml-Ma-Cp | 1 | 2.7 | 2.8 | 0.83 |
| Total | | | 337.1 | 100.0 |

Sole cropping accounted for 32%, 77% and 29% of the cultivated hectarage in zones 1, 2 and 3 respectively while the remaining hectarage was allotted to mixed cropping. The predominant sole crops were sorghum, millet and tomato in zone 1, maize, sorghum and cotton in zone 2 and sorghum, cotton and millet in zone 3. Sorghum seems to be an important crop in all the zones in terms of meeting family food requirement. The crop mixtures in all the zones as indicated in Tables 4.3a-3c were cereal and legume based. The major reasons given for intercropping cereal with legumes were: higher yield, low insect infestation, and soil improvement for continuous cropping and risk aversion. Intercropping two crops was the most common combination in all the zones. None of the households surveyed in all the zones recorded more than three crops in a mixture

Fig 4.2 presents the volume of total production of major crops cultivated across the three zones. It can be observed from the figure that the volume of sorghum produced in the state was highest in zone 1 followed by zones 2 and 3 in that order. Millet was produced more in zone 1 followed by zone 3 while none of the farmers cultivated millet in zone 2. About 84% of the maize produced in the study area was from zone 2 while the remaining was recorded in zone 3. Also, about 52% of cotton produced in the study area was from zone 2 while the remaining proportion was cultivated in zone 3. Groundnut and cowpea were produced more in zone 1 while the least of groundnut was in zone 2 and the least of cowpea was in zone 3.

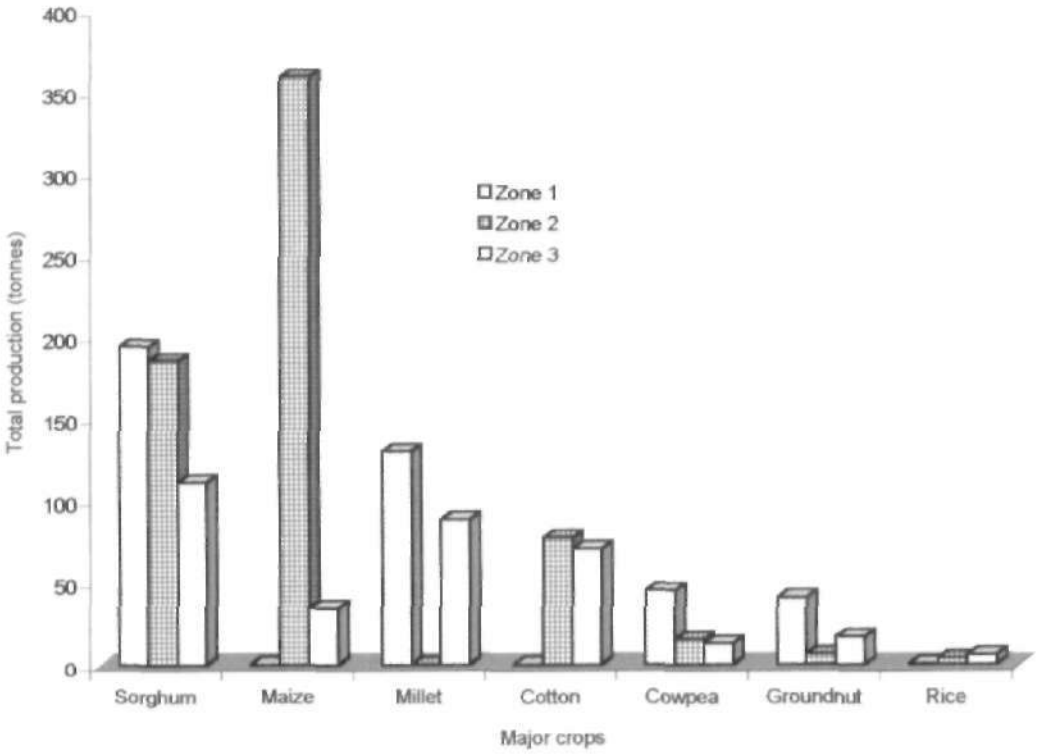



Fig 4.2: Volume of total production of major crops cultivated across the zones.

### 4.1.5 Livestock size structure

The major livestock species in the study area were cattle, sheep, goat, donkeys, poultry, camel and horses. In terms of population, poultry was the most common followed by goat, sheep and cattle in that order. The livestock ownership structure in the three zones studied revealed that 54% of the households surveyed had an average of two work bulls, about 43% had between 3 to 8 while less than 3% had more than 10 heads. About 25% and 40% of the households had between 2 to 5 sheep and goats respectively while 36% and 41% had between 6 to 10 sheep and goats respectively. The livestock population structure in the three zones is presented in Table 4.4. The average numbers of each of the livestock species per household during the year under study was estimated from Table 4.4 using the formula (CARDI, 1989):

$$\frac{(\text{End} + \text{Exit}) + (\text{Beginning} + \text{Entry})}{2}$$

Where:

End = Number of livestock at the end of the year under study

Entry = Number that entered the stock in the year (birth, bought)

Beginning = Number of livestock at the beginning of the year.

Exit = Number that left the stock within the year (sold, died, consumed)



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Table 4.4: Livestock population structure in the study area.

| Livestock | Initial No. | No. sold | No. bought | No. of birth | No of dead | Consumed | Final No. |
|---|---|---|---|---|---|---|---|
| Zone 1 | | | | | | | |
| Cattle | 91 | 35 | 37 | 0 | 0 | 0 | 93 |
| Sheep | 238 | 59 | 19 | 12 | 9 | 5 | 196 |
| Goat | 445 | 80 | 28 | 34 | 15 | 7 | 405 |
| Zone 2 | | | | | | | |
| Cattle | 179 | 24 | 20 | 0 | 0 | 0 | 165 |
| Sheep | 302 | 26 | 31 | 23 | 10 | 10 | 310 |
| Goat | 421 | 48 | 31 | 35 | 6 | 12 | 403 |
| Zone 3 | | | | | | | |
| Cattle | 121 | 28 | 31 | 0 | 0 | 0 | 114 |
| Sheep | 259 | 40 | 21 | 22 | 5 | 17 | 238 |
| Goat | 413 | 61 | 18 | 30 | 15 | 13 | 371 |

The analysis revealed that the average number of cattle, sheep and goat in zone 1 were three, seven and thirteen respectively. The numbers in zone 2 were five, nine and twelve while the averages in zone 3 were four, eight and twelve for cattle, sheep and goats respectively. Work bulls were kept mainly for cultivation purposes while sheep and goats were kept mainly for meeting household cash need. Other reasons identified by the respondents for keeping livestock in the study area include food security, savings and investment and as a source of income. Although manure is becoming very important for soil improvement in the study area, none of the households interviewed kept livestock only for the manure.

The off-take rates, calculated as the proportion of the total stock that left the farm (sold, died, consumed) during the survey period were 38%, 37% and 23% for cattle, sheep and goat in zone 1, the rates in zone 2 were 13%, 15% and 16% while the rates in zone 3 were 23%, 24% and 24% for the respective livestock types. The off-take rates were higher for cattle than sheep and goat in zone 1 while the rates were higher for sheep and goats than cattle in the two other zones. All the cattle that left the stock during the survey year were sold in all the zones. None of the respondents indicated cattle mortality or slaughter during the survey year. Of the total sheep and goat off-take, the proportion sold were 81% and 78% respectively in zone 1, 57% and 73% in zone 2 and 65% and 69% in zone 3. The study also revealed that income from sale of cattle was the highest followed by goat and then sheep.

### 4.1.6 Pattern of crop-livestock integration

The most prominent features of crop-livestock integration are the extent to which crop residues are used to feed livestock, work animals providing draught power and manure applied to improve soil fertility. Households in the study area were actively involved in integrated crop and livestock production systems at varying levels. All the households surveyed fed their livestock with crop residue from their farms, used manure to fertilize their farms and made use of draught power for cultivation purposes. Reasons given for the integration of crop and livestock include: to diversify risk from only crop production, as a source of draught power, traditional practice, income maximization.

The nature of crop-livestock integration in the study area is presented in fig 4.3. Crop residue from crop production was used as a feed resource for livestock production while manure from livestock production was used as fertilizer source for improving the soil for crop production. Also livestock production provided draught power as labour resource while the household residual labour was used for livestock production during the off-farming season. Revenue from crop production and other off farm income was invested into purchasing livestock as a form of savings/investment while livestock production provided ready cash for purchasing crop inputs and meeting other household expenditure. Income from crop and livestock constituted the total farm income in the integrated crop-livestock systems in the study area. However, all the households surveyed in the three zones claimed that their major income was from crop production.

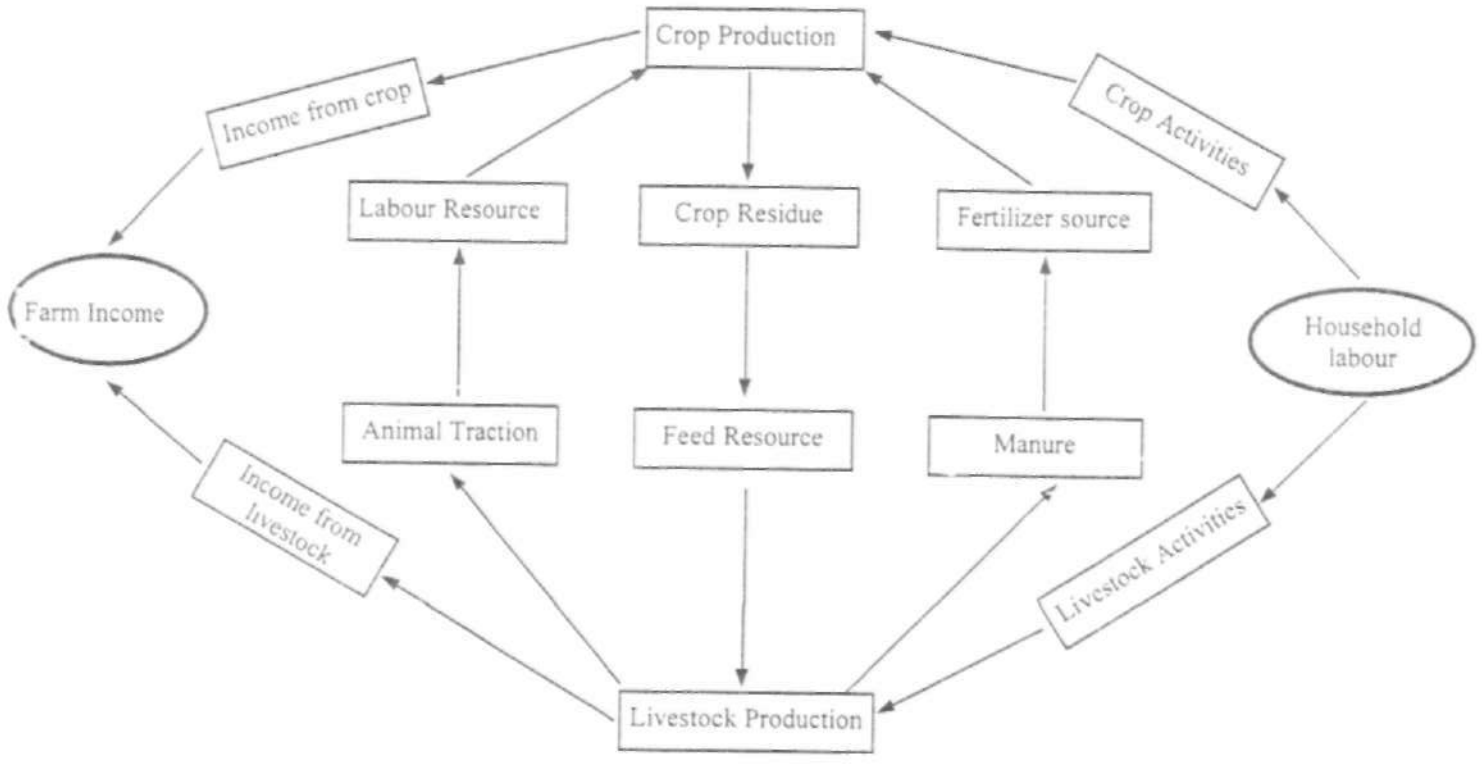



Fig. 4.3 . Pattern of crop-livestock integration in the farm-household systems.

Source: Field Survey, 1998

None of the respondents produced fodder for livestock feeding. The major reasons were: they did not see the need for its production, lack of knowledge on production while some indicated inadequate land as their reason for not embarking on fodder production. Crop residue was a major feed resource in the study area, particularly during the dry season. The study revealed that straws from cereal crops were left on the field and livestock were allowed to graze these fields (those close to the homestead). However, legume haulms (cowpea, groundnut) were transported to the household for feeding the animals. The reason given was that the legume haulms had significantly higher nutritive value than cereal straws moreover the former attract higher price. It was also observed that the crop residues usually last only between four to six months in the dry season. Crop residue supplementation accounted for about 70% of the total feed intake during this period.

The respondents in the study area recognized the value of livestock droppings (manure) for soil fertility. In addition to livestock droppings, farmyard manure was also made up of kitchen waste and debris. The study revealed that the available manure from the households was not able to go round all the farms plots therefore in most cases it was used on farms closer to the homestead. This was attributed to its bulkiness and the insufficient quantity produced. The respondents claimed that the manure from the household constituted between 10%-100% of the total manure used on the farms, with an average of about 40%. The balance was usually purchased. Manure was sold for #40.00 per *mangala* (donkey load), a cart load (*omolanke*) equivalent to 5 *mangala* was sold at #200.00 while a tipper load

equivalent to 12 *mangala* was sold at ₦450.00 each. The transportation and spreading of manure is labour intensive and can most effectively be undertaken using a cart or tipper. Over 80% of the households in the study area used donkeys and carts, about 32% used tippers while a few cases of head transport were noted. Manure was applied mostly on cereal crops. The quantity applied varied from 20 *mangala* (400 kg) to 100 *mangala* (2000 kg) per hectare. The use of manure in the study area was attributed to increasing cost and or unavailability of inorganic fertilizer and reduction or elimination of fallow period.

The major animals used for traction in the study area were oxen and donkey. However, oxen were more commonly used in all the zones for the various crop cultivation processes while donkey was mainly used for carting and transport. The principal tasks performed with the aid of draught animals in the study area were planting, weeding, and harvesting of groundnut and transport of manure, farm inputs and harvested produce. Equipment used for harnessing these animals were ridger (*garma*), weeder (*chakarkara*), cart (*omolanke*) and woven basket (*mangala*).

### 4.2 Cost-Return Analysis

The profitability of the specialized crop production and the integrated crop-livestock systems were determined by looking at the relationship between input costs and returns in the two production systems. The gross margin, which is the difference between total variable costs and total revenue, were estimated for the average household in the three zones. The prevailing market prices of the input and output were used in estimating the values of costs and returns for easy comparison. The overall picture of the

costs and the accrued revenue are presented in Tables 4.5a and 4.5b for crop and integrated crop-livestock production systems respectively.

### 4.2.1 Costs

In estimating the total cost of production, only the variable cost elements were considered. The cost items considered in the specialized crop production systems were, seed, fertilizer, agro-chemical, farmyard manure and labour, in addition to these, livestock supplementary feed, drugs and veterinary services were included in the integrated system. The average wage rate prevailing in the zones were used in computing the labour cost. These were: ₦20.17, ₦29.06 and ₦19.89 per man-hour in zones 1, 2 and 3 respectively. The higher wage rate in zone 2 could be attributed to the high demand for labour by experimental fields' setup by Institute for Agricultural Research (IAR) and International Institute for Tropical Agriculture (IITA) located around the villages surveyed. The analysis of the cost of production as shown in Table 4.4a and 4.4b revealed that the major components of costs were hired labour, manure, fertilizer and agro-chemicals in the specialized crop system in addition to drugs, veterinary services and livestock supplementary feeds in the integrated system. Labour cost accounted for about 71%, 67% and 71% of the total variable cost in the specialized crop system while the percentages dropped to 57%, 56% and 59% in the integrated systems of zones 1, 2 and 3 respectively. The low proportion of the hired labour cost to the total variable cost in the integrated system was because none of the households interviewed hired labour for livestock activities. The high proportion of labour cost to the total costs confirms the assertion that labour constitutes a high proportion of costs in traditional agriculture.

Farmyard manure was an important input in the crop production system in zones 1 and 3 while fertilizer was more important in zone 2. Farmyard manure accounted for about 12%, 14% of the total cost in zones 1 and 3 while fertilizer accounted for about 20% of the total cost in zone 2. Households in zone 2 depends more on inorganic fertilizer compared to those in zones 1 and 3 who tend to use more of farmyard manure. This could be attributed to the fact that the households surveyed in zone 2 tend to cultivate larger farm sizes and also farmers in this zone have more understanding and access to fertilizer as a result of greater involvement of research institutes like IAR and IITA in this zone. The analysis of the integrated system further highlights the fact that feed supplement was the most costly livestock input. The cost of feed supplement accounted for about 17%, 13% and 15% of the total cost in zones 1, 2 and 3 respectively.

The total costs of production were ₦37,821.15, ₦62,100.57 and ₦44,648.30 in the specialized crop system while in the integrated system, the total cost were; ₦47,102.05, ₦73,632.58 and ₦54,042.80 for zones 1, 2 and 3 respectively. The higher cost in the integrated systems was due to additional cost incurred on livestock inputs. An analysis of the costs incurred on crop and livestock inputs in the integrated systems revealed that the cost on crop inputs were about 77%, 82% and 79% of the total cost in the three respective zones. This implies that the cost of livestock inputs was very minimal compared to the crop input.



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Table 4.5a. Gross margin analysis of crop production by household across the zones.

| Item | Zone 1 (Naira) | Zone 2 (Naira) | Zone 3 (Naira) |
|---|---|---|---|
| Average farm size (ha) | 8.93 | 9.85 | 9.11 |
| **Costs:** | | | |
| Seed | 3162.50 | 3683.40 | 3489.50 |
| Fertilizer | 2490.66 | 12139.98 | 2789.10 |
| Agro-chemical | 691.84 | 1172.00 | 363.78 |
| FYM | 4668.20 | 3706.90 | 6143.73 |
| **Labour:** | | | |
| Family lab. (Man-hour) | 3187 72 | 3643.50 | 4267.21 |
| Hired lab. (Man-hour) | 1329.10 | 1424.58 | 1601.92 |
| Total lab. (Man-hour) | 4516.82 | 5068.08 | 5874.10 |
| Wage rate (Naira/hour) | 20.17 | 29.06 | 19.89 |
| Hired labour cost | 26807.95 | 41398.29 | 31862.19 |
| **Total variable cost** | 37821.15 | 62100.57 | 44648.30 |
| **Revenue from crops** | 77053.80 | 165327.50 | 85206.30 |
| Gross Margin (GM) | 39232.65 | 103226.93 | 40558.00 |
| Gross margin/ha | 4393.35 | 10476.16 | 4451.11 |
| GM / Naira invested | 1.04 | 1.66 | 0.91 |
| GM / Man-hour family labour | 12.31 | 28.33 | 9.50 |

Table 4.5b: Gross margin analysis of crop-livestock production by household across the zones

| Item | Zone 1 (Naira) | Zone 2 (Naira) | Zone 3 (Naira) |
|---|---|---|---|
| Average farm size (ha) | 8.93 | 9.85 | 9.11 |
| **Costs:** | | | |
| Seed | 3162.50 | 3683.40 | 3489.50 |
| Fertilizer | 2490.66 | 12139.98 | 2789.10 |
| Agro-chemical | 691.84 | 1172.00 | 363.78 |
| FYM | 3266.00 | 2159.48 | 4086.23 |
| Supplementary. Feed | 7852.84 | 9481.78 | 8291.05 |
| Drug/vet. Services | 2830.26 | 3597.65 | 3160.95 |
| **Labour:** | | | |
| Family lab. (Man-hour) | 4541.72 | 5564.70 | 5891.21 |
| Hired lab. (Man-hour) | 1329.10 | 1424.58 | 1601.92 |
| Total lab. (Man-hour) | 5870.82 | 6989.28 | 7493.13 |
| Wage rate (#/hour) | 20.17 | 29.06 | 19.89 |
| Hired labour cost | 26807.95 | 41398.29 | 31862.19 |
| **Total variable cost** | 47102.05 | 73632.58 | 54042.80 |
| **Returns:** | | | |
| Crop sales | 77053.80 | 165327.50 | 85206.30 |
| Hiring out work animal | 7366.50 | 6778.92 | 10167.49 |
| Livestock output | 25248.00 | 22098.87 | 17922.52 |
| **Total Return** | 109668.30 | 194205.29 | 113296.31 |
| Gross Margin (GM) | 62566.25 | 120572.71 | 59253.51 |
| Gross margin/ha | 7006.30 | 12236.52 | 6502.88 |
| GM / Naira invested | 1.33 | 1.64 | 1.10 |
| GM/Man-hour family labour | 13.78 | 21.67 | 10.06 |

### 4.2.2 Returns

The returns from sales of crop output constituted the total returns in the crop system while in addition to this, the value of livestock output, income from hiring out work animals and implements constituted total returns in the integrated system. The gross revenues generated from the sale of crops were ₦77,053.80, ₦165,327.50 and ₦85,206.30 for zones 1, 2 and 3 respectively while the total revenues generated from both crop and livestock in the integrated systems were ₦109,668.30, ₦194,205.29 and ₦113,296.31 for the respective zones. These show about 42%, 17% and 33% increases in gross return of the integrated system to the specialized crop system. The higher gross return in the integrated crop-livestock system could be attributed to additional income from livestock output. The contributions of livestock to the gross return were 29%, 15% and 25% for zones 1, 2 and 3 respectively. The implication of this is that, crop production was the major income-generating venture among the households in the study area.

### 4.2.3 Gross Margin

Gross margin represents the difference between the total value of all outputs (gross return) and the total variable cost incurred on the farm. The gross margins for the specialized crop production system were; ₦39,232.65, ₦103,226.93 and ₦40,558.00 in zones 1, 2 and 3 respectively while the values for the integrated system were ₦62,566.25, ₦120,572.71 and ₦59,253.51 in the respective zones. There were appreciable differences between the gross margins for the two production systems in all the zones. The result indicates that farmers practicing integrated crop-livestock production system earned higher gross margin compared to the crop-based farmers. This relationship is



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expected because households practicing integrated crop-livestock production system are supposed to use resources more efficiently and generate better economic return than in the crop-based production system. In addition to the extra return from livestock output, inputs like farmyard manure were considered as resource endowment to the household in the integrated system. The study shows that about 40% of the farmyard manure applied on the integrated farm was obtained from the household livestock waste and debris. Also, the lower cost of livestock input in the integrated system was as a result of the use of crop residue from the households. The general conclusion emerging from this analysis is that integrated crop-livestock production system was more profitable than the crop-based production system in the study area.

### 4.2.4 Resource use efficiency

In order to assess the efficiency pattern of the resources used in the two production systems, the return to the individual factors of production and the marginal rate of return were estimated. The pattern of land, capital and labour use efficiency associated with the two production systems is presented in Tables 4.5a and 4.5b. The analysis indicates that gross margin per average land cultivated were ₦4,393.35, ₦10,476.16 and ₦4,451.11 in zones 1, 2 and 3 of the crop-based systems and ₦7,006.30, ₦12,236.52 and ₦6,502.88 for the respective zones of the integrated systems. The comparison of the gross margins per hectare between the crop-based and the integrated crop-livestock production systems is depicted in Figure 4.3. There were increases of about 59%, 17% and 46% in gross margin per hectare for the integrated systems over the crop-based systems. Using this ratio as a

measure of land use efficiency, it can be deduced that land was more efficiently used in the integrated crop-livestock systems compared to the crop-based systems. The gross margins per Naira invested on variable items were 1.04, 1.66 and 0.91 in the three respective zones for crop system and 1.33, 1.64 and 1.10 in the integrated system. The implication of this is that a Naira invested would yield higher net benefit in the integrated systems compared to the crop-based systems of zones 1 and 3 while the reverse was observed in zone 2. The difference in zone 2 could be attributed to the fact that though the households in this zone were also actively involved in integrated crop-livestock system, they tend to concentrate their capital outlay on crop production.

The gross margins per man-hour family labour in the crop-based systems were; 12.31, 28.33 and 9.50 for zones 1, 2 and 3 respectively while the values in the integrated systems were; 13.78, 21.67 and 10.06 in the respective zones. When these values were compared to their corresponding wage rates in the two production systems, it can be deduced that there was inefficiency in labour use in both systems as the estimated ratios were lower than their respective wage rates in each zone. This implies that it will be more beneficial for the family members to hire out their labour than working on their own farms. The analysis also revealed that the integrated crop-livestock systems utilized labour more efficiently than the crop-based systems in zones 1 and 3 while the reverse was observed in zone 2.

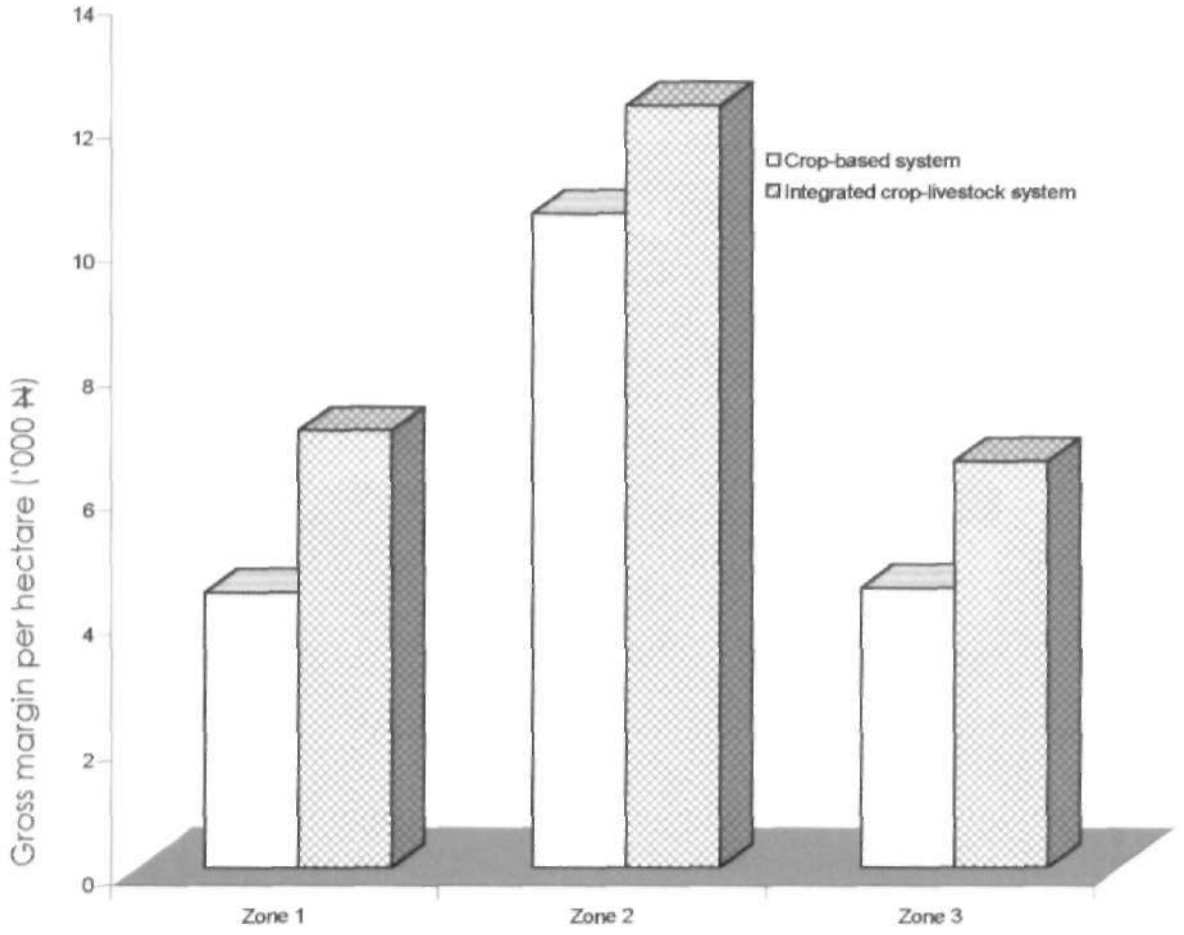



Fig. 4.4. Comparison of gross margin per hectare between crop-bases system and integrated crop-livestock production systems across the zones.

The marginal rate of return (MRR) was used to compare the productivity of the two production systems. The MRR was computed as the ratio of the marginal net benefit to the marginal variable cost. It is the extra benefit that accrues to the household that practice integrated crop-livestock systems instead of crop-based production systems. The extra benefit (MRR) obtained by integrating crop and livestock in zones 1, 2 and 3 respectively were 2.51, 1.50 and 1.99 (Table 4.6). This indicates that an extra Naira invested as a result of integrating livestock into the crop-based system will yield ₦2.51, ₦1.50 and ₦1.99 in zones 1, 2 and 3 respectively.

Table 4.6 Marginal Rate of Return from integrating livestock into a crop-based System

| | Zone 1 (Naira) | Zone 2 (Naira) | Zone 3 (Naira) |
|---|---|---|---|
| a. Net benefit (C-L) | 62566.25 | 120572.71 | 59253.51 |
| b. Net benefit (Crop) | 39232.65 | 103226.93 | 40558.00 |
| Extra benefit (a-b) | 23333.6 | 17342.78 | 18695.51 |
| c. TVC (C-L) | 47102.05 | 73632.58 | 54042.80 |
| d. TVC (Crop) | 37821.15 | 62100.57 | 44648.30 |
| Extra cost (c-d) | 9230.90 | 11532.01 | 9394.5 |
| MRR | 2.5[1] | 1.50 | 1.99 |

The analysis also shows that the benefits from the integrated systems were higher in zone 1 followed by zones 3 and 2 in that order. This result is expected because in one of the villages surveyed in zone 1, livestock was an important economic venture contributing as high as 30% of the total farm income. In the other two zones, livestock were kept mainly for farm work and as a source of savings/investment. The contribution of livestock to the total farm income was therefore lower in these zones.

### 4.3 Estimates of the Profit Model

In determining the nature of relationship between the resources used in the production process and the profit level, a multiple regression technique using the ordinary least squared method (OLS) was employed. Cobb-Douglas function was fitted to the data set because of its ease of computation and the fact that it allows diminishing productivity for each of the resources. It was also observed that the coefficients had a good fit with moderate coefficients of determination, the overall significance of the f-values and the correct signs of the parameters. The specification of the model function is;

$$\ln P = b_o + b_1 \ln W - b_2 \ln L - b_3 \ln K$$

Where;

| | | |
|---|---|---|
| **P** | = | Profit (Gross margin) |
| **W** | = | Wage rate (Naira/man-hour) |
| **L** | = | Farm size (Hectare) |
| **K** | = | Capital or Total variable costs (Naira) |
| **ln** | = | log form of the respective parameters |
| **bi** | = | regression coefficients |

#### 4.3.1 Empirical results of the model function

The result of the estimated Profit function for the crop-based and integrated crop-livestock production systems are presented in Table 4.7a and Table 4.7b respectively. The coefficient of multiple determination ($R^2$) which show the degree of association between independent variable (farm size, total variable cost and labour) and dependent variable (Profit or gross margin) were 52%, 63% and 56% in the crop-based systems and 59%, 68% and 77% for the integrated system. These values indicate the proportion of the gross margin that is explained by the explanatory variables included in the models. The $R^2$ value for the two production systems also shows that the

explanatory variables in the integrated system had greater impact on the gross margin compared to the specialized system in all the zones. The F-ratios were highly significant at the one percent level for both production systems in all the zones, implying that the independent variables included in the models, collectively were important in explaining variations in the gross margins of both production systems.

Table 4.7a Regression Estimates from Crop-based Production Profit Model

| Coefficients | Zone1 | Zone2 | Zone3 |
|---|---|---|---|
| No. of observations. | 40 | 38 | 37 |
| $b_o$ | 9.646* | 14.023* | 9.830* |
| | (1.404) | (2.697) | (1.565) |
| $b_1$ | -0.350 | -0.104 | -0.353*** |
| | (0.254) | (0.324) | (0.227) |
| $b_2$ | 0.479* | 1.341* | 0.556* |
| | (0.115) | (0.285) | (0.128) |
| $b_3$ | -0.046** | -0.502*** | -0.109 |
| | (0.021) | (0.267) | (0.462) |
| $R^2$ | 0.522 | 0.629 | 0.557 |
| Adj$R^2$ | 0.467 | 0.592 | 0.500 |
| F-value | 7.576* | 17.205* | 10.22* |
| Prob > F | 0.0005 | 0.0001 | 0.0001 |

Where,

Dependent variable = Profit or gross margin
$b_o$ = intercept coefficients
$b_1$ = coefficient of labour
$b_2$ = coefficient of land
$b_3$ = coefficient of capital (TVC)
* = Significant at 1% level of probability
** = Significant at 5% level of probability

Table 4.7b: Regression Estimates from Integrated Crop-livestock Production Profit Model

| Coefficients | Zone 1 | Zone 2 | Zone 3 |
|---|---|---|---|
| No. of observations. | 40 | 38 | 37 |
| $B_0$ | 10.361* | 10.523* | 9.830* |
| | (2.716) | (1.801) | (1.565) |
| $B_1$ | 0.126 | -0.309*** | -0.353*** |
| | (0.282) | (0.281) | (0.227) |
| $B_2$ | 1.011* | 0.677* | 0.556* |
| | (0.329) | (0.147) | (0.128) |
| $B_3$ | -0.054 | 0.103 | -0.059 |
| | (0.334) | (0.192) | (0.102) |
| $R^2$ | 0.593 | 0.681 | 0.769 |
| Adj$R^2$ | 0.531 | 0.640 | 0.748 |
| F-value | 11.468* | 16.702* | 36.545* |
| Prob > F | 0.0001 | 0.0001 | 0.0001 |

The regression coefficients represent direct elasticities of production of the resources used. All the estimates, excluding land in zones 1 and 2 of the crop-based systems, had elasticities of less than unity. That is, one- percent increase in any of the explanatory variables, holding all others fixed, would result in less than one- percent increases in gross margin. With the exception of integrated systems of zone 1, labour had negative elasticities in both production systems in all zones. This Implies that as wage rate increases, gross margin decreases. However, the elasticities of labour were significant at the 10% levels in zones 2 and 3 of the integrated systems. The coefficients of farm size in both production systems of all zones were positive and significant at 1% level. The implication of this is that when other inputs are held constant, increasing the level of farm size will increase gross margin by

the corresponding percentage of the elasticities of farm size. The magnitudes of the coefficient of land were higher in the crop-based systems than in the integrated systems. It can therefore be deduced that varying the level of farm size will yield higher economic return in the crop-based systems than in the integrated systems. The coefficients of capital were negative in all the zones for both production systems except in the integrated systems of zone 2. This indicates an inverse relationship between gross margin and capital that is an increase in the use of capital will lead to a decrease in profit. The regression coefficients with respect to capital were significant at 5% and 10% levels in zones 1 and 2 of the crop-based systems respectively while none of the coefficients were significant in the integrated systems.

A closer look at the coefficients of capital and labour in the two production systems revealed that while the coefficients of capital were not significant in the integrated systems in all the zones, the coefficients of labour were also not significant in the crop-based systems except in zone 3. It can thus be deduced that the crop-based production systems were relatively more capital intensive in production while the integrated systems were relatively more labour intensive. The coefficients of land in both production systems indicate that land was a very important resource in terms of generating profit. The magnitude of the coefficient however, indicates that the economic return to land was higher in the crop-based systems compared to the integrated systems.

The intercept terms for both production systems in all zones were statistically different from zero at the one percent level. The result further shows that the intercept terms of the integrated systems in zones 1 and 3 were higher than those of the crop-based systems. This means that the

integrated crop-livestock production systems had profit functions that were shifted upward above the values for the crop-based systems in zones 1 and 3. The intercept term of the Cobb-Douglas function measures the existing technical efficiency. Thus, using this parameter as a measure of relative technical efficiency, the empirical analysis indicates that the integrated systems in zones 1 and 3 were more technically efficient than the crop-based systems. The reason might be that the average input combination on the integrated farms was more effectively matched to the size of the farmland than that of the crop-based farms. The dependent variables (profit) were measured in monetary terms as such the inference made on technical efficiency with respect to the intercept terms also hold for economic efficiency. This is because the integrated systems had higher net revenue per unit of each of the resources used than the crop-based systems. It can thus be concluded that the integrated production systems were relatively more economically efficient than the crop-based production systems in zones 1 and 3 while the reverse hold for zone 2. The direct implication of this result appear to be that measures designed to promote further integration of crop and livestock under the same management system are not inconsistent with efficiency in the use of available resources.

Indirect estimates of the sum of production elasticities of the explanatory variables were made in order to assess the relative technical return to scale in both production systems. The result is presented in Table 4.8. The total elasticities in the crop system were; 0.58, 0.85 and 0.59 in zones 1, 2 and 3 respectively, the corresponding values in the integrated systems were, 0.74, 0.83 and 0.72. The values of total elasticities for the two production systems in zone 2 were not significantly different from one



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implying that the households in this zone were operating under constant return to scale. The sums of elasticities in the production systems of the other zones were less than one implying a decreasing return to scale. The implication of this is that an increase in all the inputs will result in less than one percent increase in the gross margins of zone 1 and 3.

Table 4.8: Indirect estimates of sum of production elasticities

| **Crop** | Zone 1 | Zone 2 | Zone 3 |
|---|---|---|---|
| Labour | 0.259 | 0.094 | 0.261 |
| Land | 0.355 | 1.214 | 0.411 |
| Capital | -0.034 | -0.455 | -0.080 |
| Total | 0.580 | 0.853 | 0.592 |
| **Crop-livestock.** | | | |
| labour | 0.112 | 0.236 | 0.185 |
| Land | 0.898 | 0.517 | 0.582 |
| Capital | -0.048 | 0.079 | -0.048 |
| Total | 0.738 | 0.832 | 0.719 |

The relative technical returns to scale of the two production systems were compared using their indirect sums of elasticities. The sum of elasticities of production of all the factors measures the response of profit to a percentage change in all the inputs. The sums of elasticities of production in the crop-based systems were 0.58, 0.85 and 0.59 while the values in the integrated systems were 0.74, 0.83 and 0.72 in zones 1, 2 and 3 respectively. This result clearly show that the levels of responses in profit to changes in all the factors were higher in the integrated crop-livestock systems of zones 1 and 3 than in the crop-based systems while the reverse was observed in zone 2. Thus, it can be deduced that integrated farms of zones 1 and 3 had higher technical return to scale than specialized crop systems in these zones.

**CHAPTER 5**

# MIXED INTEGER AND LINEAR PROGRAMMING ANALYSIS AND RESULTS

## 5.0 Introduction

This chapter presents the empirical findings of the mixed integer and linear programming analyses. The focus of this analysis is to identify the optimum farm plan that would maximize the objectives of the farm-household given the available resources and production constraints. Attempt was also made to assess the effect of imposing variations and restrictions of some limiting resources on the farm objective. The analysis is static throughout in the sense that only a single production season was considered. The average household in each zone was used as the representative farm for the zone.

The analysis takes into account the resource restrictions, the various activities and enterprises, the net prices of resources and activities. Detailed budgets on per hectare basis were estimated for all the crop activities identified in each zone together with their respective yield and net prices. The same estimates were also made for livestock activities. Data generated for the study by survey were used to estimate the necessary coefficients of the models in each of the production systems. The basic structures of the matrices for each of the production systems in each zone are presented in appendix 1-6. The outputs generated from the analysis are the optimal and the dual solutions. The optimal solution gives the value of the objective function, optimum enterprise combinations, and the non-optimal activities with the cost of forcing each into the optimum plan. The dual solution on the

other hand provides the level of resources used in the optimum plan with their respective marginal value products (shadow prices).

A total of six models were considered comprising of two basic models and two other variants each of the basic models. The average farm-household (representative farm) of the crop-based and integrated crop-livestock production systems constitute the basic Models 1 and 2 respectively. The two other variants considered households with 5 hectares (50% of the total household) and 20 hectares (15% of the total household). In the integrated systems, the numbers of livestock owned by this group of households were also used in these two variants. The objective of these variations was to assess the effect of land constraints on the integrated crop-livestock and the crop-based production systems.

## 5.1 Optimum Farm Plan of the Basic Models

The basic model in each production system was designed to represent the average household constructed from the survey. The matrices for these models were obtained from existing resource use levels in the crop-based and integrated crop-livestock production systems. The characteristics of the optimum farm plan under the existing resource use levels in both production systems are presented below.

### 5.1.1 Activities in the optimum plan

The activities in the optimum plans of crop-based and integrated crop-livestock production models are presented in Tables 5.1a, 5.1b and 5.1c for zones 1, 2 and 3 respectively. The average farm size of 8.93, 9.85 and 9.11 hectares in the respective zones were completely used up in the optimum

plan of both production systems. However, out of the 16, 13 and 20 existing crop enterprises, 3, 4 and 5 were selected as meeting the household food requirement and generating the maximum return in the crop production system (Model 1.0) of zones 1, 2 and 3 respectively. The feasible crop enterprises in Model 1.0, zone 1 were millet-cowpea, sorghum-groundnut and *maiwa*-cowpea. Those in zone 2 were sole crop maize and *maiwa*, maize-sorghum and cotton-cowpea mixtures, while the crops in zone 3 were *maiwa*, maize-cotton, cotton-cowpea, sorghum-cowpea and millet-groundnut. None of the three crop mixtures entered the optimum plans of Model 1.0 in all the zones. The striking point of the cropping pattern that has emerged from the programming results of zones 1 and 2 is that the optimum plan does not deviate much from the dominant existing cropping pattern in the study area. The dominant crop enterprises in zones 1, 2 and 3 were; millet-cowpea, sole maize and maize-cotton respectively These enterprises accounted for 74%, 64% and 55% of the total land cultivated in zones 1, 2 and 3 respectively. A minimum hectare of land under sorghum and *maiwa* was imposed into the model to meet the household subsistence food requirement.

The same crop enterprises selected in the optimum plans of crop-based production systems in zones 1 and 2 were retained in the integrated crop-livestock system. There was a reallocation of crop enterprises in the integrated system of zone 3. The enterprises included in the optimum plan were cotton-cowpea, rice, cotton, millet-sorghum, sorghum-cotton and *maiwa*.

The existing number of cattle, sheep and goat specified in the matrix of zone 1 were 3, 7 and 13 respectively, the numbers in zone 2 were 5, 9 and 12 respectively while the numbers in zone 3 were 4, 8 and 12 respectively.

Table 5.1a: Real activity levels in the optimum farm plan of the basic models.

(Zone 1)

| Activities | Unit | Model 1.1.0 | Model 1.2.0 |
|---|---|---|---|
| **Crop production** | Ha | | |
| Millet-cowpea | Ha | 6.63 | 6.82 |
| Sorghum-g/nut | Ha | 1.43 | 1.25 |
| *Maiwa*-cowpea | Ha | 0.86 | 0.86 |
| **Livestock production:** | | | |
| Cattle | No. | - | 3 |
| Sheep | No. | - | 7 |
| Goat | No. | - | 13 |
| **Labour hiring** | | | |
| May-August | Man-hour | 796.99 | 998.97 |
| Sept.-December | Man-hour | 0.00 | 244.41 |
| FYM purchased | Kg | - | 5249.77 |
| **Selling Activity** | | | |
| Millet | Naira | 43065.6 | 44605.52 |
| Cowpea | Naira | 57711.7 | 59530.40 |
| Groundnut | Naira | 14146.7 | 12325.08 |
| Cattle | Naira | - | 22548.00 |
| Sheep | Naira | - | 3981.00 |
| Goat | Naira | - | 7093.00 |
| **Total Return** | Naira | 114924.00 | 150083.00 |
| **Consumption:** | | | |
| Sorghum | Kg | 1000 | 1000 |
| Millet | Kg | 1016 | 1016 |
| *Maiwa* | Kg | 568 | 568 |
| Cowpea | Kg | 582 | 582 |

Table 5.1b: Real activity levels in the optimum farm plan of the basic models

(Zone 2)

| Activities | Unit | Model 2.1.0 | Model 2.2.0 |
|---|---|---|---|
| **Crop production** | Ha | | |
| Maize | Ha | 6.31 | 6.31 |
| Cotton-cowpea | Ha | 1.93 | 1.93 |
| Maize-sorghum | Ha | 1.20 | 1.20 |
| *Maiwa* | Ha | 0.41 | 0.41 |
| **Livestock production** | | | |
| Cattle | No. | - | 5 |
| Sheep | No. | - | 9 |
| Goat | No. | - | 4 |
| **Labour hiring** | | | |
| May-August | Man-hour | 639.50 | 902.90 |
| Sept.-December | Man-hour | *0.00* | *332.00* |
| FYM purchased | Kg | - | 2942.00 |
| **Selling Activity** | | | |
| Maize | Naira | 168836.60 | 168740.61 |
| Cotton | Naira | 33109.25 | 33109.25 |
| Cattle | Naira | - | 22670.00 |
| Sheep | Naira | - | 3904.20 |
| Goat | Naira | - | 1434.40 |
| **Total Return** | Naira | 201945.850 | 229858.00 |
| **Consumption** | | | |
| Sorghum | Kg | 1212 | 1212 |
| Maize | Kg | 850 | 850 |
| *Maiwa* | Kg | 376 | 376 |
| Cowpea | Kg | 564 | 564 |

Table 5.1c: Real activity levels in the optimum farm plan of the basic models

(Zone 3)

| Activities | Unit | Model 3.1.0 | Model 3.2.0 |
|---|---|---|---|
| **Crop production** | Ha | | |
| Maize-cotton | Ha | 5.01 | - |
| Millet-groundnut | Ha | 1.34 | - |
| Sorghum-cowpea | Ha | 1.12 | - |
| *Maiwa* | Ha | 0.64 | 0.64 |
| Cotton-cowpea | Ha | 1.00 | 2.37 |
| Cotton | Ha | - | 1.66 |
| Millet-sorghum | Ha | - | 1.34 |
| Rice | Ha | - | 1.97 |
| Sorghum-cotton | Ha | - | 1.13 |
| **Livestock production** | | | |
| Cattle | No. | - | 4 |
| Sheep | No. | - | 8 |
| Goat | No. | - | 12 |
| **Labour hiring** | | | |
| May-August | Man-hour | 840.2 | 1039.2 |
| Sept.-December | Man-hour | 323.2 | 633.2 |
| FYM purchased | Kg | - | 4911.8 |
| **Selling Activity** | | | |
| Cotton | Naira | 90036.5 | 84368.5 |
| Maize | Naira | 51042.9 | - |
| Groundnut | Naira | 10959.8 | 11077.9 |
| Rice | Naira | - | 43033.4 |
| Millet | Naira | - | 15840.0 |
| *Maiwa* | Naira | - | 6984.0 |
| Cattle | Naira | - | 22670.0 |
| Sheep | Naira | - | 3904.2 |
| Goat | Naira | - | 1434.4 |
| Total Return | Naira | 152039.20 | 229858.00 |
| **Consumption** | | | |
| Sorghum | Kg | 886 | 886 |
| Millet | Kg | 1320 | 1320 |
| *Maiwa* | Kg | 582 | 582 |
| Cowpea | Kg | 625 | 625 |

All the heads of cattle, sheep and goat specified in zones 1 and 3 entered the optimum plan while the optimum plan of zone 2 included all the cattle and sheep but only one third of the total number of goats. The inclusion of the livestock enterprises into the optimum plan of the integrated system suggests that livestock had positive and significant impact on the gross return of the basic model plan of crop-livestock system.

Family labour was augmented by hired labour in the optimum farm plan. Labour was hired at the prevailing wage rate in the zone for each period. Tables 5.1a – 5.1c show that, in the crop-based systems, labour was hired in the peak labour demand period of May-August in zones 1 and 2 while in zone 3 labour was also hired in the period of September-December. However, in the integrated systems, labour was hired during the two periods in all the zones. The higher amount of labour hired in the integrated system can be attributed to the extra labour required for livestock activities.

The crops offered for sale in the crop production optimum plan were millet, cowpea and groundnut in zone 1, cotton and maize in zone 2 and cotton, maize and groundnut in zone 3. This result is consistent with the existing cash crops identified in the various zones. Sorghum and *maiwa* only entered the optimum plan to provide the minimum food requirement for the household. The crops offered for sale in the integrated system were the same as in the crop production systems of zones 1 and 2. However, in zone 3 the crops included in the selling activity were cotton, groundnut, rice, *maiwa* and millet. Cowpea selling activity did not enter the optimum plan. Despite its high market value, it's relative low yield in the mixture and its high place in the dietary system of the household did not allow for any marketable surplus.

There was no direct selling activity for livestock. The values of livestock output were obtained by computing the average of in-take and off-take. Thus the output of each of the livestock in the optimum plan entered into the programme as returns.

The food consumption requirement specified for sorghum, millet, *maiwa* and cowpea in zones 1 and 3 and maize, sorghum, *maiwa* and cowpea in zone 2 were satisfied in the optimum plans of all the zones. All the *maiwa* and sorghum produced in all the zones were consumed while only about 5% of the maize produced in zone 2 was consumed. All the cowpea and millet produced in zones 2 and 3 were consumed while only 21% of cowpea and 22% of millet produced in zone 1 were consumed. Thus the activities included in the optimum plan of both production systems were feasible for meeting the food security goal of the household as well as satisfying the income maximization objective.

### 5.1.2 Resource use level in the optimum plan

The resource use levels in the optimum plan of the basic models are presented in Tables 5.2a, 5.2b and 5.2c for zones 1, 2 and 3 respectively. The total available land in the three zones (8.93, 9.85 and 9.11) was completely used up to produce the selected crops in the optimum plan of both production systems. The labour profile of the optimum plan revealed that a total of 4,902.5, 5,547.9 and 6,386 3 man-hours was used in the crop production system while the amount in the integrated system was 6,251.6, 7,268.4 and 7,647.0 man-hours for zones 1, 2 and 3 respectively. Of these, family labour constituted about 84%, 88% and 82% of the total labour in the crop-based systems and 80%, 83% and 78% of the total labour used in the integrated

systems of the respective zones. The potential family labour supply was in surplus in the periods of January-April and September-December in the crop-based production systems of all the zones while there was labour surplus only in the period of January-April in the integrated system. The potential family labour supply was completely used up in May-August period because this period is the peak farming activities thus the highest amount of labour was hired in this period in both production systems.

The total operating capital used in the crop-based production optimum plans were ₦29,515.00, ₦62,101.00 and ₦35,201.54 for zones 1, 2 and 3 respectively. The values in the integrated system were ₦47,102.00, ₦73,633.00 and ₦54,043.00 in the respective zones. The total operating capital constitutes the total variable cost incurred on seed, fertilizer, agro-chemical, manure and hired labour in the crop-based systems while besides these, the costs of supplementary feed, drugs and veterinary services were included in the integrated system.

Farmyard manure entered into the programme as an activity and as a constraint in the integrated system. The available farmyard manure from the household was completely used up in all the zones. These were augmented by purchasing manure at the prevailing market price. Of the total manure used in the optimum plan, the amount from the household constitutes about 35%, 59% and 43% while the remaining was purchased.

Only about 30%, 24% and 50% of the available crop residues from the households were used in feeding the livestock in the optimum plans of zones 1, 2 and 3 respectively. The study indicated that the crop residue from the ghousehold lasted between three to six months in all the zones.

Table 5.2a: Resource use levels in the optimum plan of the basic models

(Zone 1)

| Resource | Unit | Model 1.1.0 | Model 1.2.0 |
|---|---|---|---|
| Land | Ha | 8.93 | 8.93 |
| **Livestock** | | | |
| Cattle | No. | - | 3 |
| Sheep | No. | - | 7 |
| Goat | No. | - | 13 |
| **Family labour** | | | |
| January-April | Man-hour | 115.5 | 808.2 |
| May-August | Man-hour | 2100.0 | 2100.0 |
| Sept.- December | Man-hour | 1890.0 | 2100.0 |
| Work animal labor | Man-hour | - | 1150.0 |
| FYM from farm | Kg | - | 2806.0 |
| Crop residue | Kg | - | 5705.0 |
| Operating capital | Naira | 29515.0 | 47102.0 |
| Gross return | Naira | 114924.0 | 150083.0 |
| Gross margin | Naira | 85409.0 | 102981.0 |
| Gross margin/ha | Naira | 9564.3 | 11532.0 |

Table 5.2b: Resource use levels in the optimum plan of the basic models

(Zone 2)

| Resource | Unit | Model 2.1.0 | Model 2.2.0 |
|---|---|---|---|
| Land | Ha | 9.85 | 9.85 |
| **Livestock** | | | |
| Cattle | No. | - | 5 |
| Sheep | No. | - | 9 |
| Goat | No. | - | 4 |
| **Family labour** | | | |
| January-April | Man-hour | 102.4 | 993.5 |
| May-August | Man-hour | 2520.0 | 2520.0 |
| Sept.- December | Man-hour | 2286.0 | 2520.0 |
| Work animal labor | Man-hour | - | 1160.3 |
| FYM from farm | Kg | - | 4317.0 |
| Crop residue | Kg | - | 7188.3 |
| Operating capital | Naira | 62101.0 | 73633.0 |
| Gross return | Naira | 201945.9 | 229858.0 |
| Gross margin | Naira | 139844.9 | 156225.0 |
| Gross margin/ha | Naira | 14197.0 | 15867.0 |

Table 5.2c: Resource use levels in the optimum plan of the basic models

(Zone 3)

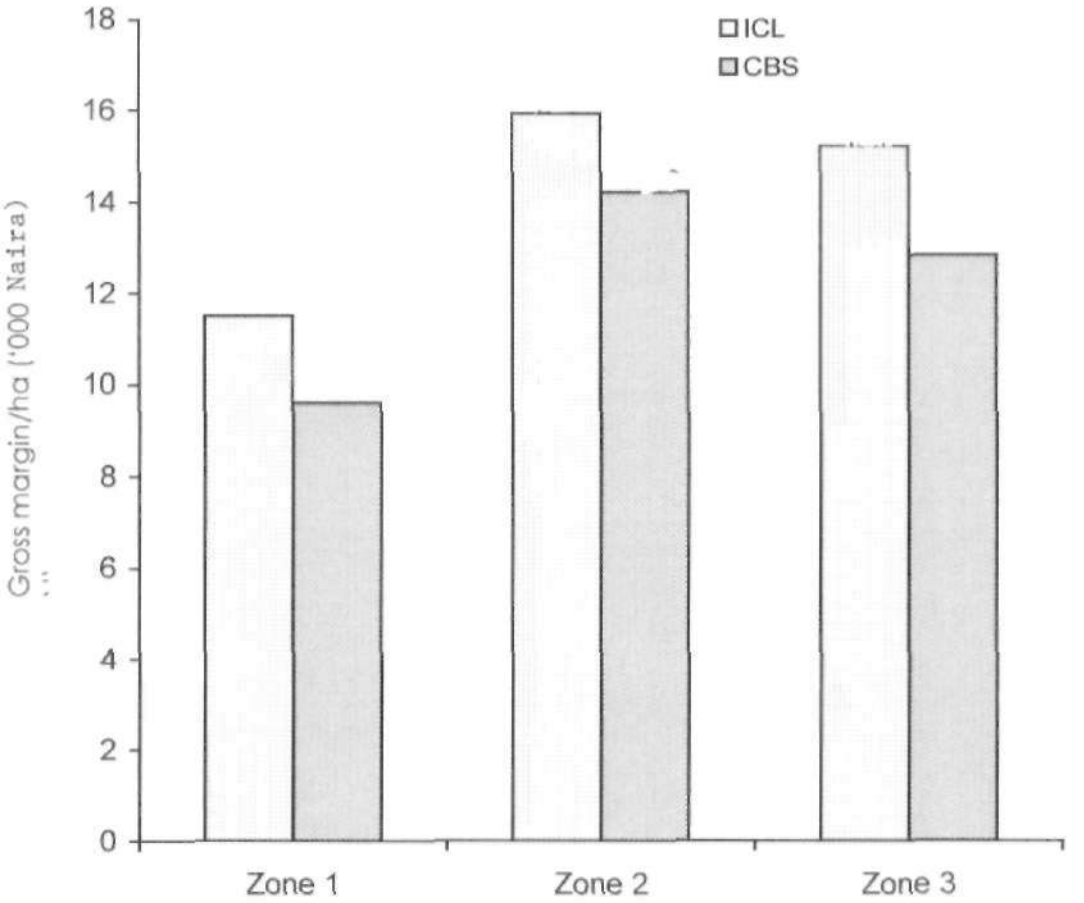
| Resource | Unit | Model 3.1.0 | Model 3.2.0 |
|---|---|---|---|
| **Land** | Ha | 9.11 | 9.11 |
| **Livestock** | | | |
| Cattle | **No.** | - | **4** |
| Sheep | **No.** | - | **8** |
| Goat | **No.** | - | **12** |
| **Family labour** | | | |
| January-April | Man-hour | 183.0 | 934.6 |
| May-August | Man-hour | 2520.0 | 2520.0 |
| Sept.- December | Man-hour | 2520.0 | 2520.0 |
| Work animal labor | Man-hour | - | 1122.0 |
| **FYM from farm** | **Kg** | - | 3648.0 |
| Crop residue | **Kg** | - | 6846.0 |
| Operating capital | Naira | 35201.5 | 54043.0 |
| Gross return | Naira | 152039.2 | 229858.0 |
| Gross margin | Naira | 116837.7 | 138524.4 |
| Gross margin/ha | Naira | 12825.2 | 15205.8 |

The total available crop residue should have been sufficient to meet the livestock feed requirement for the year based on the number of livestock in the household. However, because of bad management and lack of adequate storage facilities, more than half of the crop residue from the household was being wasted.

### 5.1.3 Gross margin

The gross margin for each of the model plans was obtained by subtracting the operating capital from the gross return (Tables 5.2a-2c). The gross return in the crop-based systems was made up of sales of the selected

crop activities while besides this the gross return from the integrated systems included the value of livestock output. The contributions of crop and livestock to gross return in the optimum plan of the integrated systems revealed that crop contributed about 78%, 88% and 84% in zones 1, 2 and 3 respectively. The gross margins from the optimum plan were $*85,409.00, $$139,844.85 and **116,837.66 for the crop-based models of zones 1, 2 and 3 respectively while the values in the integrated systems were $*102,981.00, 1*156,225.00 and 1*138,524.39 for the respective zones. The analysis revealed increases of about 21%, 12% and 19% in the gross margins of the integrated systems over the crop-based systems of zones 1, 2 and 3 respectively. Thus, attempt to reorganize resources in both production systems will generate higher economic returns in the integrated systems compared to the crop-based systems. Land use efficiency was higher in the integrated optimum plans than in the crop-based plans. This is evident by the higher gross margin per hectare in the integrated systems of all the zones (Figure 5.1).




**Note**: ICL = Integrated crop-livestock CBS = Crop-based System.

Fig. 5.1 Gross margin per hectare of the basic model plans.

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A comparison of the gross margins of the existing farm plans to the optimal plans revealed that the gross margins of the optimal plans for the crop-based systems were 117%, 49% and 127% higher than the respective values of the existing plans in zones 1, 2 and 3 respectively. The increases in the integrated system were 65%, 30% and 134% for zones 1, 2 and 3 respectively. The differences in gross margin between the existing and the optimal plan were higher for the crop-based systems compared to the integrated systems. The implication of this is that the exiting integrated farms were operating rrearer to optimal returns compared to the existing crop systems. It can therefore be deduced that allocative efficiency is higher in the integrated systems than the crop-based systems. It can also be inferred that efficiencies of resource allocation in both production systems were higher in zone 2 followed by zones 1 and 3 in that order.

### 5.1.4 Marginal value productivity of resources

The marginal value products (MVP) of the resource restrictions presented in Tables 5.3a and 5.3b are also the shadow prices on the disposable activities of the optimum plan. The marginal value product of a resource is defined as the increase in the value of total output that is obtained from the use of an additional unit of the resource with all other inputs held constant. The MVP in this study indicates the amount by which the gross margin would be increased or decreased by using an additional unit of the resources. The MVPs are zero for excess or slack resources and positive for limiting resources. A high MVP indicates the degree of scarcity of the resources (Etuk, 1979). Thus the more limiting the resource, the higher the MVP that has to be considered relative to the marginal factor costs of the

resources. It is profitable to acquire more of a resource if it's MVP is higher than its factor cost.

Land was a critical input in both production systems. This is evident by its high shadow price or MVP of ₦18,357.00, ₦25,060.00 and ₦25,455.00 in the crop-based systems and ₦14,613.96. ₦25,060.00, ₦7,682.87 in the integrated systems of zones 1, 2 and 3 respectively. A higher MVP was recorded for the crop-based production systems compared to the integrated systems implying that a unit increase in farm size will add more to gross margin in the crop-based systems than in the integrated crop-livestock systems. The implication of this is that a larger farm size will be of more economic benefit in the crop-based systems than in the integrated systems. Information was not available on the value of land or rent during the survey period, hence, the comparison between MVP and MFC was not possible.

Although there were three labour restrictions built into the model, January - April family labour was not a limiting factor in both production systems of all the zones. This is apparent by its zero shadow price implying an under employment of labour in this period. Though the May - August family labour was completely used up in the production process of the crop-based systems of all the zones, their marginal value products were zero. This also means that an increment of labour in this period would not add to the value of the programme. It can thus be concluded that there was surplus potential family labour in the crop-based systems in the study area.

The MVPs of family labour for May-August and September-December period were both positive in the integrated systems of all the zones. Thus labour was in limited supply in these periods. The MVPs of family labour in these periods were higher than their respective wage rates in zones 2 and 3 but

lower in zone 1. The implication of this is that an additional use of labour by hiring would add more than the wage rate to farm income in zones 2 and 3, but less to the farm income in zone 1.

The MVPs of capital were zero for the crop-based systems in all the zones while the values were 0.31, 1.40 and 1.09 for the integrated crop-livestock systems in zones 1, 2 and 3 respectively. Thus capital was not a production constraint in the crop-based systems, increasing the use of capital would have no effect on the farm income of this production system. However, the use of more capital by borrowing will increase the farm income of the integrated system by the values of the MVP. It was also observed that the values of the MVP were less than the prevailing interest rate of about 21% in the survey year, it can be deduced that there is inefficiency in the use of capital in this production system.

Livestock was constraining in the integrated crop-livestock production systems. The MVPs of cattle, sheep and goat were positive in zones 1 and 3 but negative in zone 2. The negative MVP of cattle, sheep and goat in zone 2 indicates that an addition of one head of any of the livestock into the optimum plan would decrease the objective function by the value of the MVP. The MVPs of livestock in zone 1 were more than the extra cost of raising each of the livestock types, it can thus be said that livestock production is more profitable in this zone. The MVPs of livestock in zone 2 were lower than the extra cost required in raising an additional head of each of the livestock types. This indicates inefficiency in livestock production in this zone.

Table 5.3a: Marginal value products (MVP) of resources in the crop production basic models

| Resource | Unit | Zone 1 (naira) | Zone 2 (naira) | Zone 3 (naira) |
|---|---|---|---|---|
| Land | Hectare | 18357 | 25060 | 25455 |
| **Family labour** | | | | |
| January-April | Man-hour | 0 | 0 | 0 |
| May-August | Man-hour | 0 | 0 | 0 |
| Sept-Dec. | Man-hour | 0 | 0 | 0 |
| Capital | Naira | 0 | 0 | 0 |
| **Crop output** | | | | |
| Sorghum | Kg | 12 | 9 | 14 |
| Millet | Kg | 12 | - | 18 |
| Tomato | Kg | 70 | - | - |
| Groundnut | Kg | 22 | 23 | 22 |
| Rice | Kg | 37 | 37 | 37 |
| Cowpea | Kg | 26 | 27 | 45 |
| *Maiwa* | Kg | 17 | 27 | 28 |
| Maize | Kg | - | 10 | 10 |
| Cotton | Kg | - | 25 | 25 |
| Soybean | Kg | - | 22 | - |
| **Consumption** | | | | |
| Sorghum | Kg | -12 | -9 | -14 |
| *Maiwa* | Kg | -17 | -27 | -28 |
| Cowpea | Kg | -26 | -27 | -45 |
| Millet | Kg | -12 | - | -18 |
| Maize | Kg | - | -10 | - |

Table 5.3b: Marginal value products (MVP) of resources in the integrated crop-livestock production basic models

| Resource | Unit | Zone 1 (Naira) | Zone 2 (Naira) | Zone 3 (Naira) |
|---|---|---|---|---|
| Land | Hectare | 14614 | 25060 | 7682.9 |
| **Livestock:** | | | | |
| Cattle | No. | 6149 | -3112 | 716 |
| Sheep | No. | 414 | -274 | 13 |
| Goat | No. | 399 | -324 | 17 |
| **Family labour** | | | | |
| January-April | Man-hour | 0 | 0 | 0 |
| May-August | Man-hour | 6.3 | 40.6 | 21.7 |
| Sept-Dec. | Man-hour | 5.8 | 35.7 | 19.2 |
| FYM | Kg | 0.15 | 0.70 | 0.54 |
| Capital | Naira | 0.31 | 1.40 | 1.09 |
| **Crop output** | | | | |
| Sorghum | Kg | 11 | 10 | 11 |
| Millet | Kg | 12 | - | 16 |
| Tomato | Kg | 70 | - | - |
| Groundnut | Kg | 22 | 24 | 22 |
| Rice | Kg | 37 | 37 | 37 |
| Cowpea | Kg | 26 | 33 | 40 |
| *Maiwa* | Kg | 17 | 25 | 20 |
| Maize | Kg | - | 10 | 10 |
| Cotton | Kg | - | 25 | 25 |
| Soybean | Kg | - | 22 | - |
| **Consumption** | | | | |
| Sorghum | Kg | -11 | -10 | -11 |
| *Maiwa* | Kg | -17 | -25 | -8 |
| Cowpea | Kg | -26 | -33 | -40 |
| Millet | Kg | -12 | - | -4 |
| Maize | Kg | - | -10 | - |



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Crop residue and draught animal power supply were not constraining in the production of integrated crop-livestock farming systems. The MVPs of these resources were zero implying excess supply. The excess supply of draught animal power in the household is circumvented by hiring them out to generate more income. The MVPs of farmyard manure were 0.15, 0.70 and 0.54 for zones 1, 2 and 3 respectively. Except for zone 1, the MVPs of farmyard manure were greater than the unit cost (₦ 0.50/kg) of this resource. Thus, it is very profitable to purchase more farmyard manure to augment the household supply.

The shadow prices of sorghum (zones 1 and 3), millet (zone 3), groundnut (zone 2), cowpea (zones 2 and 3), and *maiwa* (zones 1, 2 and 3) were greater than their unit selling prices in both production systems indicating that a unit increase in yield of the respective crops will add more to gross returns than the unit selling prices of these crops. Thus an introduction of low input high yielding technology will have a great impact on the farm income.

The shadow prices of the restricted food consumption levels were negative implying that an additional consumption of a unit of each of the food items in the optimum plan will reduce the farm income by the value of their respective shadow prices. The shadow prices of sorghum (zone 1 and 3), millet (zone 3), cowpea (zone 2 and 3), and *maiwa* (zone 1, 2 and 3) in the crop-based systems were more than their respective unit selling prices. The shadow prices of sorghum (zones 1, 2 and 3), cowpea (zones 2 and 3), and *maiwa* (zones 1 and 2) in the integrated crop-livestock systems were also greater than their respective unit selling prices. It can thus be deduced that a

unit increase in the consumption of the restricted food crops by one unit will reduce more from farm income than the unit selling prices of these crops. The implication of this is that an extra requirement of the food items beyond the limit set in the model can be more economically met by buying from outside the farm. Millet and *maiwa* in zone 3 of the integrated system had shadow prices less than their unit selling prices indicating that these crops can be consumed beyond the set limit in the model with less impact on the farm income.

## 5.2 Optimal Solutions with Variations in Farm Size

As mentioned earlier, about half of the respondents in all the zones had an average farm size of five hectares while about 15% had farm size of 20 hectares and above. Therefore these levels of holdings were incorporated into the basic models by varying the constraint imposed on farm size in both production systems.

### 5.2.1 Activities in the variant optimal plan

The activities in the optimum plan derived from the variants of the two basic models in zones 1, 2 and 3 show that when farm size was decreased to 5 hectares (Model 1.1 and Model 2.1 for crop-based and crop-livestock systems respectively), the choice of crop enterprises did not change from those of the average farm plans in zones 1 and 2, only the hectare allocated to each of the crops were altered. In zone 3 however, there was reallocation of land from producing cotton, millet-sorghum, rice and sorghum-cotton to the production of sorghum-cowpea, millet-groundnut and sorghum-cotton-cowpea. Also, all the livestock numbers specified in the model for cattle,

sheep and goat were accepted in the integrated optimum plans of all the zones.

When the constraint imposed on land was relaxed to 20 hectares (Model 1.2 and Model 2.2 for crop-based and crop-livestock systems respectively), there were reallocations of the choice of crop enterprises in the optimum plans of both production systems. The feasible crop enterprises in the crop-based models were millet-cowpea, rice, sorghum-groundnut-cowpea and millet-sorghum-*maiwa* in zone 1, the crops in zone 2 were maize, cotton-cowpea, maize-sorghum and *maiwa*. The feasible crops in the optimum plan of zone 3 were maize-cotton, millet-maize, millet-maize-cowpea, sorghum-cowpea and *maiwa*. Some of these crop enterprises were replaced in the integrated crop-livestock optimum plans. One of the striking features of the enterprise choice in model 2.2 was that there seems to be a move toward sole cropping in all the zones. The predominant crop enterprises in the crop-based production optimum plans were rice (79%), maize (75%) and maize-cotton (67%) in zones 1, 2 and 3 respectively, while the predominant crop enterprises in the integrated crop-livestock systems were rice (80%), maize (78%) and rice (71%) in the respective zones. Except for the crop-based systems of zone 3, all the other zones devoted the highest land area to the cultivation of sole cash crop in the optimum plan of both production systems while the remaining farmland was devoted to the production of mixed crops. The crop mixtures in the optimum plans of model 2.2 were mainly those required to meet the imposed family food requirement. This finding seems to agree with some of the reasons given for practicing mixed cropping in the study area that is maximizing land use and food security. When the constraint on land was

relaxed, the programme utilized the minimum land area for producing crops required for household subsistence and devoted a greater part for producing cash crops that were of more economic benefit to the household.

The results of the integrated systems of model 2.2 also show that all the livestock activities were excluded from the optimum plan except in zone 1 where 6 heads of cattle entered the plan. The implication of this is that as land became readily crop-based production systems yielded higher economic return than integrated crop-livestock production system. This is expected because when dealing with large farm size, the feasibility of using draught power and farmyard manure becomes limited. A larger head size required for meeting the demands for draught power and animal manure would mean more capital outlay to maintain these animals that may not be economical in the long run.

The results of model 1.1 and model 2.1 (5ha) indicate that labour hiring activity did not enter the optimal plan of both production systems in all the zones. However, as more land was brought under cultivation in model 1.2 and model 2.2 (20ha), the need for additional farm labour arose to augment the available family labour in the peak labour demand period of May-August and September-December. Labour was hired at the prevailing wage rate in the zone for each period. Family labour in the crop-based model 1.2 constituted about 59%, 65% and 59% of the total labour in the optimum plans of zones 1, 2 and 3 respectively while the contributions of family labour in the integrated Model 2.2 were 59%, 59% and 51% in the respective zones. By comparing these percentages to the corresponding values for the average farm size and models 1.2 and 2.2, it can be observed that the contribution of family labour to total labour requirement diminished with increase in farm size. This is

expected as a result of the restriction imposed on potential supply of family labour in the household.

The crops offered for sale in models 1.1 and 2.1 were the same as obtained in the average household models in all the zones. However, the crops offered for sale in model 1.2 were rice, groundnut and millet in zone 1, cotton and maize in zones 2 and 3. While the crops in model 2.2 were rice, *maiwa* and millet in zone 1, cotton and maize in zone 2 and rice, cotton, maize, millet and *maiwa* in zone 3. The quantity of marketable surplus relative to the quantity of subsistence household food requirement increased with increase in farm size thus resulting in higher gross return per hectare.

### 5.2.2 *Resource use level in the variant plan*

The resource use levels in the variants of the basic models are presented in Tables 5.4a, 5.4b and 5.4c for zones 1, 2 and 3 respectively. The total farm size of 5 hectares incorporated into models 1.1 and 2.1 were completely used up to produce the selected crops in the optimum plan of both production systems. However, the available farm size of 20 hectares in Models 1.2 and 2.2 were in excess supply. A total of 15.2 hectares 14.4 hectares and 13.5 hectares in model 1.2 and 15.12 hectares, 16.09 hectares and 16.4 hectares in model 2.2 were used in producing the selected crops in the optimum plans of the respective zones. Capital and family labour were limiting in models 1.2 and 2.2, thus there was insufficient fund to hire additional labour required to purchase extra inputs to cultivate the total available farm size. The labour profile of the optimum plan revealed that a total of 2,746.9, 2,958.4 and 3,425.7 man-hours were used in Model 1.1 and 3,555.3, 3,747.7 and 4,343 man-hours in model 2.1 while the amount in model

1.2 were 7,145.7, 7,997.1 and 9,055.5 man-hour and 8,613, 8,917.9 and 10,011.2 man-hours in model 2.2 for zones 1, 2 and 3 respectively. Of these, family labour constituted about 100% in models 1.1 and 2.1 and about 59%, 65% and 59% of the total labour in model 1.2 and 59%, 59% and 51% of the total labour used in model 2.2 of zones 1, 2 and 3 respectively. The apparent reason for this is that as farm size increases, the contribution of family labour to the total labour requirement decreases while the need for more hired labour becomes inevitable. The potential family labour supply was not a limiting factor in production throughout the season when the farm size was reduced to 5 hectares in models 1.1 and 2.1. Thus the optimum plans of both models indicated surplus potential labour throughout the year in all the zones.

All the potential labour supply in the periods of May-August and September-December were completely used up in the optimum plans of models 1.2 and 2.2. Only about half of the total labour required during the period of May-August were supplied by the household members while the rest was hired. Less than 10% of the potential labour supply in the period of January to April was used in models 1.2 and 2.2 in all the zones except for model 2.2 zone 1 where about 41% of the labour supply were utilized.

The total operating capital used in the optimum plans of the variant Models are presented in Tables 5.4a-c. The Tables show that the operating capital per hectare for the 5 hectares Models were lower than the 20 hectares Models in all the zones. This is to be expected since there was no labour hiring activity in the models with farm size of 5 hectare. The need for additional hired labour in the 20 hectares models necessitated the utilization of more capital to offset the expenditure on this activity.

Table 5.4a: Resource use levels in the optimum plans of the variant models

(Zone 1)

| Resource | Unit | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| | | Model 1.1 | Model 1.2 | Model 2.1 | Model 2.2 |
| Land | Ha | 5 | 15.1 | 5 | 15.0 |
| **Livestock** | | | | | |
| Cattle | No. | - | - | 2 | 6 |
| Sheep | No. | - | - | 4 | 0 |
| Goat | No. | - | - | 6 | 0 |
| **Family Labour** | | | | | |
| Jan-April | Man-hour | 64.6 | 41.7 | 480.3 | 862.3 |
| May-Aug. | Man-hour | 1638.6 | 2100.0 | 1757.2 | 2100.0 |
| Sept-Dec. | Man-hour | 1043.7 | 2100.0 | 1317.8 | 2100.0 |
| **Hired Labour** | | | | | |
| May-Aug. | Man-hour | 0 | 2151.0 | 0 | 2275.0 |
| Sept.-Dec. | Man-hour | 0 | 753.0 | 0 | 1276.0 |
| FYM (own) | Kg | - | - | 1824.0 | 2681.0 |
| FYM (buy) | Kg | - | - | 2525.9 | 0 |
| Crop residue | Kg | - | - | 3423.0 | 6846.0 |
| Capital | Naira | 7239.0 | 75600.0 | 12515.3 | 97000.0 |
| Gross return | Naira | 42781.0 | 207126.9 | 64902.4 | 250272.0 |
| Gross margin | Naira | 35542.0 | 131526.9 | 52387.1 | 153272.0 |
| Gross margin/ha | Naira | 7108.4 | 8705.0 | 10477.0 | 10205.0 |

Table 5.4b: Resource use levels in the optimum plans of the variant models

(Zone 2)

| Resource | Unit | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| | | Model 1.1 | Model 1.2 | Model 2.1 | Model 2.2 |
| Land | Ha | 5 | 14.4 | 5 | 16.1 |
| **Livestock** | | | | | |
| Cattle | No. | - | - | 2 | 0 |
| Sheep | No. | - | - | 3 | 0 |
| Goat | No. | - | - | 6 | 0 |
| **Family Labour** | | | | | |
| Jan-April | Man-hour | 53.1 | 149.1 | 459.5 | 203.9 |
| May-Aug. | Man-hour | 1666.7 | 2520.0 | 1788.5 | 2520.0 |
| Sept-Dec. | Man-hour | 1238.4 | 2520.0 | 1499.7 | 2520.0 |
| **Hired Labour** | | | | | |
| May-Aug. | Man-hour | 0 | 2052.0 | 0 | 2561.0 |
| Sept.-Dec. | Man-hour | 0 | 756.0 | 0 | 1113.0 |
| FYM (own) | Kg | - | - | 1763.0 | 0 |
| FYM (buy) | Kg | - | - | 1318.6 | 8634.0 |
| Crop residue | Kg | - | - | 3308.9 | 0 |
| Capital | Naira | 31051.0 | 124202.0 | 16863.0 | 153877.0 |
| Gross return | Naira | 80404.9 | 316910.2 | 92925.9 | 358359.1 |
| Gross margin | Naira | 49353.9 | 192708.2 | 76062.9 | 204482.1 |
| Gross margin/ha | Naira | 9870.8 | 13345.0 | 15212.6 | 12708.6 |

Table 5.4c: Resource use levels in the optimum plans of the variant models

(Zone 3)

| | | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| Resource | Unit | Model 1.1 | Model 1.2 | Model 2.1 | Model 2.2 |
| Land | Ha | 5 | 13.5 | 5 | 16.4 |
| **Livestock** | | | | | |
| Cattle | No. | - | - | 2 | 0 |
| Sheep | No. | - | - | 4 | 0 |
| Goat | No. | - | - | 6 | 0 |
| **Family Labour** | | | | | |
| Jan-April | Man-hour | 91.7 | 262.5 | 520.0 | 74.2 |
| May-Aug. | Man-hour | 1818.0 | 2520.0 | 2033.0 | 2520.0 |
| Sept-Dec. | Man-hour | 1516.0 | 2520.0 | 1790.0 | 2520.0 |
| **Hired Labour** | | | | | |
| May-Aug. | Man-hour | 0 | 2239.0 | 0 | 3138.0 |
| Sept.-Dec. | Man-hour | 0 | 1514.0 | 0 | 1759.0 |
| FYM (own) | Kg | - | - | 1824.0 | 0 |
| FYM (buy) | Kg | - | - | 3349.0 | 17287.0 |
| Crop residue | Kg | - | - | 3423.0 | 0 |
| Capital | Naira | 7776.0 | 89296.0 | 11358.0 | 115648.0 |
| Gross return | Naira | 47419.1 | 249887.8 | 83682.0 | 307376.4 |
| Gross margin | Naira | 39643.1 | 160591.8 | 72324.0 | 191728.4 |
| Gross margin/ha | Naira | 7928.6 | 11887.0 | 14464.8 | 11683.6 |

There was no supply of farmyard manure in zones 2 and 3 of Model 2.2 because of the exclusion of livestock in the optimum plans of this model. The total farmyard manure used in the optimum plans of these zones was purchased. The available farmyard manure from the household in zone 1 was completely used up There was no purchasing activity for this resource in this zone.

### 5.2.3 Gross margin of the variant optimum plans

The gross margins for each of the model plans were obtained by subtracting the operating capital from the gross return. The contribution of crop and livestock to gross return in the integrated optimum plan of Model 2.1 and 2.2 revealed that crop contributed about 68%, 86% and 81% of the gross return in zones 1, 2 and 3 respectively and 82%, 100% and 100% in the respective zones in Model 2.2. The implication of this is that as the restraint on farm size was relaxed in the integrated system, the contribution of livestock to the gross return was negligible. A graphical illustration of this relationship is presented in Figure 5.2.

The contributions of livestock to gross return in the model with farm size of 5 hectares was highest followed by the average farms and when the available farm size was increased to 20 hectares, the returns from livestock became zero. It can be deduced from this result that the economic returns from livestock in an integrated crop-livestock farming system is more pronounced in a low land resource based system, when land area was not limiting, the contribution of livestock to the gross income was zero.

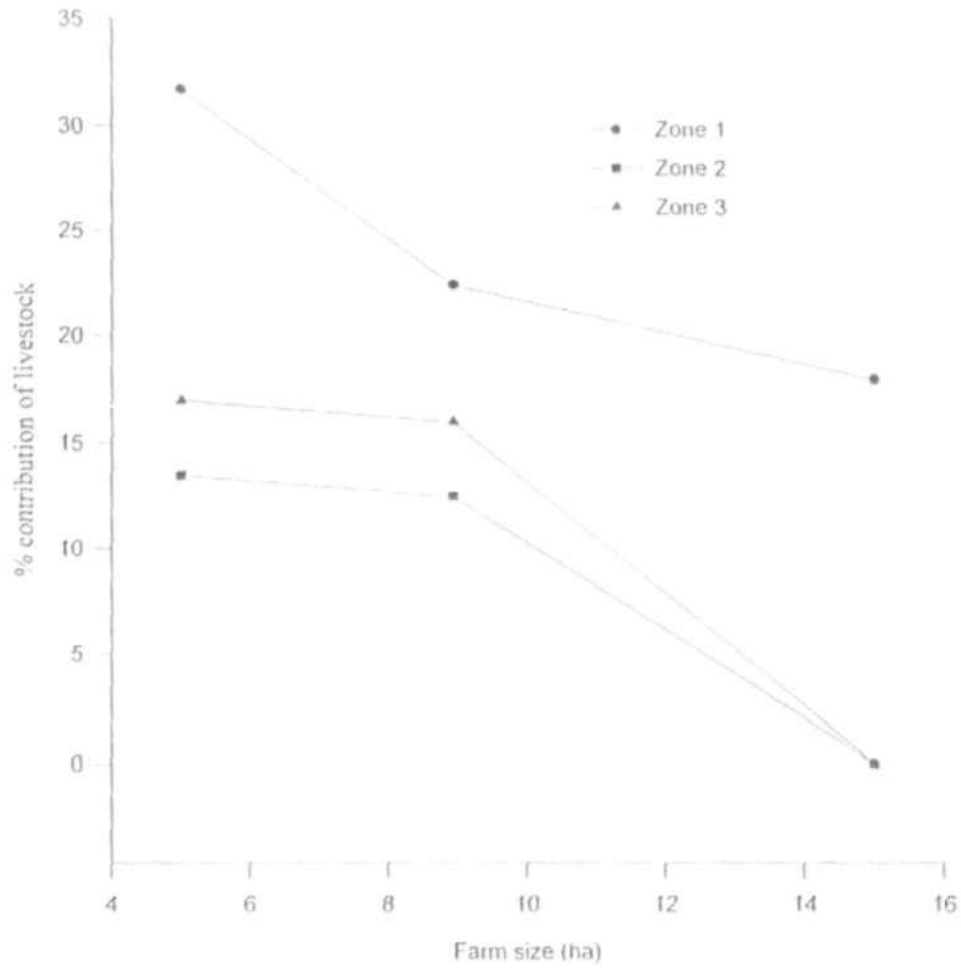



Fig. 5.2. Contributions of livestock to gross return in the integrated model plans.

Note: Only the result of the optimum plans of the three farm size variations were considered

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The gross margin from the optimum plans of the variant Models are presented in Tables 5.4a-c. The analysis revealed increases of 47%, 64% and 82% in the gross margins of the integrated systems (Model 2.1) over the crop-based systems (Model 1.1) of zones 1, 2 and 3 respectively. The increment in the gross margins of the integrated systems of Model 2.2 to the crop-based systems of Model 1.2 were 17%, 6% and 19% in zones 1, 2 and 3 respectively. The differences in gross margin between the crop-based and the integrated crop-livestock systems were larger with 5 hectares farm size than with 20 hectares. The analysis also revealed that the gross margin per hectare in the crop-based systems were higher in the models with 20 hectares than the 5 hectares models while the reverse was observed in the integrated systems. This further shows that, when land was not limiting but capital and labour were restricted, crop-based production systems was more favored in terms of efficiency of resource utilization. It can be concluded from the foregoing result that a sustainable integrated crop-livestock farming system is more applicable to a low resource based situation.

### 5.2.4 Marginal value productivity of resources in the variant models

The MVPs of resources under the different farm sizes are presented in Tables 5.5a, 5.5b and 5.5c for zones 1, 2 and 3 respectively. Land was limiting in the Models with 5 hectares of land in both production systems. This can be seen from the MVP of ₦18,357.00, ₦25,060.00 and ₦25455.00 in the crop-based systems and ₦18,357.00, ₦25,060.00, ₦34232.63 in the integrated systems of zones 1, 2 and 3 respectively. With the exception of zone 3 where the MVP of land in the integrated farm plan was higher than the value in the crop-based plan, there were no significant differences in the MVP of land in

both production systems in the other two zones The shadow price of land in the Models with 20 hectare of farm Lands was zero in both production systems for all the zones implying excess supply of this resource. The conclusion resulting from this is that bringing more land under cultivation in the models with 5 hectares of farm land will have a positive impact on farm income while this will be of no economic benefit in the 20 hectare models.

Family labour was not a constraint to production in the three labour restrictions' periods built into the Models with 5 hectares of land. This is apparent by the zero shadow prices in each of the periods implying under employment of labour. It is not surprising that family labour was in limited supply in the periods of May-August and September-December in Models 1.2 and 2.2 (20 hectares). The shadow prices of labour in these periods as presented in Tables 5.5a-c were over 50% higher than their respective wage rates in zones 1 and 3 and about 40% higher in zone 2. These percentages were also higher than the values observed in the optimum plans of the average household. The possible explanation for this is that when land constraint was relaxed without a corresponding increase in the potential family labour supply, family labour became more limiting with higher shadow prices.

Capital was not a production constraint in both production systems with farm size of 5 hectares. The MVPs of capital were zero for all the zones in Models 1.1 and 2.1 while the values were 1.64, 1.39 and 1.77 in Models 1.2 of zones 1, 2 and 3 respectively and 1.64, 1.40 and 1.68 in the respective zones of Model 2.2. The result shows that there was no significant difference in the shadow prices of capital in the crop-based and integrated production systems when farm size was increased to 20 hectares. This is expected as the integrated models with farm size of 20 hectares excluded livestock in the

optimum plan and thus had similar characteristics with the crop-based models. It was also observed that the MVPs of capital were less than the prevailing interest rate of about 21% in the survey year, it can be deduced that there was inefficiency in the use of capital in both production systems.

Table 5.5a: Marginal value products of the resources in the variant models

(Zone 1)

| Resource | Unit | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| | | Model 1.1 ₦ | Model 1.2 ₦ | Model 2.1 ₦ | Model 2.2 ₦ |
| Land | Ha | 18357 | 0 | 18357 | 0 |
| **Livestock** | No. | | | | |
| Cattle | No. | - | - | 7516 | 274 |
| Sheep | No. | - | - | 569 | 0 |
| Goat | Man-hour | - | - | 546 | 0 |
| **Family Labour** | Man-hour | | | | |
| Jan-April | Man-hour | 0 | 0 | 0 | 0 |
| May-Aug. | Man-hour | 0 | 33 | 0 | 33 |
| Sept-December | Man-hour | 0 | 31 | 0 | 31 |
| FYM | Kg | - | - | 0 | 0 |
| Capital | Naira | 0 | 1.64 | 0 | 1.64 |

Table 5.5b: Marginal value products of the resources in the variant models

(Zone 2)

| Resource | Unit | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| | | Model 1.1 | Model 1.2 | Model 2.1 | Model 2.2 |
| | | ₦ | ₦ | ₦ | ₦ |
| Land | Ha | 25060 | 0 | 25060 | 0 |
| **Livestock** | | | | | |
| Cattle | No. | - | - | 4534 | 0 |
| Sheep | No. | - | - | 434 | 0 |
| Goat | No. | - | - | 359 | 0 |
| **Family Lab** | | | | | |
| Jan-April | Man-hour | 0 | 0 | 0 | 0 |
| May-Aug. | Man-hour | 0 | 40 | 0 | 40 |
| Sept-Dec. | Man-hour | 0 | 36 | 0 | 36 |
| FYM | Kg | - | - | 0 | - |
| Capital | Naira | 0 | 1.39 | 0 | 1.40 |

Table 5.5c: Marginal value products of the resources in the variant models

(Zone 3)

| Resource | Unit | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| | | Model 1.1 | Model 1.2 | Model 2.1 | Model 2.2 |
| | | ₦ | ₦ | ₦ | ₦ |
| Land | Ha | 25455 | 0 | 34233 | 0 |
| **Livestock** | | | | | |
| Cattle | No. | - | - | 5608 | 0 |
| Sheep | No. | - | - | 462 | 0 |
| Goat | No. | - | - | 428 | 0 |
| **Family Labour** | | | | | |
| Jan-April | Man-hour | 0 | 0 | 0 | 0 |
| May-Aug. | Man-hour | 0 | 35 | 0 | 33 |
| Sept-Dec. | Man-hour | 0 | 31 | 0 | 36 |
| FYM | Kg | - | - | 0 | - |
| Capital | Naira | 0 | 1.77 | 0 | 1.68 |

Livestock was a constraint in the integrated crop-livestock systems of Model 2.1 with farm size of 5 hectares. The MVPs of cattle, sheep and goat were higher in this model compared to the average household optimum plans. Thus livestock was more limiting in the model with 5 hectares than in the average farm plan. Except for cattle in zone 1 the shadow prices of all the livestock types were zero in the model with farm size of 20 hectares. This means that forcing any of the livestock types into the optimum plan would have no effect on the farm income.

### 5.3 Parametric Programming Models

The average farm plans were subjected to three parametric models to observe the effect of adjusting some of the limiting resources on the optimum plan. The three resources subjected to sensitivity analysis were family labour supply , net prices of outputs and input costs.

#### 5.3.1 Effect of variations in potential labour supply on the optimum plan

The potential labour supply in each of the three labour demand periods were decreased by 10% and 20% in both production systems of the average household models. The result of this analysis is presented in Tables 5.6a, 5.6b and 5.6c for zones 1, 2 and 3 respectively. The result revealed that a 10% decrease in the potential family labour supply in the crop-based systems did not affect the choice of enterprises and the total land area cultivated but there were 14%, 30% and 27% increases in the operating capital as a result of hiring labour to augment the limited potential family labour supply in zones 1, 2 and 3 respectively. There was excess supply of capital in the average optimum plans thus with this adjustment, the surplus capital was able to

offset the extra cost required for hiring labour. The resulting optimum plan emanating from this adjustment showed that the gross margin decreased by about 5%, 10% and 9% in the respective zones. The contributions of family labour to the total labour decreased from 84%, 88% and 82% in the average farm plan of zones 1, 2 and 3 respectively to 79%, 79% and 74% in the respective zones of the adjusted plan.

A 20% decrease in the potential family labour in the crop-based systems however, resulted in about 4% decreased in the total farm size cultivated in zones 2 and 3 and about 2% decrease in zone 1. The optimum plan with this adjustment showed a reorganization of the farm activities and resource use levels. The adjusted plan in zone 1 contains 4 crop enterprises instead of three in the average optimum plan. The crops in the new plan are; sole rice, millet-cowpea, sorghum-groundnut and millet-sorghum-*maiwa*. A closer look at the choice of enterprises in the adjusted plan shows that a three-crop mixture was introduced into the plan with 20% further restriction in the available family labour. The implication of this is that when labour becomes limiting to the point of reducing the land area that can be cultivated, there is the tendency to embark on longer crop chains to satisfy the objectives of the farm-household.

A reduction in the potential family labour by 20% in zone 2 did not change the crop choice in the optimum plan. However, there was about 2% reduction in the area allocated to cotton-cowpea production. Adjustment in labour supply in zone 3 also resulted in the introduction of three-crop mixture in the optimum plan. Cotton-cowpea in the average farm plan was changed to millet-maize in the adjusted plan possibly because cotton-cowpea is more

labour demanding than millet-maize. Also millet-groundnut in the average farm plan was changed to millet-maize-cowpea in the new plan to maximize land use and meet the food security objective of the farm household.

Table 5.6a: Resource use levels with variations in labour supply.

(Zone 1)

| Resource | Unit | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| | | 10% | 20% | 10% | 20% |
| Land | Ha | 8.93 | 8.93 | 8.93 | 8.93 |
| **Livestock** | | | | | |
| Cattle | No. | - | - | 2 | 2 |
| Sheep | No. | - | - | 4 | 2 |
| Goat | No. | - | - | 6 | 0 |
| **Family Labour** | | | | | |
| Jan-April | Man-hour | 114.5 | 98.8 | 520.0 | 374.2 |
| May-Aug. | Man-hour | 1890.0 | 1680.0 | 1890.0 | 1680.0 |
| Sept-Dec. | Man-hour | 1890.0 | 1680.0 | 1890.0 | 1680.0 |
| **Hired Labour** | | | | | |
| May-Aug. | Man-hour | 1007.0 | 1049.3 | 1092.5 | 1269.4 |
| Sept.-Dec. | Man-hour | 0 | 180.1 | 291.9 | 487.9 |
| FYM (own) | Kg | - | - | 1824.0 | 1177.1 |
| FYM (buy) | Kg | - | - | 3349.0 | 3995.9 |
| Crop residue | Kg | - | - | 3423.0 | 2530.5 |
| Capital | Naira | 33755.1 | 37821.0 | 47102.0 | 47102.0 |
| Gross return | Naira | 114924.0 | 111769.0 | 145243.5 | 137725.0 |
| Gross margin | Naira | 81168.9 | 73948.0 | 98141.5 | 90623.0 |
| Gross margin/ha | Naira | 9089.5 | 8280.9 | 10990.1 | 10148.2 |

Table 5.6b: Resource use levels with variations in labour supply.

(Zone 2)

| Resource | Unit | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| | | 10% | 20% | 10% | 20% |
| Land | Ha | 9.85 | 9.45 | 9.85 | 9.85 |
| **Livestock** | | | | | |
| Cattle | No. | - | - | 3 | 0 |
| Sheep | No. | - | - | 9 | 9 |
| Goat | No. | - | - | 0 | 0 |
| **Family Labour** | | | | | |
| Jan-April | Man-hour | 102.4 | 98.4 | 667.1 | 320.1 |
| May-Aug. | Man-hour | 2037.6 | 2016.0 | 2268.00 | 2016.0 |
| Sept-Dec. | Man-hour | 2268.0 | 2016.0 | 2268.0 | 2016.0 |
| ***Hired Labour*** | | | | | |
| May-Aug. | Man-hour | 1121.9 | 1143.5.0 | 1057.0 | 1203.4 |
| Sept.-Dec. | Man-hour | 178.0 | 269.0 | 372.4 | 398.1 |
| FYM (*own*) | *Kg* | - | - | 4317.0 | 4317.0 |
| FYM (buy) | Kg | - | - | 2945.3 | 2945.3 |
| Crop residue | Kg | - | - | 4495.9 | 1627.2 |
| Capital | Naira | 62101.0 | 62101.0 | 73633.0 | 73633.0 |
| Gross return | Naira | 201945.8 | 192120.6 | 218487.8 | 207088.3 |
| *Gross margin* | *Naira* | 139844.8 | 130019.6 | 144854.8 | 133455.3 |
| Gross margin/ha | Naira | 14197.4 | 13758.7 | 14706.1 | 13548.8 |

Table 5.6c: Resource use levels with variations in labour supply.

(Zone 3)

| Resource | Unit | Crop production | | Crop-livestock | |
|---|---|---|---|---|---|
| | | 10% | 20% | 10% | 20% |
| Land | Ha | 9.11 | 9.09 | 9.11 | 9.11 |
| **Livestock** | | | | | |
| Cattle | No. | - | - | 4 | 2 |
| Sheep | No. | - | - | 0 | 0 |
| Goat | No. | - | - | 2 | 1 |
| **Family Labour** | | | | | |
| Jan-April | Man-hour | 182.9 | 164.3 | 682.6 | 392.5 |
| May-Aug. | Man-hour | 2268.9 | 2016.0 | 2268.0 | 2016.0 |
| Sept-Dec. | Man-hour | 2268.0 | 2016.0 | 2268.0 | 2016.0 |
| **Hired Labour** | | | | | |
| May-Aug. | Man-hour | 1091.7 | 1084.4 | 1286.6 | 1461.2 |
| Sept.-Dec. | Man-hour | 574.9 | 590.6 | 653.5 | 704.2 |
| FYM (own) | Kg | - | - | 3648.0 | 3455.0 |
| FYM (buy) | Kg | - | - | 3741.1 | 3897.0 |
| Crop residue | Kg | - | - | 4792.2 | 2396.1 |
| Capital | Naira | 44648.0 | 44648.0 | 54043.0 | 54043.0 |
| Gross return | Naira | 152022.6 | 137368.7 | 182169.8 | 170405.5 |
| Gross margin | Naira | 107374.6 | 92720.7 | 128126.8 | 116362.5 |
| Gross margin/ha | Naira | 11789.5 | 10200.3 | 14064.4 | 12773.1 |

Reduction in the potential labour supply by 20% in the crop-based systems resulted in about 28%, 30% and 27% increase in the operating capital as a result of hiring labour to augment the limited potential family labour supply in zones 1, 2 and 3 respectively. The resulting optimum plan emanating from this adjustment showed that the gross margin decreased by 15%, 19% and 26 in the respective zones. The contributions of family labour to the total labour decreased from 84%, 88% and 82% in the average farm plan of zones 1, 2 and 3 respectively to 73%, 77% and 71% in the respective zones of the adjusted farm plan with 20% decrease in family labour supply.

The analysis of the effect of decreasing the potential labour in the crop-based production systems revealed that where there was surplus capital to offset the extra cost required for hiring labour there was little or no adjustment in farm activities. However as capital became limiting, there was reorganization of activities and resource use levels in terms of reduction in farm size, selecting enterprises that is less labour demanding and still satisfying the farm objectives and maximizing land use through cultivation of longer chain of crops.

A different scenario was observed when the potential family labour was decreased by 10% and 20% in the integrated crop-livestock farm pan. A 10% reduction in the potential family labour did not have any significant effect on the choice of crop activities in the adjusted integrated optimum plans of all the zones. That is, all the crop activities in the average farm plan were retained and the available farmland completely utilized in producing the crops selected in all the zones. However, there were reorganizational livestock activities with the 10% reduction in family labour supply in zones 2

and 3. The sizes of cattle, sheep and goat were decreased from 5, 9 and 4 respectively in the average optimum plan of zone 2 to 3, 9 and 0 respectively in the adjusted optimum plan. The size of cattle, sheep and goat accepted in the average optimum plan of zone 3 decreased from 4, 8 and 12 respectively to 4, 0 and 2 respectively in the adjusted farm plan. The implication of this result is that when potential family labour become limiting with no adjustment in farm land, livestock size and operating capital there is the tendency to reduce the flock size and concentrate the available resources on crop production. This is expected because of the low contribution of the livestock sector to farm income in the integrated system.

The resulting optimum plan with 10% decrease in labour supply in the integrated crop-livestock production system revealed that there was no change in the amount of operating capital as this was in limited supply in the average farm plan. The analysis also show that the gross margins from the adjusted optimum plan decreased by 4%, 8% and 7% in the respective zones compared to the values of the average optimum plan. The percentage difference in the gross margins between the average optimum plans and the adjusted optimum plans of both production systems when labour wais decreased by 10% revealed that the ratios were wider for the crop-based farms than the integrated farm. The possible explanation for this is that the surplus operating capital in the optimum plan of the crop-based systems were used to offset the extra cost required for hiring labour with little or no effect on the gross return. However, capital was limiting in the average farm plan of the integrated systems, therefore adjustment in the available labour implies that activities had to be reorganized to accommodate the available capital with a consequence reduction in farm return. It can thus be deduced

that a squeeze in the available family labour supply will have a greater impact on the farm income of the integrated crop-livestock farms than the crop-based farms. The contributions of family labour to the total labour decreased from 80%, 83% and 78% in the average integrated farm plans of zones 1, 2 and 3 respectively to 76%, 78% and 73% in the respective zones when family labour was decreased by 10% in the integrated farm plans.

There was further reduction of livestock size when family labour was decreased by 20% in all zones while the crop activities remained unchanged in zones 1 and 2. The number of cattle, sheep and goat accepted in the adjusted optimum plan with 20% decrease in family labour were 2, 2, and 0 respectively in zone 1, 0, 9 and 0 in zone 2 and 2, 0 and 1 respectively in zone 3. Except for zone 2, sheep and goat were the first to be eliminated from the optimum plan when labour was restricted. This is because cattle seem to have a higher net benefit than sheep and goat.

The level of operating capital remained the same as in the average optimum plan with 20% decrease in the potential family labour supply. However, the shadow prices of capital were higher in the adjusted optimum plan than in the average farm plan indicating a higher level of scarcity of capital in the adjusted plan. The 20% decrease in the family labour of the integrated models resulted in 12%, 17% and 19% decreases in the optimum gross margins of zones 1, 2 and 3 respectively. The contributions of family labour to the total labour decreased from 84%, 88% and 82% in the average farm plan of zones 1, 2 and 3 respectively to 68%, 73% and 67% in the respective zones of the adjusted farm plan.

The analysis of the effect of decreasing the potential labour in the integrated crop-livestock production systems revealed that as labour became limiting at a given level of land, livestock size and capital, the livestock activities were eliminated from the optimum plan starting with goat, sheep and then cattle in that order. However, as labour became more limiting, there was reorganization of crop activities and resource use level in terms of reduction in farm size, selecting enterprises that were less labour demanding and still satisfying the farm-household objectives. It can be inferred from these findings that when family labour becomes limiting while other resources are held fixed there is the possibility of deviating from integrated crop-livestock system and embarking on crop-based production systems. The possible reason for this is that, integrated crop-livestock systems is labour demanding particularly during the peak farming period, also the monetary returns from livestock activities were low compared to crop production thus in order to maximize the objective function, livestock activities had to be eliminated from the farm plan. An inverse relationship was observed between the potential labour supply and their respective MVP. As the potential labour supply became more limiting, there was a decrease in its MVP.

### 5.3.2 Optimal plan with variations in input costs

This model looks at the effect of increasing the costs of all inputs used in the production of the specified crop and livestock activities on the average optimum plan. A 10% increase in the cost of inputs used in the crop-based systems of the average household revealed that there were no differences in the resulting optimum plans of all the zones. The activities and resource use

level remained unchanged except the total operating capital that increased by 10% in all the zones. The increase in the operating capital caused by the increase the input costs resulted in a reduction in the gross income by 4% in zone 1 and 3% in zones 2 and 3. The consequence of this is that an increase in the costs of inputs used in crop-based production systems without a corresponding increase in the available capital resulted in lower gross margin even though the level of real activities and resource use remained unchanged.

With 10% increase in the costs of all inputs in the integrated system, the number of cattle sheep and goat in the average optimum plan decreased from 5, 9 and 4 to 4, 9 and 1 respectively in zone 2. The number decreased from 4, 8 and 12 to 4, 0 and 9 respectively in zone 3 while the numbers remained the same in zone 1. The total farmlands introduced into the model with 10% increase in input costs were completely used up in all the zones. The crop enterprises selected in the new optimum plan were similar in all respect to the average optimum plan of zone 2. However, the adjusted optimum plans of zones 1 and 3 indicated a reorganization of crop activities and resource use levels. Instead of millet-cowpea (6.82 hectares), sorghum-groundnut (1.5 hectares), *maiwa*-cowpea (0.86 hectares) and sorghum-*maiwa* (0.005 hectares) in the average optimum plan of zone 1 the adjusted plan selected millet-cowpea (6.33 hectares), rice (1.24 hectares), sorghum-*maiwa* (0.94 hectares) and sorghum-groundnut (0.42 hectares). Thus *maiwa*-cowpea was replaced by rice in the new plan possibly because the unit cost of production was lower with no significant difference in economic return. The new plan in zone 3 contained the same crop enterprises as in the average

optimum plan. However, the plot size allotted to rice and millet-cotton changed from 1.66 and 1.97 hectares respectively to 0.04 and 3.59 hectares respectively. In this zone, rice was replaced by millet-cotton for the same reason given above.

Capital was in limited supply in the average optimum plan of the integrated crop-livestock system. The increase in the input costs without relaxing the constraint on capital resulted in decreased production activities to accommodate the resulting extra expenditure. The gross margins resulting from the new optimum plan were ₦100,124.20, ₦15,0711.60 and ₦133,016.60 compared to ₦102,981.00, ₦156,225.00 and ₦138,524.39 in the average optimum plan of zones 1, 2 and 3 respectively. There were 3%, 4% and 4% decreases in the gross margin of the adjusted optimum plans in the respective zones. The implication of this is that an increase in the cost of inputs used in integrated crop-livestock production system without a corresponding increase in the available capital resulted in reduction in the level of livestock activities and reorganization of crop activities and resource use levels. It can thus be said that when capital become limiting as a result of increased input costs in the integrated system there is the tendency to eliminate livestock activities and move towards crop-based production systems. Although livestock production is not as operating capital intensive as in crop production, the return to capital in the livestock sector is low, thus the available capital is more economically utilized for crop production than livestock.

### 5.3.3 Optimal plan with variations in output prices

The prices of all crop and livestock output were increased by 10% and decreased by 10% to observe the effect of the variations on resource allocation holding all activities and restrictions in the basic model fixed. The analysis revealed that there were no significant changes in the real activity and resource use levels in both production systems when the output prices were increased by 10% and decreased by 10%. The value of operating capital remained unchanged but there was a change in the gross returns with variation in output prices in both production systems.

The resulting effect of 10% decrease in output prices in the average crop-based plans were reduction in the gross margins from ₦85,409.00, ₦154,316.32 and ₦116,837.66 in the average plan to ₦73,916.20, ₦134,121.72 and ₦101,633.66 in the new plans of zones 1, 2 and 3 respectively. This represented about 15% decrease in the new gross margin of each of the zones. The new gross margins with 10% increase in output prices in the crop-based systems were ₦96,901.00, ₦174,510.92 and ₦132,041.60 in zones 1, 2 and 3 respectively representing about 13% increase in the new gross margin of each of the zones. The effect of the adjustment in output prices on the resulting gross margin was higher with the 10% decrease than with the 10% increase in output prices.

A 10% decrease in the output prices of the integrated crop-livestock production system resulted in lower gross margins of ₦87,072.10, ₦132,892.90 and ₦118,590.60 in zones 1, 2 and 3 respectively compared to ₦102,981.00, ₦156,225.00 and ₦138,524.39 in the integrated average optimum plans of the respective zones. These represent about 18%, 18% and 17%

decreases in the new gross margins of the respective zones. The gross margins resulting from 10% increase in output prices were ₦117,093.20, ₦179,038.90 and ₦157,390.30 representing about 14%, 15% and 14% increases in zones 1, 2 and 3 respectively. The effect of variations in output prices on gross margin in both production systems revealed that the impact on the integrated systems were higher than in the crop-based systems.

The analysis also showed that the shadow prices of all binding resources were higher than observed in the average optimum plan when the output prices were increased by 10% and lower when the prices were decreased by 10%. This can be attributed to the fact that with 10% increase in output prices, the binding resources became more limiting implying that a unit increase in these resources will add more to the value of the objective function. Similarly, a 10% decrease in output prices will relax the limitation of these resources and an additional use will contribute less to the objective function.



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CHAPTER 6

# SUMMARY, CONCLUSION, POLICY IMPLICATIONS AND RECOMMENDATIONS

## 6.1 Summary

Agriculture has a very important role to play in the economic development of the country in terms of feeding the steadily growing population and providing the investible resources for national development. Despite the various efforts made by the government, returns to the economy from this sector have been very much below the potential. Efforts at improving productivity in the various sub-sectors of agriculture will need to take account of the pronounced diversity of the natural and human resources, and how to optimally allocate these resources at the farm level

This study is designed to assess ways of intensifying crop and livestock production in Northern Nigeria through an examination of farm level reorganization of resources and activities. It is anticipated that the study would throw some light on the following issues: (a) feasible interactions between crop and livestock systems, (b) the potential roles of crop and livestock production in the system, (c) pattern of resource allocation within the system, (d) farm-level reorganization required to provide an efficient integrated system, (e) Socio-economic and technical constraints in the existing modes of production and (f) policy implication and institutional support towards adoption of integration activities. This study is expected to provide the much needed baseline economic information necessary for evaluating integrated crop-livestock system as a means of maximizing the efficiency of resource utilization.

The data used for this study were collected from 20 households each in six villages in Katsina state using structured questionnaire. The tools of analysis used were simple descriptive statistics; farm business analysis, profit function and Linear and mixed programming models. The results from the analysis are summarized below:

### 6.1.1 Description of the farm-household systems

The study revealed that the households surveyed operated under a relatively secure tenurial arrangements as most of them owned the plot of land they cultivated. The average farm size were 8.93, 9.85 and 9.11 hectares in zones 1, 2 and 3 respectively. One notable feature in the study area was the inequitable distribution of farmland among the sampled households. In quantitative terms, about 50% of the households surveyed cultivated about 0.5-5ha of land, 35% cultivated between 5.1 to 20ha while about 15% cultivated above 20ha of land in all the zones.

The household size in the study area consists of an average of 13 individuals with an average consumption unit of 10.21, 9.90 and 10.96 man-equivalents in zones 1, 2 and 3 respectively. Adult male and female members between 15 and 60 years comprised about 43% of the entire family size. Adolescents between 7-14 years were about 32% of the household population while elderly people above 60 years and children below 7 years comprised one fourth of the household size in the study area. In terms of household labour supply, about 56%, 66% and 66% of the household members in zones 1, 2 and 3 respectively were capable of providing the family labour force.

Most of the households in the study area relied heavily on workbulls and farm implements, such as hoe, cutlass, ox-plough (*garma*), weeder

(*Chakarkara*), and carts (*Omolanke*). Only about 4.2% of the households surveyed owned tractor. Personal savings from sales of crop and livestock constituted the major source of capital for financing agricultural activities in the study area. Very few households (11%) borrowed money from informal sources like friends and relatives. The predominant crops grown in the study area include sorghum, millet, maize, cotton, *maiwa*, rice, groundnut, cowpea, soybean, cocoyam and tomato. These crops were grown either as sole stands or in mixture of two to three crops. Sole cropping accounted for 32%, 77% and 29% of the cultivated hectarage in zones 1, 2 and 3 respectively while the remaining hectarage was allotted to mixed cropping. The crop mixtures in all the zones were cereal and legume based. The major reasons given for intercropping cereal with legumes were; higher yield, low insect infestation, soil improvement for continuous cropping and risk aversion.

The major livestock species in the study area were cattle, sheep, goat, donkeys, poultry, camel and horses. The livestock ownership structure in the three zones studied revealed that 54% of the household surveyed had an average of two work bulls, about 43% had between 3 to 8 while less than 3% had more than 10 heads. About 25% and 40% of the household had between 2 to 5 sheep and goats respectively while 36% and 41% had between 6 to 10 sheep and goats respectively. The analysis revealed that the average number of cattle, sheep and goat in zone 1 were three, seven and thirteen respectively. The numbers in zone 2 were five, nine and twelve while the average in zone 3 were four, eight and twelve for cattle, sheep and goats respectively. Work bulls were kept mainly for cultivation purposes while sheep and goats were kept mainly for meeting household cash need. Other

reasons given by the respondents for keeping livestock in the study area include: food security, savings and investment and as a source of income. Although manure is becoming very important for soil improvement in the study area, none of the households interviewed kept livestock only for the manure. The study also revealed that income from sale of cattle was the highest followed by goat and then sheep.

Households in the study area were actively involved in integrated crop and livestock production systems at varying intensities. Reasons given for the integration of crop and livestock include; to diversify risk from only crop production, as a source of draught power, traditional practice, income maximization. The major livestock species used for traction purposes in the study area were oxen and donkey. However, oxen were commonly used in all the zones for the various crop cultivation processes while donkey were mainly used for carting and transport. The principal tasks performed with the aid of draught animals in the study area were planting, weeding, harvesting of groundnut and transport of manure, farm inputs and harvested produce. Equipment used for harnessing these animals includes: plough (*garma*), weeder (*chakarkara*), cart (*omolanke*) and woven basket (*mangala*).

### 6.1.2 Cost-Return Analysis

The total variable cost was higher for the integrated systems than the crop- based systems. The higher cost in the integrated systems was due to additional cost incurred on livestock inputs. An analysis of the costs incurred on crop and livestock inputs in the integrated systems revealed that the cost on crop inputs were about 77%, 82% and 79% of the total cost in the three respective zones.

There were about 42%, 17% and 33% increase in gross return of the integrated systems to the crop-based systems. The contribution of livestock to the gross return were 29%, 15% and 25% for zones 1, 2 and 3 respectively. This showed that crop production was the major income-generating venture among the households in the study area. There were appreciable differences between the gross margins of the two production systems in all the zones. Households practicing integrated crop-livestock production systems earned higher gross margin than the households practicing crop-based production systems.

*Gross margins per hectare were higher in the integrated crop-livestock* systems than in the crop-based systems. Using this ratio as a measure of land use efficiency, it can be deduced that land was more efficiently utilized in the integrated crop-livestock systems than in crop-based systems. The returns to capital were 1.04, 1.66 and 0.91 in the three respective zones for crop-based systems and 1.33, 1.64 and 1.10 in the integrated systems. Thus a naira invested would yield higher net returns in the integrated systems than in the crop-based systems of zones 1 and 3 while the reverse was observed in zone 2. The integrated crop-livestock systems utilized labour more efficiently than the crop-based systems in zones 1 and 3 while the reverse was observed in zone 2.

The marginal rate of return (MRR) obtained by integrating crop and livestock in zones 1, 2 and 3 respectively were; 2.51, 1.50 and 1.99. This indicates that an extra Naira invested as a result of integrating livestock into the crop-based systems resulted in ₦2.51, ₦1.50 and ₦1.99 in zones 1, 2 and 3 respectively. However, these estimates did not include the initial cost of purchasing the animals.

### 6.1.3 Estimates of the Profit Model

The coefficient of land in both production systems indicates that land is the most important resource in terms of generating profit. The magnitude of the coefficient however, indicates that the economic returns to land was higher in the crop-based system than the integrated system. The coefficients of capital and labour in the two production systems revealed that while the coefficients of capital were not significant in the integrated systems in all the zones, the coefficients of labour were also not significant in the crop-based systems except in zone 3. The crop-based production systems were therefore relatively more capital intensive in production while the integrated systems were relatively more labour intensive.

The intercept terms for both production systems in all zones were statistically different from zero at one percent level. The result further shows that the integrated production systems had profit functions that were shifted upward above the values for the crop-based systems in zones 1 and 3. Thus the integrated farms in zones 1 and 3 were technically and economically more efficient than the corresponding crop-based farms. The direct implication of this result appear to be that measures designed to promote further integration of crop and livestock under the same management system are not inconsistent with efficiency in the use of available resources. The integrated crop-livestock in zone 1 and 3 had higher sum of resource elasticities and thus higher technical return to scale than the crop-based farms.

### 6.1.4 Activities and Resource Use Levels in the Basic LP Models

Of the total number of existing crop enterprises specified in the models, 3, 4 and 5 crop enterprises were selected as meeting the household food requirement and generating the maximum gross return in zones 1, 2, and 3 respectively. The total available land of 8.93, 9.85 and 9.11 hectare in zones 1, 2, and 3 respectively were completely used up in producing the selected crops in both production systems. The feasible crop enterprises in the crop-based systems consist of three 2-crop mixtures in zone 1, two sole crops and two 2-crop mixtures in zone 2 and one sole and four 2-crop mixtures in zone 3. None of the three crop mixtures entered the optimum plan of the average farm. The striking point of the enterprises choice in the optimum plans of zones 1 and 2 is that it does not deviate much from the dominant existing cropping pattern in the study area.

The same crop enterprises in the optimum plans of crop-based systems in zones 1 and 2 were retained in the integrated crop-livestock systems. There were reallocations of enterprises in the integrated system of zone 3. All the heads of cattle, sheep and goat specified in zones 1 and 3 entered the optimum plan while the plan for zone 2 took all the cattle and sheep but only one third of the total number of goats. The inclusion of the livestock enterprises into the optimum plan of the integrated systems suggests that livestock has positive and significant impact on the gross return of the basic model plan of crop-livestock system.

The labour profile of the optimum plan revealed that family labour constituted about 84%, 88% and 82% of the total labour in the crop-based systems and 80%, 83% and 78% of the total labour used in the integrated



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systems of the respective zones. Labour was only hired at the peak labour demand period of May-August in the crop-based systems and May-August and September -December in the integrated systems.

The contributions of crop and livestock to gross return in the optimum plan of the integrated systems revealed that crop contributed about 78%, 88% and 84% in zones 1, 2 and 3 respectively. The analysis also revealed increases of about 21%, 12% and 19% in the gross margin of the integrated systems over the crop-based systems in zones 1, 2 and 3 respectively. Thus, attempt to reorganize resources in both production systems will generate higher economic returns in the integrated system compared to the crop-based systems. Land use efficiency was higher in the integrated optimum plans than in the crop-based plans. This is evident by the higher gross margin per hectare in the integrated systems of all the zones

The most limiting resource in the basic models of both production systems was land. This is evidence by its high shadow price in all the zones. The shadow price of land was higher in the crop-based systems than in the integrated systems of zones 1 and 2, however the value was higher for the integrated crop-livestock systems than crop-based production systems in zone 3. Labour was a constraint to production in the period of May-August for both crop-based and integrated crop-livestock systems. However, the shadow price of labour for this period was zero for crop production and positive for crop-livestock systems in all the zones. Thus, there was a labour surplus in the crop-based systems. Labour in September - December period was also a constraint in the integrated systems. The shadow prices of labour in the May-August and September-December period were higher than the prevailing

wage rate in zones 2 and 3 while the value was lower in zone 1. Capital was only limiting in the integrated crop-livestock systems in all the zones. The shadow price was highest for zone3 followed by zone2 and zone 1 in that order. Draught power and crop residue utilization were not constraint to production in all the zones in integrated system. Farmyard manure produced on the farm was however a constraint, this was augmented by purchasing from outside the household.

### 6.1.5 Resource/Activity Levels in the Variant Models

The optimum plans derived from the variants of the two basic models revealed that when farm size was increased to 5 hectares the choice of crop enterprise did not change from the average farm plan and all the livestock numbers specified in the model for cattle sheep and goat were accepted. However, when the farm size was increased to 20 hectares, there was a reallocation of the choice of enterprises and in addition to this, all the livestock enterprises were excluded from the optimum plan except in zone 1 where 6 heads of cattle were included in the plan. The implication of this is that as land becomes more readily available without corresponding increase in capital outlay, crop-based production systems gives higher economic returns than integrated crop-livestock systems.

Contribution of livestock in the model with farm size of 5 hectares was highest in all zones followed by the average farm. When the farm size was increased to 20 hectares in zones 2 and 3, the contribution of livestock to gross returns was zero. Thus the economic importance of livestock in an integrated crop-livestock system is more pronounced in a low land resource base system. Family labour in the crop-based models with 20 hectares

constituted about 59%, 65% and 59% of the total labour in the optimum plans of zones 1, 2 and 3 respectively while the contributions of family labour in the integrated systems were 59%, 59% and 51% in the respective zones. The results of the variant models also show that contributions of family labour to total labour requirement decreased with increase in farm size.

The contributions of crop and livestock to gross return in the integrated optimum plan of the Models with 5 hectares of land revealed that crops contributed about 68%, 86% and 81% of the gross return in zones 1, 2 and 3 respectively and 82%, 100% and 100% in the respective zones in the Model with 20 hectares of land. This shows that as the restraint on farm size is relaxed in the integrated systems, the contribution of livestock to the gross return becomes negligible.

The gross margins per hectare in the crop-based systems were higher in the models with 20 hectares land than in the 5 hectares models while the reverse was observed in the integrated systems. This further shows that, when land is not limiting but capital and labour are restricted, crop-based production systems are more favored in terms of efficiency of land utilization. It can be inferred from the foregoing result that a sustainable integrated crop-livestock farming system is more applicable to a low land base situation.

A 10% decrease in the available family labour in the crop-based enterprises did not affect the choice of enterprises but there was an increase in the total variable cost as a result of hiring more labour. However, when the available labour was decreased by 20%, there was about 4% decrease in the total land cultivated in zones 2 and 3. The scenario is different in the case of the integrated systems. As labour became more limiting as a result of

reduction in the available family labour, the livestock enterprises were removed from the optimum plan.

An increase in the cost of production had less impact on gross return in the crop-based production systems compared to the integrated systems. With 10% increase in the costs of all inputs in the integrated system, the number of cattle sheep and goat in the average optimum plan decreased. A 10% increase in the cost of each of the enterprises specified in the average farm models resulted in about 4% decrease in the gross margin.

There was no significant change in the real activity and resource use levels in both production systems when the output prices were increased by 10% and decreased by 10%. The effect of variations in output prices on gross margin in both production systems revealed that the impact on the integrated system was higher than in the crop-based systems. The shadow prices of all binding resources were higher than observed in the average optimum plan when the output prices were increased by 10% and lower when the prices were decreased by 10%.

### 6.2 Conclusion

The households in the study area were actively involved in crop-livestock integration. This system of production was found to be more rewarding than the crop-based systems because of the additional source of income generated from livestock and the utilization of slack resources between the two production systems. However, a significant increase in farm productivity can be obtained by reorganizing the existing mode of crop-livestock integration in the study area. The integrated crop-livestock production system was found to favour a low resource- base situation. As the pressure on land is removed

without a corresponding increase in capital outlay, optimum benefit would be derived by reducing the herd size or completely eliminating livestock from the production system.

Shortage of land is the major production constraint in the study area. With the prevailing land tenure condition in this area, the intensification of production in conjunction with integrated crop-livestock farming systems represent an important means of enhancing the productivity of the agricultural sector in this state. Efforts should therefore be intensified to ensure a more efficient integration of the crop and livestock sub-sectors.

### 6.3 Policy Implications and Recommendations

The objective and strategy of agricultural planning in Nigeria have been geared to the idea of attaining self-sufficiency in food production to meet up with the growing population. This Study has shown that sustainable agricultural production systems and an overall economic growth can be attained by integrating and using crop-livestock linkages. The strategy of an appropriate package for intensifying this production system is bound to accomplish the desired objective. The main policy recommendations arising from the study are the following:

Though integrated crop-livestock production system is predominant in the study area, the efficiency of integration is still below the potential. The existing resources are not being used to their optimum capacity. Efforts geared at encouraging farmers to reorganize activities and available resources will increase agricultural productivity in this production system. Research and extension interventions will be required in the area of improved

livestock husbandry, adoption of improved crop production practices, efficient crop residue and manure management and use.

Land is the most valuable and limiting asset in the study area. There is a need to concentrate efforts on programmes designed to allocate land rights to individuals in the communities. This will entail both the formulation of appropriate legislation, and the introduction of enhanced land-use management schemes.

The contribution of livestock to total farm income in the integrated system is very low. This can be raised by introducing improved fodder production schemes and intensive fattening of livestock. This will require extension and training programmes in animal husbandry and an efficient livestock marketing channel.

Capital is a constraint in the integrated crop-livestock production system. This has serious implications on the resource base of the farmers and the adoption of improved production techniques. There is therefore the need for supplementary measures to enhance the initial investment in draught animals and implements and the procurement of improved production inputs. Such measures will entail development of low-cost credit, savings schemes and input supply arrangements.

Animal traction is mainly used for ridging and weeding in the study area. More efforts need to be made by government organizations and research institutes towards the development of other appropriate animal-drawn implements for operations such as harvesting, threshing, etc. This will help animal traction to make further impact in agricultural production.

Policy choice should not only be geared towards enhancing a closer and efficient integration of crop and livestock but also on the constraints that will militate against the achievement of optimum benefit from this production system. It is hoped that the results of this study will contribute immensely to understanding the areas of intervention and encourage renewed efforts towards sustainable and increased agricultural production.

## 6.4 Limitations of the Study

The reliance of data collected in a single year is a limitation of this study. The dynamic nature of agricultural production in terms of variations in output due to the vagaries of nature and changing price situation may limits the scope to which results of the study can be applied. The results of this study need to be complemented with the results of similar studies in other areas and in different years. This will enhance a comprehensive picture that permits broad generalization in the pattern and resource productivity of the integrated crop-livestock production system.

The use of the average farm-household in modeling could be misleading as this may not be a true representation of factor endowments and managerial efficiency of the farm-households in the study area.

In spite of these limitation the study has achieved the objective of highlighting the resource use pattern and productivity of integrated crop-livestock production systems in the study area.

## 6.5 Suggestions for further research

Livestock production has long gestation period, there is therefore the need to initiate long term studies to account for the various levels of productivity using multi-period programming techniques.

Further indepth economic investigation is necessary on the impact of improved production technologies in the existing crop-livestock production systems.

There is the need for intensive agronomic studies on the management and contribution of manure to crop yield and the appropriate rate required for optimum yield.

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## Appendix 1 Basic Model Constraints and Real Activities Matrix for Crop Production ( Zone 1)

| | | | | CROP PRODUCTION ACTIVITIES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Row | RESOURCE | UNIT | Constraint | 1 So | 2 Mi | 3 Tom | 4 Gn | 5 Ri | 6 Mi-Cp | 7 So-Gn | 8 Sc-Cp | 9 Mi-Gn | 10 Mwa-Cp | 11 So-Mwa |
| | | | | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha |
| | **Returns** | (Naira) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | **Land** | (ha) | < 8.93 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | **Labour:** | | | | | | | | | | | | | |
| 2 | Jan-April | (*man-hrs*) | < 2100 | 17.1 | 10.2 | 0 | 0 | 0 | 12.7 | 14.3 | 8.3 | 7.9 | 11.3 | 10.7 |
| 3 | May-Aug. | (*man-hrs*) | < 2100 | 246.4 | 259.6 | 197.7 | 273.3 | 277.6 | 320.2 | 360.9 | 381.2 | 319.9 | 295.9 | 199.4 |
| 4 | Sept-Dec. | (*man-hrs*) | < 2100 | 164.2 | 177.8 | 253.2 | 216.3 | 183.1 | 215.4 | 192.6 | 227.9 | 197.8 | 214.8 | 209.5 |
| 5 | **Working capital** | (Naira) | < 37821 | 1038.0 | 807.8 | 918.9 | 1217 | 1108.0 | 1578 | 1270.0 | 1306.895 | 1579.5 | 1436.0 | 1045.6 |
| | **Output allocation:** | | | | | | | | | | | | | |
| 6 | Sorghum | (Kg) | < 0 | -1104.4 | | | | | | -795.3 | -803.4 | | | -705.2 |
| 7 | Millet | (Kg) | < 0 | | -986.0 | | | | -694.5 | | | -689.1 | | |
| 8 | Tomato | (basket) | < 0 | | | -66.8 | | | | | | | | |
| 9 | Groundnut | (Kg) | < 0 | | | | -702.5 | | | -447.1 | | -320.3 | | |
| 10 | Rice | (Kg) | < 0 | | | | | -450.0 | | | | | | |
| 11 | Cowpea | (Kg) | < 0 | | | | | | -385.5 | | -224.0 | | -285.2 | |
| 12 | Manva | (Kg) | < 0 | | | | | | | | | | -659.4 | -603.0 |
| | **Food Consumption:** | | | | | | | | | | | | | |
| 13 | Sorghum | (Kg) | > 1000 | | | | | | | | | | | |
| 14 | Millet | (Kg) | > 1016 | | | | | | | | | | | |
| 15 | Cowpea | (Kg) | > 582 | | | | | | | | | | | |
| 16 | Manva | (Kg) | > 568 | | | | | | | | | | | |

## Appendix 1 (cont.)

| | | | | | HIRING LABOUR | | SELLING ACTIVITY | | | | | | | CONSUMPTION ACT. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 |
| Mi-Gn-Cb | So-Gn-Cb | Mi-So-Cb | Mi-So-Gn | Mi-So-Mwa | May-Aug. | Sept.-Dec. | So | M | Tom | Gnt | Ri | Cb | Mwa | So | Mi | Cb | Mwa |
| 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 man-hr | 1 man-hr | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 12 | 70 | 22 | 37 | 26 | 12 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | |
| 20.1 | 7.4 | 15.2 | 6.2 | 13.5 | | | | | | | | | | | | | |
| 332.9 | 322.7 | 336.4 | 314.1 | 269.4 | -1 | | | | | | | | | | | | |
| 230.1 | 215.6 | 239.0 | 197.0 | 204.0 | | -1 | | | | | | | | | | | |
| 1567.0 | 1488.9 | 1237.9 | 1777.7 | 1477.9 | 20.17 | 18.75 | | | | | | | | | | | |
| | -692.2 | -604.0 | -720.0 | -546.5 | | | 1 | | | | | | | 1 | | | |
| -537.6 | | -498.3 | -480.0 | -437.4 | | | | 1 | | | | | | | 1 | | |
| | | | | | | | | | 1 | | | | | | | | |
| -431.2 | -314.3 | | -125.6 | | | | | | | 1 | | | | | | | |
| | | | | | | | | | | | 1 | | | | | | |
| -92.11 | -109.5 | -113.5 | | | | | | | | | | 1 | | | 1 | | |
| | | | | -350.0 | | | | | | | | | 1 | | | | 1 |
| | | | | | | | | | | | | | | 1 | | | |
| | | | | | | | | | | | | | | | 1 | | |
| | | | | | | | | | | | | | | | | 1 | |
| | | | | | | | | | | | | | | | | | 1 |

## Appendix 2 : Basic Model Constraints and Real Activities Matrix for Crop-Livestock Integration ( Zone 1)

| | | | | LIVESTOCK PRODUCTION | | | CROP PRODUCTION ACTIVITIES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| Row | RESOURCE | UNIT | Constraint | Cattle | Sheep | Goat | Sc | M | Tom | Gn | R | Mi-Cp | So-Gn | SO-Cp | Mi-Gn | Mwa-Cp |
| | | | | 1 head | 1 head | 1 head | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha |
| | RETURNS | (Naira | 0 | 7513.6 | 568.7 | 545.6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | Land | (ha. | < 9.93 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | Livestock: | | | | | | | | | | | | | | | |
| 2 | Cattle | ( Head. | < 3 | 1 | | | | | | | | | | | | |
| 3 | Sheep | ( Head | < 7 | | 1 | | | | | | | | | | | |
| 4 | Goat | ( Head | < 13 | | | 1 | | | | | | | | | | |
| | Human labour: | | | | | | | | | | | | | | | |
| 5 | Jan-April | (man-hrs. | < 2100 | 135 | 14 | 14 | 17.1 | 13.2 | 0 | 0 | 0 | 12.7 | 14.3 | 5.3 | 7.9 | 11.3 |
| 6 | May-Aug | (man-hrs | < 2100 | 42 | 4.2 | 4.2 | 246.4 | 259.6 | 197.7 | 278.3 | 277.8 | 320.2 | 350.9 | 361.2 | 319.9 | 295.9 |
| 7 | Sept-Dec | (man-hrs | < 2100 | 90 | 9 | 9 | 164.2 | 177.8 | 353.0 | 215.3 | 183.1 | 215.4 | 192.6 | 227.9 | 197.8 | 214.8 |
| 8 | Draught ani. labor | (man-hrs | > 0 | 0 | 0 | 0 | 147.0 | 139.0 | 0.0 | 152.0 | 84.0 | 127.0 | 130.0 | 145.0 | 125.0 | 141.0 |
| 9 | Farmyard manure | (Kg. | < 3040 | 0 | 0 | 0 | 1281.2 | 974.2 | 1444.9 | 0.0 | 0.0 | 842.6 | 1059.9 | 1154.5 | 1562.5 | 350.0 |
| 10 | Crop residue | (Kg. | < 16738 | 1140.6 | 114.1 | 114.1 | | | | | | | | | | |
| 11 | Working capital | (Naira | < 47102 | 1878.3 | 245.2 | 218.9 | 387.4 | 320.7 | 189.4 | 1217.0 | 1106.0 | 1105.7 | 745.0 | 714.7 | 795.0 | 1251.0 |
| | Output allocation: | | | | | | | | | | | | | | | |
| 12 | Sorghum | (Kg | < 0 | | | | -1104.4 | | | | | | -795.3 | -803.4 | | |
| 13 | Millet | (Kg | < 0 | | | | | -986 | | | | -694.5 | | | -669.1 | |
| 14 | Tomato | (basket. | < 0 | | | | | | -65.6 | | | | | | | |
| 15 | Groundnut | (Kg | < 0 | | | | | | | -702.5 | | | -447.1 | | -320.3 | |
| 16 | Rice | (Kg | < 0 | | | | | | | | -450.0 | | | | | |
| 17 | Cowpea | (Kg | < 0 | | | | | | | | | -385.5 | | -224.0 | | -285.2 |
| 18 | Malwa | (Kg | < 0 | | | | | | | | | | | | | -656.4 |
| | Food Consumption: | | | | | | | | | | | | | | | |
| 19 | Sorghum | (Kg | > 1000 | | | | | | | | | | | | | |
| 20 | Millet | (Kg | > 1016 | | | | | | | | | | | | | |
| 21 | Cowpea | (Kg | > 582 | | | | | | | | | | | | | |
| 22 | Malwa | (Kg | > 568 | | | | | | | | | | | | | |

Appendix 2 (cont.)

| | | | | | | LABOUR HIRING | | buying | SELLING ACTIVITY | | | | | | | CONSUMPTION | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 |
| So-Mwa | Mi-Gn-Cp | So-Gn-Cp | Mi-So-Cp | Mi-So-Gn | Mi-So-Mw | May-Aug | Sept.-Dec. | FYM | So | Mi | Tom | Gnt | Ri | Cp | Mwa | So | Mi | Cp | Mwa |
| 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 man-hr | 1 man-hr | 1 Kg | 1 Kg | 1 Kg | 1 Kg | 1 Kg | 1 Kg | 1 Kg | 1 Kg | 1 Kg | 1 Kg | 1 Kg | 1 Kg |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 12 | 70 | 22 | 37 | 28 | 12 | 0 | 0 | 0 | 0 |
| - | - | - | - | - | 1 | | | | | | | | | | | | | | |
| 10.7 | 20.1 | 7.4 | 15.0 | 6.0 | 13.5 | | | | | | | | | | | | | | |
| 199.4 | 330.9 | 322.7 | 336.4 | 314.1 | 269.4 | | | | | | | | | | | | | | |
| 209.5 | 230.1 | 215.6 | 239.0 | 197.0 | 204.0 | | | | | | | | | | | | | | |
| 124.0 | 133.0 | 149.0 | 130.0 | 145.0 | 132.0 | | | | | | | | | | | | | | |
| 887.5 | 937.5 | 1305.6 | 2205.9 | 1575.0 | 1500.0 | | | | | | | | | | | | | | |
| 601.9 | 1096.3 | 832.1 | 734.6 | 840.0 | 727.9 | 20.17 | 15.75 | 0.5 | | | | | | | | | | | |
| -705.0 | | -660.0 | -604.0 | -700.0 | -548.5 | | | | | | | | | | | | | | |
| | -537.6 | | -496.3 | -490.0 | -457.4 | | | | | | | | | | | | | | |
| | -431.0 | -314.0 | | -125.6 | | | | | | | | | | | | | | | |
| | -82.11 | -109.5 | -113.5 | | | | | | | | | | | | | | | | |
| -803.0 | | | | | -350.0 | | | | | | | | | | 1 | | | | 1 |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | 1 |

Appendix 3 : Basic Model Constraints and Real Activities Matrix for Crop Production ( Zone 2)

| | | | | CROP PRODUCTION ACTIVITIES | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Row | RESOURCE | UNIT | Constraint | Maize | Sorghum | Cotton | Cowpea | Rice | Groundnut | Maiwa | Ma-So | Co-Cp | So-Cp |
| | | | | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha |
| | *Returns* | (Naira) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | **Land** | (ha) | < 9.85 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | **Labour:** | | | | | | | | | | | | |
| 2 | Jan-April | (man-hrs) | < 2520 | 10.2 | 22.6 | 0 | 0 | 0 | 0 | 11.0 | 28.1 | 0 | 11.4 |
| 3 | May-Aug | (man-hrs) | < 2520 | 307.8 | 287.8 | 302.7 | 328.7 | 311.6 | 349.5 | 303.2 | 341.7 | 353.8 | 319.2 |
| 4 | Sept-Dec | (man-hrs) | < 2520 | 215.9 | 183.9 | 224.6 | 274.5 | 239.1 | 278.0 | 199.7 | 215.5 | 302.0 | 248.7 |
| 5 | **Working capital** | (Naira) | < 62101 | 3543.2 | 3039.6 | 2117.1 | 3420.3 | 4532.7 | 2245.8 | 2767.5 | 2749.7 | 1164.2 | 1728.6 |
| | **Output allocation:** | | | | | | | | | | | | |
| 6 | Maize | (Kg) | < 0 | -2505.7 | | | | | | | -1596.3 | | |
| 7 | Sorghum | (Kg) | < 0 | | -1430.9 | | | | | | -1009.0 | | -866.4 |
| 8 | Cotton | (basket) | < 0 | | | -859.6 | | | | | | -685.9 | |
| 9 | Cowpea | (Kg) | < 0 | | | | -648.3 | | | | | -292.1 | -383.9 |
| 10 | Rice | (Kg) | < 0 | | | | | -575.5 | | | | | |
| 11 | Groundnut | (Kg) | < 0 | | | | | | -681.6 | | | | |
| 12 | Maiwa | (Kg) | < 0 | | | | | | | -925.0 | | | |
| 13 | Soybean | (Kg) | < 0 | | | | | | | | | | |
| | **Food Consumption:** | | | | | | | | | | | | |
| 14 | Maize | (Kg) | > 850 | | | | | | | | | | |
| 15 | Sorghum | (Kg) | > 1212 | | | | | | | | | | |
| 16 | Cowpea | (Kg) | > 564 | | | | | | | | | | |
| 17 | Maiwa | (Kg) | > 376 | | | | | | | | | | |

Appendix 3 (cont.)

| 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | SELLING ACTIVITY | | | | | | | | CONSUMPTION ACTIVITY | | | |
| SO-Gnt | So-Soy | Ma-Rice | May-Aug. | Sept.-Dec. | Maize | Sorghum | Cotton | Cowpea | Rice | Groundnut | Maiwa | Soybean | Maize | Sorghum | Cowpea | Maiwa |
| 1 ha | 1 ha | 1 ha | 1 man-hr | 1 man-hr | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg |
| 0 | 0 | 0 | 0 | 0 | 10 | 9 | 25 | 26 | 37 | 22 | 12 | 22 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | | | | | | | | | | | | | | |
| 15.5 | 22.2 | 19.5 | | | | | | | | | | | | | | |
| 387.6 | 314.9 | 381.1 | -1 | | | | | | | | | | | | | |
| 239.5 | 217.3 | 233.2 | | -1 | | | | | | | | | | | | |
| 1757.8 | 1054.8 | 2912.6 | 29.06 | 25.50 | | | | | | | | | | | | |
| | | -1216.3 | | | 1 | | | | | | | | 1 | | | |
| -1150.0 | -874.5 | | | | | 1 | | | | | | | | 1 | | |
| | | | | | | | 1 | | | | | | | | | |
| | | | | | | | | 1 | | | | | | | 1 | |
| | | -285.1 | | | | | | | 1 | | | | | | | |
| -622.5 | | | | | | | | | | 1 | | | | | | |
| | | | | | | | | | | | 1 | | | | | 1 |
| | -515.8 | | | | | | | | | | | 1 | | | | |
| | | | | | | | | | | | | | 1 | | | |
| | | | | | | | | | | | | | | 1 | | |
| | | | | | | | | | | | | | | | 1 | |
| | | | | | | | | | | | | | | | | 1 |

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Appendix 4 : Basic Model Constraints and Real Activities Matrix for Crop-Livestock Integration ( Zone 2)

| | | | | LIVESTOCK PRODUCTION | | | CROP PRODUCTION ACTIVITIES | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
| Row | RESOURCE | UNIT | Constraint | Cattle | Sheep | Goat | Ma | So | Co | Cp | Ri | Gn | Mwa | Ma-So |
| | | | | 1 head | 1 head | 1 head | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha |
| | **RETURNS** | (Naira) | 0 | 4534 | 433.79 | 358.64 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | **Land** | (ha) | < 9.85 | | | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | **Livestock:** | | | | | | | | | | | | | |
| 2 | Cattle | ( Head ) | < 5 | 1 | | | | | | | | | | |
| 3 | Sheep | ( Head ) | < 9 | | 1 | | | | | | | | | |
| 4 | Goat | ( Head ) | < 12 | | | 1 | | | | | | | | |
| | Human labour: | | | | | | | | | | | | | |
| 5 | Jan-April | (man-hrs) | < 2520 | 138 | 14 | 14 | 13.2 | 22.6 | 0 | 0 | 0 | 0 | 11.0 | 28.1 |
| 6 | May-Aug | (man-hrs) | < 2520 | 42 | 4.2 | 4.2 | 307.8 | 287.8 | 302.7 | 328.7 | 311.6 | 349.5 | 303.2 | 341.7 |
| 7 | Sept-Dec. | (man-hrs) | < 2520 | 90 | 9 | 9 | 215.9 | 183.9 | 224.6 | 274.6 | 239.1 | 278.0 | 199.7 | 215.5 |
| 8 | **Draught ani. labor** | (man-hrs) | > 0 | 0 | 0 | 0 | 121.6 | 93.3 | 102.2 | 108.9 | 0.0 | 120.3 | 107.2 | 110.4 |
| 9 | **Farmyard manure** | (Kg) | < 4317 | 0 | 0 | 0 | 1002.5 | 861.8 | 633.0 | 0.0 | 1206.9 | 1041.7 | 1125.0 | 1135.2 |
| 10 | **Crop residue** | (Kg) | < 29388 | 1140.6 | 114.1 | 114.1 | | | | | | | | |
| 11 | **Working capital** | (Naira) | < 73633 | 1953 | 154.52 | 136.97 | 3042.0 | 2608.7 | 1798.1 | 3420.3 | 3922.3 | 1725.0 | 2225.0 | 2682.1 |
| | **Output allocation:** | | | | | | | | | | | | | |
| 12 | Maize | (Kg) | < 0 | | | | -2505.7 | | | | | | | -1596.3 |
| 13 | Sorghum | (Kg) | < 0 | | | | | -1430.9 | | | | | | -1009.0 |
| 14 | Cotton | (basket) | < 0 | | | | | | -859.6 | | | | | |
| 15 | Cowpea | (Kg) | < 0 | | | | | | | -648.3 | | | | |
| 16 | Rice | (Kg) | < 0 | | | | | | | | -575.5 | | | |
| 17 | Groundnut | (Kg) | < 0 | | | | | | | | | -681.6 | | |
| 18 | Maiwa | (Kg) | < 0 | | | | | | | | | | -925.0 | |
| 19 | Soybean | (Kg) | < 0 | | | | | | | | | | | |
| | **Food Consumption:** | | | | | | | | | | | | | |
| 20 | Maize | (Kg) | > 850 | | | | | | | | | | | |
| 21 | Sorghum | (Kg) | > 1212 | | | | | | | | | | | |
| 22 | Cowpea | (Kg) | > 564 | | | | | | | | | | | |
| 23 | Maiwa | (Kg) | > 376 | | | | | | | | | | | |

## Appendix 4 (cont.)

| | | | | | Labour Hiring | | buying | SELLING ACTIVITY | | | | | | | | CONSUMPTION | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 |
| Co-Cp | So-Cp | SO-Gnt | So-Soy | Ma-Rice | May-Aug. | Sept.-Dec. | FYM | Ma | So | Co | Cp | Ri | Gn | Mwa | Soy | Ma | So | Cp | Mwa |
| 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 man-hr | 1 man-hr | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 9 | 25 | 26 | 37 | 22 | 12 | 22 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | |
| 0 | 11.4 | 15.5 | 22.2 | 19.5 | | | | | | | | | | | | | | | |
| 353.8 | 319.2 | 337.6 | 314.9 | 361.1 | -1 | | | | | | | | | | | | | | |
| 302.0 | 248.7 | 239.5 | 217.3 | 233.2 | | -1 | | | | | | | | | | | | | |
| 111.8 | 87.3 | 126.9 | 92.1 | 118.1 | | | | | | | | | | | | | | | |
| 0.0 | 1785.8 | 1187.5 | 111.6 | 1083.4 | | | -1 | | | | | | | | | | | | |
| 1164.2 | 835.7 | 1164.0 | 999.0 | 2371.0 | 29.06 | 25.50 | 0.5 | | | | | | | | | | | | |
| | | | | -1216.3 | | | | 1 | | | | | | | | 1 | | | |
| | -866.4 | -1150.0 | -874.5 | | | | | | 1 | | | | | | | | 1 | | |
| -685.9 | | | | | | | | | | 1 | | | | | | | | | |
| -292.1 | -383.9 | | | | | | | | | | 1 | | | | | | | 1 | |
| | | | | -285.1 | | | | | | | | 1 | | | | | | | |
| [illegible] | | -622.5 | | | | | | | | | | | 1 | | | | | | |
| | | | | | | | | | | | | | | 1 | | | | | 1 |
| | | | -518.8 | | | | | | | | | | | | 1 | | | | |
| | | | | | | | | | | | | | | | | 1 | | | |
| | | | | | | | | | | | | | | | | | 1 | | |
| | | | | | | | | | | | | | | | | | | 1 | |
| | | | | | | | | | | | | | | | | | | | 1 |

## Appendix 5: Basic Model Constraints and Real Activities Matrix for Crop Production ( Zone 3)

| Row | Resource | Unit | Constraint | CROP PRODUCTION ACTIVITIES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| | | | | So | Co | Mi | Mwa | Ri | Gn | Mi-Co | So-Co | So-Gn | Mi-Cp | So-Cp | Ma-Co |
| | | | | I ha | I ha | I ha | I ha | I ha | I ha | I ha | I ha | I ha | I ha | I ha | I ha |
| | **Returns** | (Naira) | < 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | **Land** | (ha) | < 9.11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | **Labour:** | | | | | | | | | | | | | | |
| 2 | Jan-April | (man-hrs) | < 2520 | 16.0 | 0.00 | 25.7 | 22.6 | 0 | 0 | 0 | 19.6 | 24.7 | 11.4 | 15.8 | 22.2 |
| 3 | May-Aug. | (man-hrs) | < 2520 | 294.5 | 301.2 | 312.6 | 234.9 | 351.1 | 312.4 | 425.6 | 370.8 | 346.8 | 376.7 | 322.5 | 375.2 |
| 4 | Sept-Dec. | (man-hrs) | < 2520 | 202.1 | 315.8 | 181.6 | 228.0 | 266.8 | 350.5 | 349.1 | 222.3 | 251.1 | 271.1 | 309.0 | 322.9 |
| 5 | **Working capital** | (Naira) | < 44648 | 1338.5 | 1720.0 | 2125.3 | 1862.5 | 1180.0 | 1050.1 | 1865.2 | 2370.3 | 1801.0 | 841.6 | 1969.3 | 1219.2 |
| | **Output allocation:** | | | | | | | | | | | | | | |
| 6 | Sorghum | (Kg) | < 0 | -1050.0 | | | | | | | -617.5 | -803.5 | | -789.4 | |
| 7 | Cotton | (Kg) | < 0 | | -876.7 | | | | | -589.5 | -543.3 | | | | -610.6 |
| 8 | Millet | (Kg) | < 0 | | | -956.5 | | | | -483.0 | | | -729.4 | | |
| 9 | Maiwa | (Kg) | < 0 | | | | -912.3 | | | | | | | | |
| 10 | Rice | (Kg) | < 0 | | | | | -590.3 | | | | | | | |
| 11 | Groundnut | (Kg) | < 0 | | | | | | -719.7 | | | -452.8 | | | |
| 12 | Maize | (Kg) | < 0 | | | | | | | | | | | | -1019.28 |
| 13 | Cowpea | (Kg) | < 0 | | | | | | | | | | -173.8 | -322.7 | |
| | **Food Consumption:** | | | | | | | | | | | | | | |
| 14 | Millet | (Kg) | > 1320 | | | | | | | | | | | | |
| 15 | Sorghum | (Kg) | > 886 | | | | | | | | | | | | |
| 16 | Cowpea | (Kg) | > 625 | | | | | | | | | | | | |
| 17 | Maiwa | (Kg) | > 582 | | | | | | | | | | | | |

## Appendix 5 (cont.)

| | | | | | | | | LABOUR HIRING | | SELLING ACTIVITY | | | | | | | | CONSUMPTION ACT. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 |
| Co-Cp | Mi-Ma | Mi-Gn | Mi-So | Mi-Co-Cp | So-Co-Cp | So-Gn-Cp | Mi-Ma-Cp | May-Aug. | Sept.-Dec. | So | Co | Mi | Mwa | Ri | Gn | Ma | Cp | Mi | So | Cp | Mwa |
| l ha | l ha | l ha | l ha | l ha | l ha | l ha | l ha | 1 man-hr | 1 man-hr | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 25 | 12 | 12 | 37 | 22 | 10 | 26 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | |
| 19.5 | 8.6 | 14.8 | 25.7 | 0 | 28.3 | 16.0 | 12.6 | | | | | | | | | | | | | | |
| 421.1 | 293.8 | 406.7 | 303.6 | 413.6 | 381.4 | 417.6 | 337.0 | -1 | | | | | | | | | | | | | |
| 315.6 | 196.6 | 311.7 | 257.1 | 331.5 | 319.0 | 285.9 | 262.9 | | -1 | | | | | | | | | | | | |
| 1615.6 | 1067.0 | 1242.5 | 1478.4 | 2043.2 | 2681.4 | 1824.5 | 1382.2 | 19.89 | 17.65 | | | | | | | | | | | | |
| | | | -725.5 | | -525.5 | -711.9 | | | | 1 | | | | | | | | | 1 | | |
| -543.9 | | | | -392.0 | -383.0 | | | | | | 1 | | | | | | | | | | |
| | -562.1 | -983.2 | -552.8 | -481.3 | | | -425.1 | | | | | 1 | | | | | | 1 | | | |
| | | | | | | | | | | | | | 1 | | | | | | | | 1 |
| | | | | | | | | | | | | | | 1 | | | | | | | |
| | | -371.1 | | | | -398.0 | | | | | | | | | 1 | | | | | | |
| | -825.6 | | | | | | -507.1 | | | | | | | | | 1 | | | | | |
| -263.3 | | | | -94.0 | -132.3 | -105.9 | -217.4 | | | | | | | | | | 1 | | 1 | | |
| | | | | | | | | | | | | | | | | | | 1 | | | |
| | | | | | | | | | | | | | | | | | | | 1 | | |
| | | | | | | | | | | | | | | | | | | | | 1 | |
| | | | | | | | | | | | | | | | | | | | | | 1 |

Appendix 6: Basic Model Constraints and Real Activities Matrix for Crop-Livestock Integration ( Zone 3)

| | | | | | LIVESTOCK PROD. | | | CROP PRODUCTION ACTIVITIES | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| Row | Resource | Unit | | Constraint | Cattle | Sheep | Goat | So | Co | Mi | Mwa | Ri | Gn | Mi-Co | So-Co | So-Gn | Mi-Cp | So-Cp | Ma-Co |
| | | | | | 1 head | 1 head | 1 head | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha |
| | **Returns** | (Naira) | | 0 | 5606 | 462 | 428 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | **Land** | (ha) | < | 9.11 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| | **Livestock:** | | | | | | | | | | | | | | | | | | |
| 2 | Cattle | ( Head ) | < | 4 | 1 | | | | | | | | | | | | | | |
| 3 | Sheep | ( Head ) | < | 6 | | 1 | | | | | | | | | | | | | |
| 4 | Goat | ( Head ) | < | 12 | | | 1 | | | | | | | | | | | | |
| | *Human labour:* | | | | | | | | | | | | | | | | | | |
| 5 | Jan-April | (man-hrs) | < | 2520 | 138 | 14 | 14 | 16.0 | 0.00 | 26.7 | 22.6 | 0 | 0 | 0 | 19.6 | 24.7 | 11.4 | 15.8 | 22.2 |
| 6 | May-Aug. | (man-hrs) | < | 2520 | 42 | 4.2 | 4.2 | 294.5 | 301.2 | 312.6 | 234.9 | 351.1 | 312.4 | 425.6 | 370.8 | 346.6 | 376.7 | 322.5 | 375.2 |
| 7 | Sept-Dec. | (man-hrs) | < | 2520 | 90 | 9 | 9 | 202.1 | 315.8 | 181.6 | 228.0 | 266.8 | 350.5 | 349.1 | 222.3 | 251.1 | 271.1 | 309.0 | 322.9 |
| 8 | *Draught ani. labor* | (man-hrs) | > | 0 | 0 | 0 | 0 | 128.8 | 121.0 | 109.7 | 112.4 | 131.8 | 125.6 | 107.2 | 119.2 | 129.6 | 87.3 | 123.7 | 117.5 |
| 9 | *Farmyard manure* | (Kg) | < | 3648 | 0 | 0 | 0 | 1127.3 | 1563 | 2221.16 | 2125.2 | 850 | 0 | 1759.7 | 1386.4 | 726.4 | 318.5 | 1074.2 | 1138.0 |
| 10 | **Crop residue** | (Kg) | < | 13621 | 1140.6 | 114.1 | 114.1 | | | | | | | | | | | | |
| 11 | **Working capital** | (Naira) | < | 54043 | 2067.0 | 170.2 | 136.2 | 774.9 | 950.8 | 1214.7 | 306.3 | 880.0 | 750.5 | 835.3 | 1277.3 | 638.9 | 532.3 | 918.7 | 745.9 |
| | **Output allocation:** | | | | | | | | | | | | | | | | | | |
| 12 | Sorghum | (Kg) | < | 0 | | | | -1050.0 | | | | | | | -617.5 | -803.5 | | -789.4 | |
| 13 | Cotton | (Kg) | < | 0 | | | | | -876.7 | | | | | -589.5 | -543.3 | | | | -610.6 |
| 14 | Millet | (Kg) | < | 0 | | | | | | -956.5 | | | | -483.0 | | | -729.4 | | |
| 15 | Maiwa | (Kg) | < | 0 | | | | | | | -912.3 | | | | | | | | |
| 16 | Rice | (Kg) | < | 0 | | | | | | | | -590.3 | | | | | | | |
| 17 | Groundnut | (Kg) | < | 0 | | | | | | | | | -719.7 | | | -452.6 | | | |
| 18 | Maize | (Kg) | < | 0 | | | | | | | | | | | | | | | -1019 |
| 19 | Cowpea | (Kg) | < | 0 | | | | | | | | | | | | | -173.8 | -322.7 | |
| | **Food Consumption:** | | | | | | | | | | | | | | | | | | |
| 20 | Millet | (Kg) | > | 1320 | | | | | | | | | | | | | | | |
| 21 | Sorghum | (Kg) | > | 886 | | | | | | | | | | | | | | | |
| 22 | Cowpea | (Kg) | > | 625 | | | | | | | | | | | | | | | |
| 23 | Maiwa | (Kg) | > | 582 | | | | | | | | | | | | | | | |

## Appendix 6 (cont.)

| | | | | | | | | LABOUR HIRING | | buying | SELLING ACTIVITY | | | | | | | | CONSUMPTION ACT. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 |
| Co-Cp | Mi-Ma | Mi-Gn | Mi-So | Mi-Co-Cp | So-Co-Cp | So-Gn-Cp | Mi-Ma-Cp | May-Aug. | Sept.-Dec. | FYM | So | Co | Mi | Mwa | Ri | Gn | Ma | Cp | Mi | So | Cp | Mwa |
| 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1 ha | 1man-hr | 1man-hr | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg | 1 kg |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 9 | 25 | 12 | 12 | 37 | 22 | 10 | 26 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | | | | | | | | | | | | | | |
| 19.5 | 8.6 | 14.8 | 25.7 | 0 | 28.3 | 18.0 | 12.6 | | | | | | | | | | | | | | | |
| 421.1 | 793.8 | 408.7 | 303.6 | 413.6 | 381.4 | 417.6 | 337.0 | -1 | | | | | | | | | | | | | | |
| 315.6 | 196.6 | 311.7 | 257.1 | 331.5 | 319.0 | 285.9 | 262.9 | | -1 | | | | | | | | | | | | | |
| 118.1 | 143.2 | 120.5 | 129.0 | 187.2 | 117.6 | 105.4 | 123.3 | | | | | | | | | | | | | | | |
| 0.0 | 1400.0 | 1024.0 | 1542.0 | 598.4 | 1850.6 | 1750.3 | 1485.6 | | | -1 | | | | | | | | | | | | |
| 1146.9 | 367.0 | 612.5 | 507.4 | 1178.3 | 730.6 | 949.4 | 569.3 | 19.89 | 17.65 | 0.50 | | | | | | | | | | | | |
| | | | -725.5 | | -525.5 | -711.9 | | | | | 1 | | | | | | | | | 1 | | |
| -543.9 | | | | -392.0 | -383.0 | | | | | | | 1 | | | | | | | 1 | | | |
| | -562.1 | -983.3 | -552.8 | -481.3 | | | -425.1 | | | | | | 1 | | | | | | | | | |
| | | | | | | | | | | | | | | 1 | | | | | | | | |
| | | | | | | | | | | | | | | | 1 | | | | | | | |
| | | -371.1 | | | | -398.0 | | | | | | | | | | 1 | | | | | | |
| | -825.8 | | | | | | -507.1 | | | | | | | | | | | | | 1 | | |
| -253.3 | | | | -94.0 | -132.3 | -105.9 | -217.4 | | | | | | | | | | | | 1 | | | |
| | | | | | | | | | | | | | | | | | | | | 1 | | |
| | | | | | | | | | | | | | | | | | | | | | 1 | |
| | | | | | | | | | | | | | | | | | | | | | | 1 |