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ECONOMIC ANALYSIS OF RESOURCE ALLOCATION IN TRADITIONAL AGRICULTURE: CASE OF THE BOROMO FARM IN BURKINA FASO

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Adama Bonkian

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Gerald D. Schwab
Major professor

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ECONOMIC ANALYSIS OF RESOURCE ALLOCATION IN TRADITIONAL AGRICULTURE: CASE OF THE BOROMO FARM IN BURKINA FASO

By

Adama Bonkian

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ABSTRACT

ECONOMIC ANALYSIS OF RESOURCE ALLOCATION IN TRADITIONAL AGRICULTURE: CASE OF THE BOROMO FARM IN BURKINA FASO

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The scarcity of resources faced by traditional farmers is a constraint to the development of improved technologies. After describing the Boromo region farming system in the western central Burkina Faso, this thesis develops a linear programming model to analyze the competition between a cash crop (cotton) and food crops (red and white sorghum; maize; cowpeas) in terms of resource allocation. Two farming technologies - animal traction and hand tools - and two cropping patterns - sole cropping and mixed cropping - are evaluated. The results suggest that (1) farmers tend to allocate more fertilizer to the cash crop than to the food crops; (2) in the prevailing conditions, hand tool technology and mixed cropping tend to be economically superior to animal traction technology and sole cropping. Policy to increase producer price and crop yields would enhance profitability of animal traction and encourage farmers to practice sole cropping.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

> Generation of farm income through efficient agricultural production provides the real productivity base from which all other objectives can be discussed. Without efficient income generation the entire rural sector will be acting as a drug on both macroeconomic performance and the ability of policy makers to deal with hunger and malnutrition. (Timmer, 1983)

Agriculture is the most important sector of Burkina Faso's economy. It employs 80-90% of the 7 million population, comprises one third of the gross domestic product (G.D.P.) and supplies almost all of the export. In the past two decades Burkina Faso has experienced slow agricultural growth. The principal objective of the government today is to regain food self-sufficiency and expand national income from agriculture.[1]

Economic growth in the country is necessarily linked to the progress of the agricultural sector. This study investigates the economic relationships which characterize peasant agriculture in the Boromo region, in the western central part of Burkina Faso. Knowledge of these relationships should assist in identifying opportunities to increase production.

The first section of this chapter raises some issues about the agricultural sector and leads to three important questions related to input allocation, the competition between mixed and sole cropping system and farming technology.

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[1] The most recent to date on Burkina Faso government objectives in terms of food policy is presented by Steve Haggblade in a report prepared for U.S.A.I.D./Upper Volta on July 16, 1984. "An Overview of food Security in Upper Volta." Burkina Faso was formerly Upper Volta. All of the literature in the text referred to the country under its old name.

1. The Problem

The two major objectives set by the government for the agricultural sector are to replace food imports with increased cereals production and to diversify into export crops. Achieving food self-sufficiency in the context of the traditional agriculture of Burkina Faso depends very much on the performance of the smallholders. The efforts to increase food availability have focussed on production.

The issue about production is whether to increase food production directly or to increase output of non-food items which can then be traded for food. The government has opted for the direct production of food rather than non-food items. The government has used credit, input subsidies, extension support and research infrastructure as policy tools to promote particular commodities. For example, the fertilizer subsidies policy shows that over half of the fertilizer is used in cotton production while the remainder is divided among all the other crops. Thus, roughly half of the fertilizer subsidy of 1.4 billion CFA francs in 1982 went to cotton producers. [2]

Animal traction is the major technological innovation proposed by the government. It has been used thoughout the country but is more concentrated in the cotton production areas such as the Boromo region in western central Burkina Faso. Higher yield, an increase in land area under production, and removal of labor bottlenecks are generally believed to be among the advantages of using animal traction. The costs and returns of animal traction are difficult to determine because of ambiguous costs like labor for herding, feed supplements, damage to crops and highly variable rates of utilization. The main issue in the use

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[2] The exchange rate between the U.S. dollar and the CFA franc is about \$1 = 475 CFA francs in 1985.

of animal traction is whether the value of initial increases in agricultural production pay for the additional costs of animal traction. The argument against this short term benefit cost viewpoint is that adoption of the technique may be necessary before other measures to raise productivity and conserve land are likely to be profitable for farmers, such as improved varieties.

In the context of traditional farming in Burkina Faso, resource allocation between cotton and food crops under hand tool and animal traction technologies is still an unresolved policy issue. This question is even more important in the Boromo region where cotton production is integrated in almost all farm plans. Whether cotton production should be intensified through higher fertilizer application and animal traction cultivation hinges not only upon the projected benefits, but also upon the possible opportunity cost in terms of foregone food grain production.

2. Objectives and Organization

Today, the development of cotton as a cash crop in Burkina Faso is controversial among both farmers and decision makers because of the nationwide food shortage and the government's objective to achieve food self-sufficiency from domestic food production. Cotton growing diverts significant resources from traditional food crops, and directly reduces the domestic food supply. This study examines the reluctance of farmers in central western Burkina Faso to stop growing cotton despite the increase in food availability that could be achieved from increased food crop production. The objectives of the study are to:

1. test whether a mixed cropping system (cotton and cereals included) can effectively compete with a sole cropping system within the existing farm organization, resource base and skill of farmers.

2. evaluate the competitive position of sole cropping and mixed cropping system cultivated under hand tool and animal traction technologies.

3. examine the competition for land, labor, and purchased input in cotton versus cereals production.

To test these interrelated questions the study will be organized in seven chapters. Chapter II explores the farming system in the Boromo region and the allocation of resources between cotton and cereals. Chapter III describes the data collection methodology and the field activities. It also explains the approach used to study the problem of resource allocation at the farm level in Boromo and the limitation of the data collected during the survey. Chapter IV reviews the literature on farming system in Burkina Faso and elsewhere in Africa. Chapter V shows how the farm model in the Boromo region was constructed. Chapter VI gives the results of the maximization procedure used in running the model. A sensitivity analysis is performed in this chapter, showing the effect of change in fertilizer price, crop yield, and capital availability under different assumptions. The final chapter presents conclusions, makes policy recommendations and identifies the limitations of the analysis.

CHAPTER II

OVERVIEW OF THE FARMING SYSTEM

This chapter deals with the characteristics of the farming system in the Boromo region of Burkina Faso.

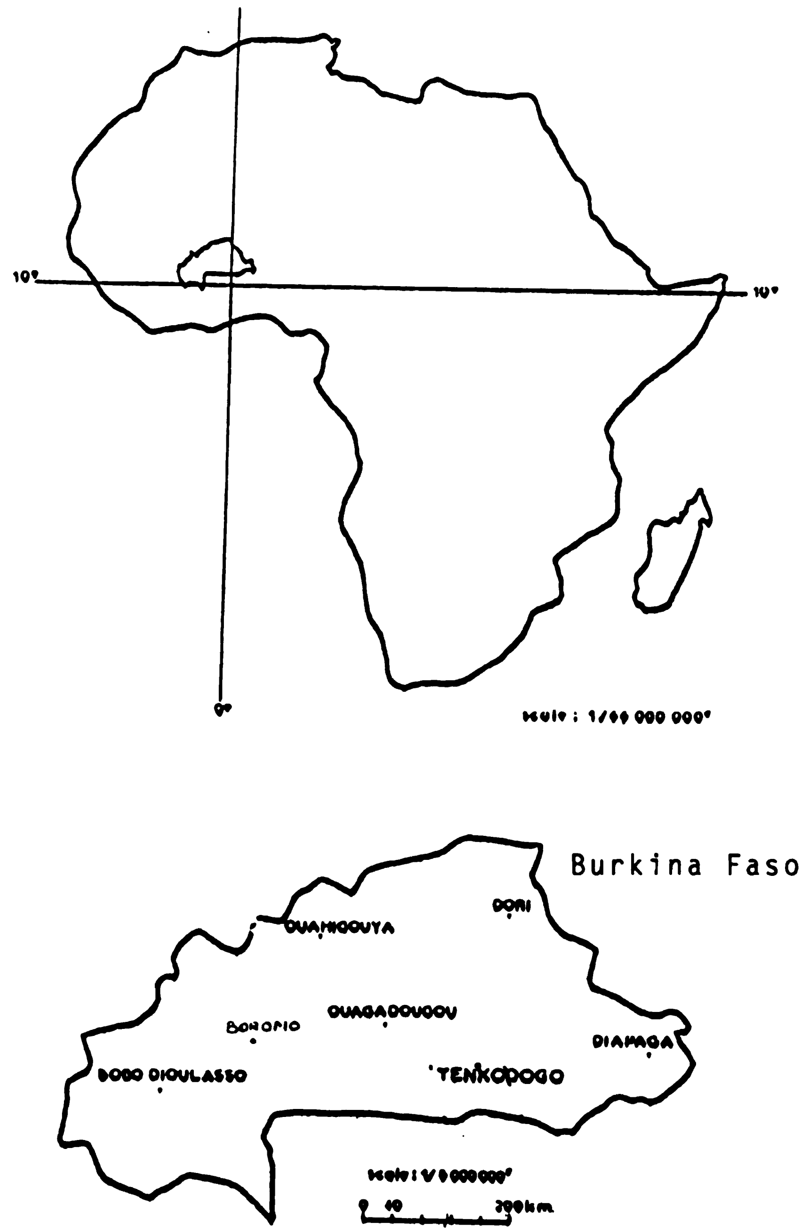
The first section examines the climate, infrastructure and cropping pattern. Next the allocation of land, labor and capital between cotton and cereals is discussed. The last section provides an introduction to the marketing system in Burkina Faso with particular emphasis on the aspects which might have an effect on the Boromo region farmers' decision making process. The institutional framework of the marketing system is comprised of the Societe Voltaique des fibres Textiles (SOFITEX) which is the marketing agency for cotton, the Office National des Cereales (OFNACER) which is the cereals marketing board, and the licenced private traders. Also,the Organismes Regionaux de Development (ORDs) intervene in the marketing system by collecting cereals for the OFNACER.

1. The Farming System

1.1 The Climate and Infractructure

The study site chosen is in the Subprefecture of Boromo, an area of about 4,000 square kilometers in the central western part of the country (see figures 2.1 and 2.2). It is a Guinea savana or south Soudanian zone, with a long term average annual rainfall of 980 mm distributed unequally from May to October.

Compared to other regions in the country, Boromo has relatively good agricultural potential with high rainfall and a low effective population density of 30 inhabitants per square km (see figures 2.3 and 2.4). Cotton is the most important cash crop. The major food crops are white and red sorghum, maize and to a lesser extent millet. There is no major irrigation infrastructure such as dams,



Source: Adopted from C.L. Delgado
(1979) p.19

Figure 2.1 Location of Boromo in Africa

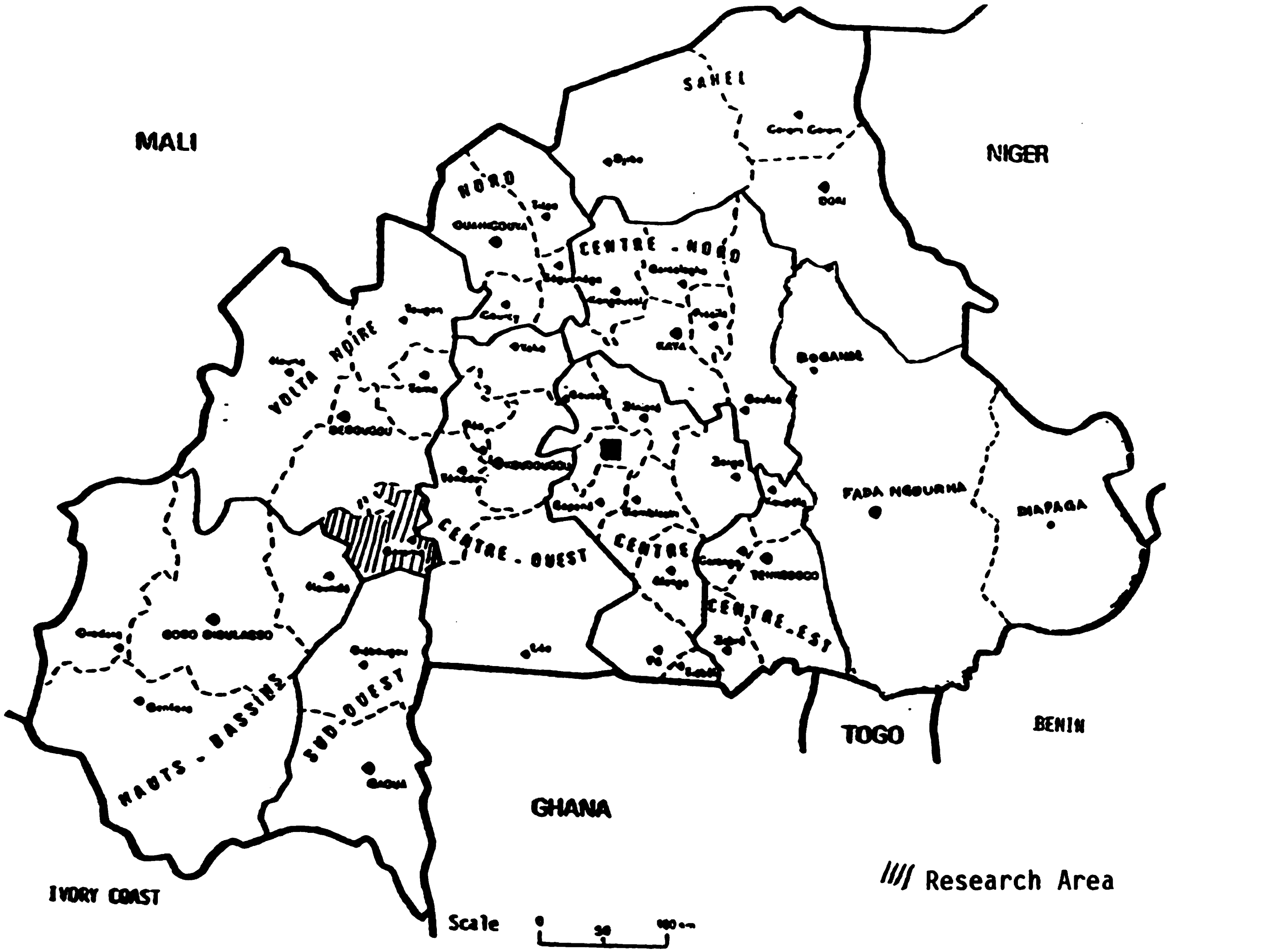


Figure 2.2 Burkina Faso (Source: Adopted from P.T. Fotzo, 1983, p. 8)

tanks or runoff control in any village in the study region which covers approximatly 250 square km. Groundwater is not used for irrigation. Farmers invest little in water control and almost none in irrigation. They practice shifting cultivation by moving from one field to another whenever they want. The ready availability of bush land lessens the need for water and erosion control investments by permitting fallowing. Cheap land also permits regeneration of grass and makes other types of soil and water conservation less necessary. No individual ownership rights are established on certain resources such as pastures and trees. There is no strong mechanism, either market or political, to control the exploitation of communal properties in the villages.

There is a general lack of public services such as health, water, electricity, education, transport and road maintenance in the Boromo region. However, there is an agricultural extension service which links the research stations and the farmers in the introduction of new technologies. Private enterprise consist only of diesel powered grain mills, hand textile manufactures, construction and sporadic transport firms.

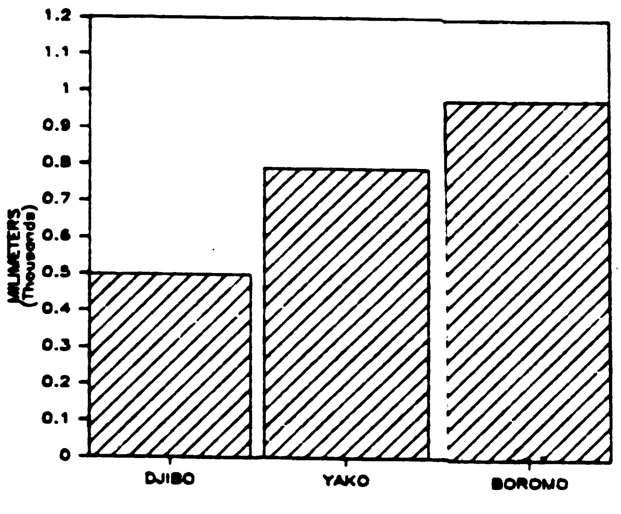


Figure 2.3
Annual Average Rainfall in three Locations of Burkina Faso, 1982

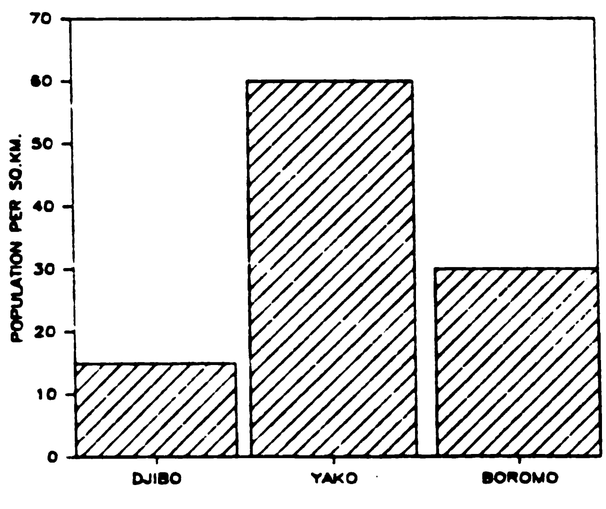


Figure 2.4
Population Density in three Locations of Burkina Faso, 1975 (pers/kmk^2).

Source: ICRISAT Annual Report 1981 p. H. 54

1.2 The Cropping Pattern

Intercropping is a common and widespread practice throughout the Boromo region. It serves to spread risks and labor demand, thereby increasing income stability. Mixed cropping is a systematic planting pattern which permits a specific spatial arrangement of many crops on the same field (D.W.Norman et al. 1982). Two or more different crops are planted on the same hill, a half meter apart from each other. Depending on the soil type and its moisture storage capacity one can identify two major cropping systems:

1) a combination of two crops of different maturity cycles, e.g. a 90 day crop with a full season 120 day crop. Example: early millet with late millet; early maize with late sorghum.

2) a combination of crops with rather similar maturity cycles; e.g. various cereals or legumes systems. Example: full season sorghum or millet with cowpeas.

Soil quality is the decisive factor in determining which intercropping system is the most appropriate. Intercropping of cereals and cowpeas is the most common combination across the study region. Under the traditional farming system cowpeas are added to the cereals at very low density and used as a grain and forage crop.

A study conducted by the International Crop Reseach Institute for the Semi Arid Tropics (ICRISAT) has shown that cotton is the dominant cash crop in the Boromo area. It competes with food grains, occupying 50% of the equivalent of millet and sorghum areas combined. Maize is the most frequently intercropped cereal, primarily with cotton between hills, and on the same rows, and with sorghum where the later serves as a border crop.

2. Resource Allocation Between Cotton and Cereals

Despite the high input level of labor and fertilizer required for cotton growing and the obvious lack of resources, remarkably few farmers choose to grow cereals. Almost all the farmers grow both cereals and cotton and therefore have to solve the problem of optimum allocation of land, labor and capital between crops on farms.

The most commonly available fertilizer in Burkina Faso is the cotton complex, 14:23:15 NPK which is imported (ICRISAT Annual Report 1982, p. G40). Although this fertilizer formula was primarily developed for use on cotton, it is also the most common mix used by farmers on food grains because of its availability within the country. Despite a 60% increase in fertilizer imports between 1977 and 1981, total national use remains low. The average application rate was less than 5 kg per hectare on cereals in 1981. In the Boromo region the application rate is about 80 kg per hectare for maize and above 100 kg per hectare for cotton.

Current development plans in the country call for a subtantial increase in fertilizer imports with the possible gradual elimination of the existing subsidies. In 1982, the FAO Burkina Faso fertilizer project estimated the real farm gate price of cotton complex fertilizer at 127 CFA francs per kg compare with 65 CFA francs per kg charged by the Organismes Regionaux de Development (ORD's) in 1982, and 55 CFA francs charged by SOFITEX. This represents subsidies borne by the government of 49% and 57%, respectively.

2.1 Labor

The supply and allocation of labor remain two important problems at the farm level. Most of the farming activities are done by family members although occasionally the farmer may get assistance from people outside the family. The heaviest period of family labor usage occurs in the days following the first heavy rains of the year. This usually corresponds to late May or early June. The entire family is mobilized to plant the crops as quickly as possible. Other peak periods of labor usage are the first and second weeding sometime in July and August and the harvesting from September to December, depending on the crops and rainfall pattern. During these periods work days are eight to ten hours long for the entire family. Farmers recognize the relationship between yields and timeliness of some farm activities. Some farmers avoid the planting season labor bottlenecks by planting directly into the untilled soil. The area plowed for both animal traction and manual farmers (Table 2.1) is relatively large for the first group during the first two weeks of the rainy season. A few manual farmers completed the land preparation task early (figure 2.5), while most of them completed it between the third and seventh week.

Table 2.1

Cumulative Frequency Distribution of Land Preparation Time for Animal Traction and Manual Farmers in Koho

	Area Plowed in Hectares at each Date					
	Animal Traction			Manual*		
Weeks	Area in ha	%	Cumul	Area in ha	%	Cumul
1	4.5	10		.5	6	
2	16.5	40	50	.5	6	12
3	4.0	8	58	1.5	17	29
4	1.5	3	61	1.5	17	46
5	4.0	8	69	1.0	12	58
6	3.0	7	76	1.0	12	70
7	8.0	18	94	1.0	12	82
8	2.0	4	98	.5	6	88
9	.5	1	99	0	0	88
10	.5	1	100	.5	6	94
11	0	0	-	.5	6	100
Total	44.5	100	100	8.5	100	100

Source: Unpublished Survey Data
*Includes only farmers who did land preparation.
More than 50% of the area was not plowed.

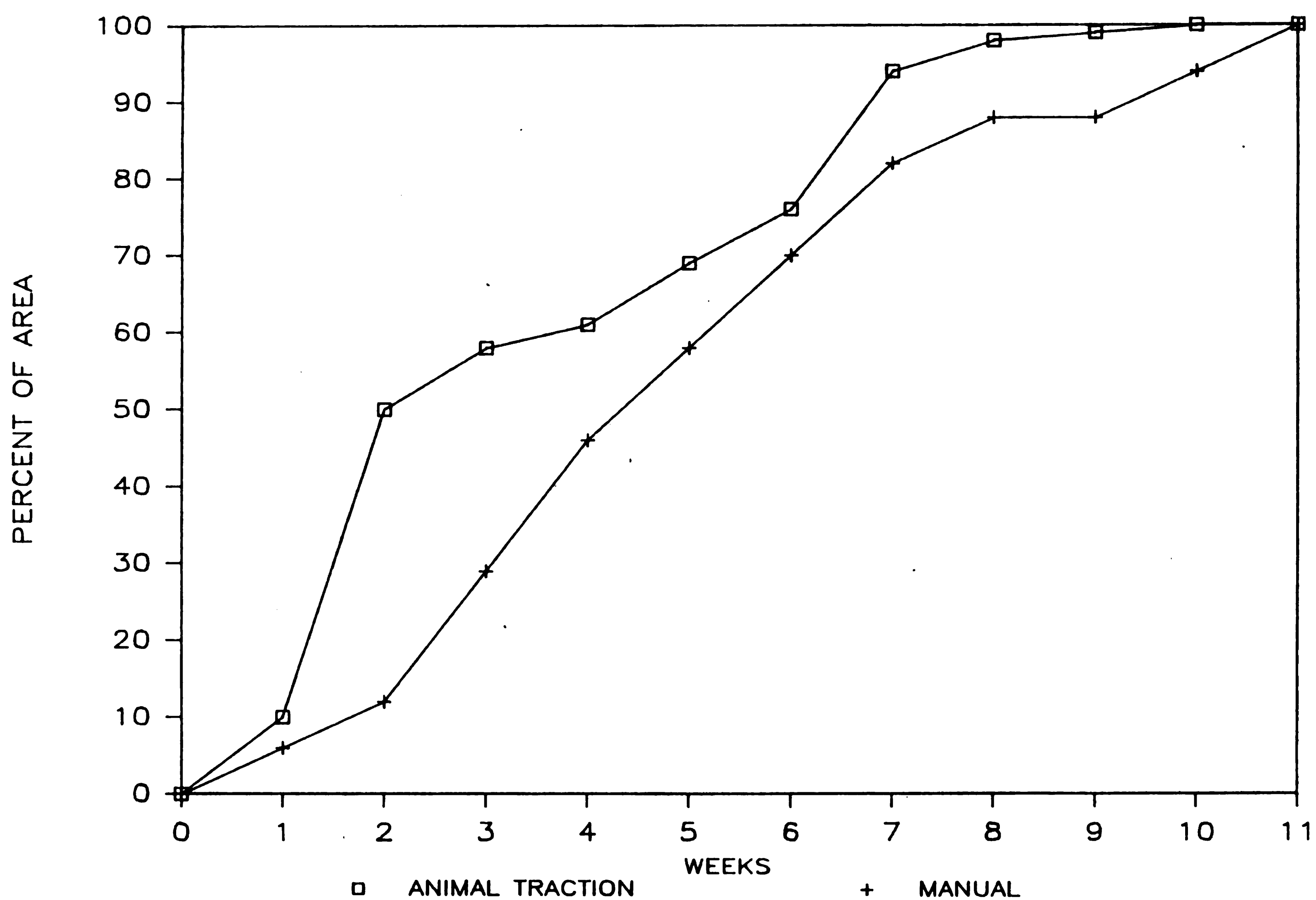


Figure 2.5 Cumulative Frequency of Land Preparation Time for Animal Traction and Hand Tool Farmers.

Farmers can alleviate labor bottlenecks and increase yield through more timely farming operations by using animal traction equipment. This should allow an expansion of cultivated areas by reducing the labor requirement of weeding (Merrit W. Sargent et al., 1981). However, requirements such as planting in rows and adequately trained animals must be met before the farmers are able to adopt animal drawn weeding.

2.2 Land

Following ICRISAT work in Burkina Faso, the distinction "next to house", "in village" and "in bush" can be made about land resources in the Boromo region.

"Next to house" land is defined as the area within a radius of 30 to 40 meters of the house (Delgado, 1978). This land is fertile because it receives all the households' organic wastes and manure from small ruminants and poultry. Some crops such as maize, tobacco, vegetables and sorghum require fertile land, and will be grown on land "next to house". Since this land is close to the dwelling, it is farmed every year. However, it remains fertile because household wastes are spread on it all year long. No purchased inputs are used on crops grown near the house.

"In village" land is defined as the fields that are less fertile than those on the "next to house" land. Millet, sorghum cowpeas and groundnuts are usually grown on this land during the wet season. It is adjacent to the "next to house" land and extends over 300 meters from the village.

"In bush" land is far from the zone of human habitation. "In bush" fields are usually over two km from the village. Depending on fertility of the natural soil, any crop can be planted on "in bush" land. Cotton, cereals and vegetables are grown on "in bush" land in a rotation system. Cotton is the main crop which receives purchased inputs, primarily fertilizer. Maize and sorghum are sometimes fertilized, but never millet.

The rotation system in the cropping pattern allows other crops to benefit from residual cotton fertilizers. In the cycle of rotation, maize and sorghum - either single or intercropped- have to come before millet. The rotation cycle can be illustrated as follows:

years	1	2	3	4	5	6

--C----C+MZ----RS+MZ----RS+MZ----ML+CP----ML+CP----

10 year fallow — 10 year fallow

C=cotton; MZ=maize; RS=red sorghum; CP=cowpeas; ML=millet

Figure 2.6 Example of Crops Rotation Cycle (Boromo 1982)

Because millet is more resistant to drought and poor fertility, it is most often grown on old fields or grown in the last years before the field is fallowed.

2.3 Capital

In the Boromo region, capital is required for investment in land development and equipment, and for seasonal financing of labor and intermediate inputs. In general, finances are supplied by the farm family itself, without much recourse to external funds. Boromo farmers finance their farming with cash earned from small sale of locally made cloth and manufactured products sold in the village. The sale of ruminants, poultry and some agricultural commodities is also an important income source for farmers.

However, external funds are sometimes used to purchase modern inputs and equipment. SOFITEX is the cotton development and marketing agency in the country. It provides fertilizer to farmers on a short term loan basis for cotton growing. At harvest, SOFITEX buys all the cotton produced from the farmers. Farmers who get loans for inputs purchase have to repay SOFITEX at the end of the cropping season when the cotton crop is sold.

Animal traction farmers need to hold cash all year long because they have to buy crop residues, salt and medicine for their oxen. A study conducted in eastern Burkina Faso has found that 3,804 CFA francs (about US $9; 1985) is needed to maintain two oxen for a year.

3. The Marketing of cotton and Cereals

> The objectives a society can reasonably hold for its marketing sector are analogous to the four basic objectives for the food system as a whole: efficient economic growth, a more equal distribution of incomes, nutritional well being, and food security. Because it links the production and consumption sectors, marketing can contribute to all four objectives through the efficiency with which it communicates signals of scarcity and abundance to decisionmakers. (Timmer et. al., 1983, p.151)

3.1 Marketing of Cereals

Donor agencies (The World Bank,1982) increasingly observe that the lack of an efficient marketing system in Burkina Faso constitutes a constraint to an increase in cereals production. The intervention of the government in the marketing system began in 1970 with the creation of the Office National des Cereales (OFNACER). In 1974 OFNACER was mandated to purchase stocks from the ORD. The ORDs and the licenced traders had a monopoly on cereal purchases, whereas OFNACER would monopolize cereals sales to consumers.

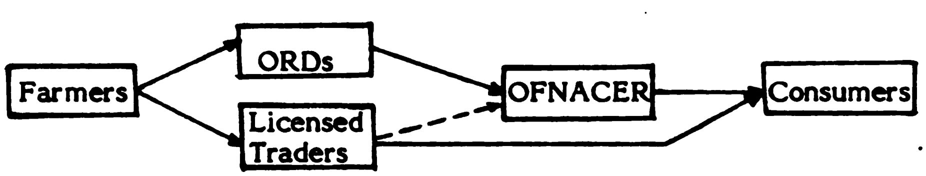


Figure 2.7 Marketing Channels for Cereals in Burkina Faso.

Because of the lack of sufficient transport, stocking capacity and good management, the ORD's were unable to play their assigned marketing role. As shown in Table 2.2, the role of OFNACER remained dominated by the distribution of imported grains.

Table 2.2

OFNACER Cereal Operations
1971/72 - 1978/79

	1971/72	1972/73	1973/74	1974/75 1/	1975/76 2/	1976/77	1977/78	1978/79 5/	1979/80 6/
Cereal Purchases on local markets									
Quantities	1.54	0.76	2.77	15.40	16.81	9.78	8.78	15.29	10.00
Values	32.78	16.12	..	569.10	--	205.34	281.10	688.52	
Cereal Imports 3/									
Quantities	35.29	27.41	29.54	24.75	5.82	18.83	50.47	36.24	..
Values	534.56	479.95	..	639.69	--	1,480.98	2,866.02	2,557.38	..
Total - Quantity	36.83	28.17	32.31	40.15	22.63	28.61	59.25	51.53	..
Values	567.34	496.07	..	1,208.79	--	1,686.32	3,147.12	3,245.90	..
Cereal Sales on Local Markets 4/									
Quantities	30.75	24.93	33.02	28.01	21.03	28.35	24.60	33.32	..
Values	539.11	469.80	..	685.65	--	1,366.93	1,165.92	1,042.59	..
Changes in stocks (Increases +)									
Quantities	6.08	3.24	-0.71	12.14	1.60	.26	34.65	18.21	..

Notes:

1/ Until 1974/75, purchases and sales of rice were the responsibility of the Societe Voltaique de Commercialisation (SOVOLCOM).
2/ Revised from original table.
3/ Imports made under food aid programs.
4/ Including some free distribution.
5/ Sales data through 3/31/79 only.
6/ Rounded.

Source: Table from CILSS/Club du Sahel, Marketing, Price Policy and Storage of Food Grain in the Sahel, Vol. II. Upper Volta Country Study, p. 15. Revised and updated based on OFNACER Stock movement reports, Ouagadougou, 1979, and information supplied verbally by Director of Commerce, OFNACER, June 1980.

1/81

Since 1978, OFNACER has served to stabilize price and manage security stocks. But the setting of uniform producer and consumer prices for all regions poses a severe financial constraint to the agency because operations in lower cost zones (near Ouagadougou) do not provide enough profit to subsidize operations where transport costs are higher.

The failure of the ORD's and OFNACER in the organization and implementation of an adequate marketing system has compelled the farmers to sell their grains to private traders. But some factors such as the poor transport linkage and low effective demand for marketed food in the very poor regions limit competition among traders. The same factors make grain collection financially unattractive for most private traders. For these reasons, an effective price incentive has not been established to stimulate cereal production. These imperfections of the marketing system result not only from the lack of organization, but also from the middleman taking undue advantage of differences between prices. The lack of competition leads to large cereal price differences between rural and urban markets.

3.2 Marketing of Cotton

The Societe Voltaique des Fibres Textiles (SOFITEX) is a privatly managed company, with about 51% of the stock belonging to the government. SOFITEX is involved in both cotton extension and marketing. It operates mostly in the cotton production areas of the country: the western Burkina Faso and the Volta Noire region including Boromo. Villages in these regions are accessible all year long because roads are maintained to ease cotton collection. Usually from December to March, SOFITEX schedules cotton purchase in each village. It takes several days to buy the entire production in each village, depending on the quantities produced. The monopsonistic structure of the cotton market and government policy, require all farmers to sell to SOFITEX at a price set each year.

4. Concluding Remarks

Even though both cereal and cotton markets do not have a competitive structure because of government intervention and generally poor organization of the marketing system, the cotton market is more satisfactory than the cereal market. Cotton producers face less risk in terms of selling their output, whereas cereal producers face more instability since marketing is affected by the inefficiency of the ORD's and OFNACER.

CHAPTER III

DATA COLLECTION AND METHODOLOGY

This chapter begins with the approach used to study the problem of resource allocation. The data were primarily collected by the ICRISAT economic program established in Burkina Faso in January 1980.

The overall economic objectives and work of this program are: 1) to contribute to the identification and development of improved technologies, through the analysis of the current farming system; and 2) to identify the constraints to production among small farmers. Furthermore, this program evaluated new technologies such as animal traction and new varieties of sorghum and millet under farmers' conditions to assess the constraints to the adoption of these technologies. To achieve these objectives, an intensive microeconomic farm survey was conducted in a set of villages chosen as broadly representative of the semi-arid region of Burkina Faso. ICRISAT hired and trained the enumerators and supervised the entire data collection process.

The last section of this chapter described various supplemental data sources since the model actually required more data than what was available from the ICRISAT data set. Only data from studies completed in similar regions of Burkina Faso are considered.

1. The Approach

The questions highlighted in the introduction can be addressed by modeling the farming opportunities in the study area. The model should take into account the intercropping system and the two types of tillage technology available in the study region. However, the number of enterprises derived from a system of mixed cropping is so large that some assumptions need to be made about the different crop combinations.

Farms in the Boromo region were modeled in a linear programming (L.P.) context. For subsistence agriculture such as we are dealing with in this study, uncertainty can have a serious effect on farmers' decision making, since farmers cannot afford to suffer a setback which may lead to starvation. The low level of rainfall, poor land, and small farm size are factors affecting farmers' decisions. The significance of uncertainty and the security factor has been widely recognized among researchers, but it has not always been introduced in decision models of subsistance agriculture because of the limited knowledge about the operation of the peasant agrarian systems. This lack of knowledge justifies caution in the transfer of concepts and tools of analysis appropriate to developed environments to circumstances of peasant farming (Odero-Ogwel,1964).

The presence of two technologies - hand tools and animal traction- appears as an important aspect of the model since animal traction is an innovation in the Boromo region's subsistence agriculture. A.R.Low(1974) has argued that innovations often create more uncertainty for the farmers than the traditional methods of cultivation. Farmers usually know the performance of traditional methods but do not know what to expect from innovations. If they are to be adopted, innovations must not only bring greater benefits than the older methods, but the benefits must also outweigh the disadvantages that arise from the uncertainty surrounding them. Low has demonstrated that quadratic programming models provide results showing optimal plans much closer to the actual ones than those generated by orthodox linear programming. But the application of this technique to peasant agriculture has limitations of a practical and theoretical nature which are beyond the scope of this work. For instance, on the practical side, Low explains that the data required to produce the necessary variancecovariance matrix are likely to prove prohibitive in most cases. On the theoretical side, it is likely that peasant farmers are concerned with achieving a minimum level of production with certainty, rather than to maximize variance.

The data used to model the Boromo farm come from a micro level farm survey designed and implemented by the Economics Program of ICRISAT in Burkina Faso. The details of the data collection are explained in the next section.

2. Data Collection

The Boromo region was selected, based on the result of a reconnaissance survey, as representative of the high rainfall zone in the semi-arid region of Burkina Faso. The survey was conducted in Koho and Sayero, two villages located approximatly 210 km west of Ouagadougou.

2.1 The Survey Methodology

2.1.1 Reconnaissance Survey (RS)

The survey objectives were to collect basic information about the farming systems in Burkina Faso. Soils, rainfall classes and population density from the 1975 Census of Population were the stratification variables in each rainfall zone of Burkina Faso's semi-arid area. Group and individual interviews were conducted with farmers during a two day visit in each zone. In every village, questions were asked about local varieties of crops, cropping patterns, animal traction and the use of modern inputs such as fertilizers and seed treatments. Interviews with farmers were supplemented by interviews with officials of the ORD's of other research organizations.

2.1.2 Sample Selection and Characteristics

The RS conducted before the rainy season began identified Koho and Sayero as study villages in the Boromo region. The main criteria of selection of these villages as representative of the agroclimatic zone were their farming system and the cropping pattern. Furthermore the villages had not been changed by any previous development project. Finally, they are accessible with a four wheel vehicle all year around.

The main objective in the household selection was to include representative individuals in the village, able to provide faithful and complete information. "Representative" covers methods involving random and purposive selection (D.J. Casley and D.A. Lury,1981). After many visits to the villages' traditional authorities, the goals of the study were explained to the inhabitants during meetings. Participants who did not understand were encouraged to ask questions. Truthful information cannot be obtained if sample members are not aware of and do not accept the goals of the study. The 1975 census list was updated and used to randomly select the sample members in both villages. D.J. Casley and D.A. Lury show that inferences cannot be drawn in a satisfactory fashion from purposive samples, but only from samples where the selected units were chosen with a known probability. The stratification variables in the sampling were ethnic group (Bwa and Dagari-Djula) and use of hoe and animal traction technologies. In Sayero, the sample was stratified using only hand tool and animal traction because there is only one unique ethnic group in the village. The Koho sample included 18 hand tool and 12 oxen traction farmers. Village traditional authorities (chiefs) were added to each sample for political reasons, when they were not randomly selected. Later, their responses were excluded during the analysis.

2.2 The Data Collected

Two enumerators, permanently stationed in Sayero and Koho, collected the data through weekly interviews with farmers for one year. The following data were obtained:

-basic information on all household members. This comprises the composition of the work force for each household by sex, age and relationship to the head of household.

-a listing of all fields farmed by household members in 1980; 1981 cropping plans for all members; the location of each field and the crops to be planted.

-an inventory of all animal traction equipment and farm operations for which animal traction was used in the previous year and forcast for the next year.

-other data such as field's yield, area and time spent on each farm operation by different labor categories were recorded during the survey.

2.2.1 Household Information

Table 3.1

Size and Composition of Households Stratified
by Ownership of Animal Traction Equipment
ICRISAT Study Villages, 1981.

	Savero		Koho	
	Traction	Manual	Traction	Manual
Age of household head	41	51*	54	48
Number of members	12.5	6.9*	23.8	9.2*
% children less than 10 y.	36	33	43	34
% household with more than one nuclear unit	71	25	82	7

*The difference between manual and traction farmers is significant at the 2.5% level.

Source: Adopted from Annual Report of ICRISAT/Upper Volta Economic Program 1982 p. G8.

Table 3.1 contains the summary statistics about the size of households in each category of technology for both Sayero and Koho villages. The table shows that animal traction farmers belong to larger households than hand tool farmers. Also, the dependency level, measured as the percentage of children under 10 years of age, shows that traction equipped households are significantly larger than non-traction equipped households.

2.2.2 Field Data

All field activities data from 1981 to 1982 was recorded with May 1, 1981 being day 1 of the survey.

The fields that were identified at the beginning of the survey provide data about their area, the principle crops planted in single or mixed cropping system and the quantities harvested by weight in kilograms per unit area for each crop.

The time spent for the main farming operations such as plowing, planting, first and second weeding was estimated and recorded in hours for each labor category. All farm workers who were not members of the household were recorded as non-family labor. Time spent in farm work does not include periods for rest, meals and travel to and from the field. Non-family labor includes reciprocal labor, work provided by friends and relatives and hired labor. Actually, the use of hired labor is almost negligible. Whenever a farmer receives help from friends, neigbors and relatives, he has to provide them with meals and drinks for the day. Animal team hours were also recorded for all activities completed with animal traction.

The output from each crop enterprise was estimated from the number of total local units harvested in the field for each specific crop. The average weight for standardized units times the number of units harvested, gives an estimate of total production. Since local measures vary from household to household, a number of samples were needed to derive the average weight for the standardized units. This method is accurate enough for crops harvested at the same time but not satisfactory for cowpeas and sweet potatoes which were harvested in pieces over a period of time. For these crops the farmers were asked to call the enumerators any time they harvested sweet potatoes or cowpeas.

Cotton production was easy to determine because cotton is all sold and the sale records are kept by the SOFITEX marketing service. The amount of fertilizer and manure used was also recorded in kilograms. The weight of manure was estimated on the basis of standardized units. Accurate records are known for fertilizer because the cotton extension service delivers it to the farmers on a kilogram basis. Farmers know how much fertilizer they get and are able to tell the enumerator the amount used. They usually buy a relatively small quantity of fertilizer, and always used all the quantity bought.

Field areas were measured using the method of "direct measurement" right after harvest when the bounderies were still easily recognizable. Two enumerators used a measuring tape and a field compass to measure each field.

3. The Data Limitations

During the data analysis and modeling, some missing data were observed in the data set. Recourse to suitable data was necessary to complete the study. Three categories not collected in the ICRISAT study were: the wage rate for hired labor, the maintenance cost for a pair of oxen used by animal traction farmers, and the market price for cereals.

3.1 Wage Rate Estimation

Wage rates are best estimated by observing the labor market. While the wage rate in Burkina Faso varies from area to area, labor is hired during the cropping season and wage rates can be estimated for communities. Daily wages, including the value of meals, range from 100 CFA francs to 500 with a mode of 300 CFA francs per day (see Table 3.2).

An ICRISAT survey shows cash wages of 250 to 300 CFA francs per day in the ORD's of Bobo-Dioulasso and Dedougou. Since Boromo is in the Dedougou ORD, this wage rate should reflect actual wages paid for the villages of Koho and Sayero.

Table 3.2

Labor Hiring Activities in Burkina Faso, 1982

Place	Description	Wage (CFA f./day)	Remarks
Fada	Agricultural laborers hired by bureaucrats	150-200	Plus meals and lodging
Bobo Dioulasso	Cotton harvest	100	Based on 5 CFA/kg and 15 to 20 kg/day
Banfora	Weeding	250	
	Ridging	300	6 hours/day plus meals
Yatenga	Hiring for few days only, especially in south of ORD.	350	Plus meals
Ouaga-dougou	Cattle keeping (10-15000 CFA f. per month)	385	Plus meals and lodging

Source: The World Bank,"Upper Volta Agricultural Issues Study". Report No 3296 U.V. October 29, 1982 p.212.

Notes: 1. Values for meals range from 50 to 125 CFA francs per day. 75 CFA francs seems to be a reasonable intermediate figure.

2. The average of the observations from the original table is 275; with meals, the total daily wage equals 350. The mode is 250, suggesting a value of 300 when meals are included.

3.2 Animal Maintenance Costs

Vincent Barrett *et al.* (1982) in their work on animal traction in eastern Burkina Faso estimate that the cash expense of maintening a pair of oxen is four times as much as that for donkeys (see Table 3.3). A large proportion of maintenance costs is spent on salt, crop residues and grains during the period of May through July, when animals are required to work the hardest.

Table 3.3

Average Cash Expenses for Maintaining Traction Animals By Quarters(1978-79).

Type of Animal	CFA francs by Quarter				Total
	May-July 1978	Aug.-Oct. 1978	Nov. 1979	Feb. 1979	
Oxen(2)	1,993	355	660	796	3,804
Donkey(1)	466	130	244	98	938

Source: Vincent Barrett, Gregory Lassiter,David Wilcock, Doyle Baker and Eric Crawford (1982).

3.3 The Prices of Cereals and Cotton

In Burkina Faso, prices are set for all agricultural commodities through government intervention. For each product, there is an official producer and consumer price.

This study assumes that farmers will sell their commodities at the official producer price, and buy at the official consummer price. Time-series Price data for white sorghum, maize, millet and cotton are presented in Tables 3.4, 3.5, 3.6, and 3.7 respectively.

Table 3.4

White Sorghum Prices in Burkina Faso
(CFA francs/kilo)

Year	Official Producer Price	Official Producer Price
1970	12	20
1971	12	20
1972	14	26
1973	18	30
1974	22	32
1975	18	3
1976	21	3
1977	32	45
1978	40	57
1979	40	57
1980	45	69
1981	50	80
1982	58	83
1983	64	88

Source: Steve Haggblade "An Overview of Food Security in Upper Volta" p.78. Report Prepared for USAID/Upper Volta. July 16. 1984.

Table 3.5

Maize Prices in Burkina Faso
(CFA francs/kilo)

Year	Official Producer Price	Official Producer Price
1970	13	20
1971	13	20
1972	15	27
1973	18	30
1974	22	32
1975	18	30
1976	21	35
1977	32	45
1978	40	57
1979	40	57
1980	45	69
1981	50	80
1982	55	missing
1983	60	missing

Source: Steve Haggblade "An Overview of Food Security in Upper Volta" p.80. Report Prepared for USAID/Upper Volta July 16, 1984.

Table 3.6

Millet Prices in Burkina Faso
(CFA francs/kilo)

Year	Official Producer Price	Official Consumer Price
1970	12	20
1971	12	20
1972	14	26
1973	18	30
1974	22	32
1975	18	30
1976	21	35
1977	32	45
1978	40	57
1979	40	57
1980	45	69
1981	50	80
1982	60	83
1983	66	90

Source: Steve Haggblade "An Overview of Food Security in Upper Volta" p.79. Report Prepared for USAID/Upper Volta. July 16. 1984.

Table 3.7

Cotton Prices in Burkina Faso
(CFA francs/kilo)

Year	Official Producer Price	Export Pricer Cotton Fiber
1970	32	97.1099
1971	32	104.734
1972	32	114.603
1973	35	115.058
1974	40	187.599
1975	40	159.748
1976	40	279.861
1977	55	352.826
1978	55	282.329
1979	55	249.265
1980	55	300.072
1981	62	369.013
1982	62	missing
1983	70	missing

Source: Steve Haggblade "An Overview of Food Security in Upper Volta" Report Prepared for USAID/Upper Volta July 16, 1984.

4. Concluding Remarks

The lack of data collected about off-farm employment and time spent on walking to the field is another weakness of the available data set. The importance of off-farm employment is noted by D. W. Norman et al. (1982) as a complementary source of income for small farmers. Even during peak farm labor demand, a male adult in Northern Nigeria spent an average of seventeen days working on the family farm, and allocates seven days to off-farm work per month. In Savanna agriculture, little income is obtained from farming activities. Therefore, members of households with small farms are compelled to work in off-farm employment even though the work need of their own farm may be high (Matlon 1977). The lack of data about off-farm employment makes the interpretation of slack labor difficult.

Nineteen eighty-two prices were used in the model. From the farmers' viewpoint, the official producer price will be the selling price of the commodity under consideration in the model. On the other hand, the official consumer price is the price charged by traders. It is entered as the buying price in the model, from the viewpoint of a farmer as a consumer. The official consumer price for maize is missing in 1982. The 1982 price will be considered the same as in 1981 for maize.

The price for cowpeas was estimated from ICRISAT survey data in the central region of Burkina Faso. (ICRISAT Upper Volta Rapport No 8, 1982, p. 24).

It is assumed in the model that the oxen used in cultivation are grazed on communal land. Therefore, no cost for grazing was included in the animal maintenance cost. However, the price for salt and other supplemental feed was estimated from the eastern ORD study previously discussed.

CHAPTER IV

REVIEW OF LITERATURE

This chapter has two objectives. First it summarizes some research aspects of the ICRISAT Economic Program in Burkina Faso. Because the research areas covered by the Economic Program are too broad to be summarized in one chapter, only the most important aspects related to resource allocation in the semi-arid region will be covered. Second other studies about resource utilization in peasant farming will be explored.

1. Some Aspects of the ICRISAT Economic Program Research

1.1 Pilot Study of Farming System

The work of the Economic Program started in June 1980 with an intensive farm level survey conducted in Nakomtenga and Nabitenga, Mossi villages located at 35 km northeast of Ouagadougou. The objectives of the pilot farm study were:

- to obtain a demographic profile for a farm unit in the region;
- to generate budgets for the major crops and crop associations;
- to describe key relationships within the local farming system. These relationships include: the use of local sorghum and millet varieties; the effect of soil variation; the effect of planting under varying "states of nature"; and the effect of animal traction on land and labor use.

1.2 Methodology and Profile of Farm Units

A sample of forty-four farmers participated in the study. They were approximately equally divided between the two villages and were members of the local farmers' association. They represent the early adopters of new technologies. Because they were selected on the basis of willingness to participate, they were believed to be somewhat more progressive than the general population. Among the participants, twenty-one possessed donkey-drawn equipment.

The data collected indicate that animal traction households are about 20% larger on average than hand tool units. The head of households are older and are more likely to have accumulated sufficient capital to invest in animal traction equipment.

1.3 Factor Use and Productivity for Major Crops

Data were collected to prepare crop enterprise budgets for the comparison of relative profitabilities for different techniques of cultivation and price relationships. A basic description of the economic alternatives facing farmers in their allocation of resources was described in the budget tables. Crop budgets represent a base standard used in the comparison of new technologies from the point of view of potential production gains and to determine the degree of change implied in the new methods.

Enterprise budgets for the major cereals including sorghum, maize and millet were calculated. Cost of production factors included were hours worked, seeds, fertilizers and manure.

The survey results show that most farmers plant directly without plowing. The data indicates that in the study villages, plowing requires more than 170 person hours per hectare when done by hand, and 60 person hours with donkey traction. There is competition for labor between soil preparation and early planting, suggesting that improved later planting technology may not reduce the land preparation labor conflict.

Weeding and thinning appear to be the most intense activities which occupied an extended period in the farming cycle. The period was especially long for sorghum, exceeding 400 hours per hectare.

Two measures of productivity were derived:

- average yield per hectare ranged from 900 kg/ha for maize intercropped with red sorghum to 250 kg/ha for millet.

- kilogram of grain per labor hour. This measure is a more relevant index in a situation where labor, not land, is the most constraining factor. This measure applied gives the same ordering of crops, with the maize-red sorghum combination giving the highest yield, followed by red sorghum.

1.4 Effect of Animal Traction

In a land surplus environment, where peak period labor limits cultivated area, mechanization of peak period activities would be expected to bring new land under cultivation.

The data show that animal traction farmers cultivated a larger area per household and per worker. The larger area under cultivation can be explained in part by the labor saving effect of animal traction in weeding. Average yield per labor hour was found to be consistently higher on animal traction fields.

While animal traction farmers tend to apply a greater rate of organic manure, the quantities for hoe farmers are low but not very different from animal traction farmers.

2. Test of New Technology: The Sorghum Variety E 35-1

The sorghum variety E 35-1 has ranked amoung the high yielding ICRISAT varieties with on-station yields averaging 2100 kg/ha in 1979 and 1980.

The objective of the trial was to determine how the variety performed under farmers' management and to evaluate the financial returns to E 35-1, compared to alternative local varieties. The test of this new variety is relevant to determine whether its introduction will depend on farmers' adoption of animal traction for land preparation.

2.1 The Methodology

Two test plots of 500 meters square each were located contiguously on the field of each farmer participating in the study. Farmers were instructed to sow one plot to E 35-1 and one to a local white sorghum variety of their choice. ICRISAT supplies sufficient fertilizer to treat each plot at a rate of 100 kg/ha. E 35-1 improved seeds were provided. Recommended practices for the new variety were explained by sorghum scientists to the farmers at the beginning of the season. Farmers were instructed to follow all recommended practices on both E 35-1 and on local variety. Detailed information on all activities performed on the test plots was obtained in weekly interviews.

2.2 The New Variety's Performance

The data reveals that the seedling emergence rate was lower for E 35-1. It was found that soil preparation was the main determinant of the emergence rate. When prepared by hand, nearly 40% of E 35-1 plots had less than 80% emergence rate, compared to only 4% of the new variety with emergence problem in traction plowed plot. This indicates that soil preparation by animal traction may be a necessary complement of E 35-1 if full stand establishment is to be expected.

Planting was completed as recommended whereas first and second weedings were delayed due to labor bottleneck. Previous on-station results have shown that E 35-1 yield can be significantly depressed with delayed weedings.

Disease and pest incidence was significantly greater on the new variety plots compared to local variety plots. But this may not be caused by varietal susceptibility since E 35-1 generally showed excellent recovery from disease and pest incidence. The test results showed no significant varietal effect on yield, with average E 35-1 yields 1297 kg/ha compared to 1167 kg/ha for the local variety. However the data reveals that the new variety was superior to the local when planted late. The average yield in late planting was 38% above the local variety's yield.

The conclusion of this test suggests that the introduction of improved crop varieties is not always a solution to the problem of small farmers' resource allocation. Improved varieties emergence rate is not always higher than local varieties' emergence rate when both are planted under farmers' management. E35-1 requires animal traction for a good land preparation operation and fertilizer to reach its full yield potential.

3. Other Studies on Resource Allocation

The problem of resource allocation at the farm level in peasant agriculture was studied in other areas, using different methodological approaches.

Monnier and Talibart (1972) estimated labor demand in the Sine-Saloun region in Senegal, using the partial enterprise budget approach. A more recent study by Delgado (1979) examines labor allocation between food grain and livestock in Southeast Burkina Faso. He concludes that a revenue maximizing farmer will entrust his cattle to the Fulani herders rather than keep them himself. However, Delgado's conclusion is weakened by the fact that he did not include any animal traction farmers in his sample. In a comparative study between animal traction farmers and hoe farmers, Barrett et al. (1982) revealed several changes in labor allocation associated with the use of animal traction. Their study of a sample of animal traction and hoe farmers showed that traction reduces the average labor time per hectare by 25%. Sixty-eight percent of this reduction occured in the category of soil tillage.

L.P. techniques, although controversial (C. Palmer- Jones, 1977; A.R. Low, 1978), have been used to assess the profitability of several adjustments at the farm level in many peasant farming situations. Palmer-Jones (1977) criticizes

Heyer (1976) on the legitimacy of using average input-output coefficients in the L.P. models for the analysis because farmers may change their strategies or technical inputs under different environmental conditions. Palmer-Jones suggests that there is no theoretical reason to believe that average inputs will give rise to average output.

Low (1972) used L.P. to study peasant farming in South East Ghana by taking uncertainty into account when presenting the production decision of farmers. He showed that subsistence farmers maximize expected income subject to meeting yearly subsistence requirement in adverse conditions.

Heyer (1972) analyzed the impact of cotton on traditional food crop systems in the semi-arid area of Kenya by using L.P. and sensitivity analysis. The study included sixteen farms representing production activities and different standards of management. A complete set of input-output data was obtained from each of the holdings, but these data were supplemented by adjusted research station results and data from similar situations elsewhere in East Africa. Heyer introduced two different "states of nature" in her model: the best and the worse that can be reasonably expected. These "states of nature" were represented in the model by factors such as market conditions, climates and diseases. Heyer concludes from the analysis that Masii farmers can only get meager incomes at present levels of technology, even with optimal resource allocation. Cotton gives higher per acre returns than traditional food crops, but this improvement represents little in terms of income. Because seasonal labor demand is spread out and unevenly distributed through the year, Heyer argues that labor saving methods can be expected to contribute much more to the level of income. Heyer found that the problem of famine for the Masii farmers cannot be solved with drought resistant crops such as millet or sorghum because of their high labor demand.

However, new varieties, with higher returns to labor could be succesful in reducing the incidence of famine.

In an application of L.P. to peasant farming in Nigeria, O. Ogunfowora (1970) demonstrated a combination of livestock and crop enterprises which could maximize farm income under alternative resource availability and farm prices. The model also highlights the competitive potential of some particular crops. It is designated to represent two types of peasant family farm in the study region:

- "small and semi-subsistence" family farms operating entirely on family labor, personal capital, and perhaps receiving some loans at peak period of capital requirement.

- "commercial" family farms introduced by relaxing the restrictions in the small and "semi-subsistence" farm model. This shows the extent to which the scale of operations, and thus, farm income, could be improved. This model is designated for a family farm which is largely commercial in nature. It assumes that more labor could be hired and more capital borrowing per month is allowed.

Each type of farm is tested in the L.P. model and the optimum farm plan can be generalized to farmers with a similar resource base. Ogunfowora concludes that efforts to increase production should not be based on the allocative efficiency, but rather on the improvement of the quality and quantity of inputs and marketing systems. He suggests that future attempts to increase the scale of peasant farming must give priority to the supply of credits and other productive inputs.

D. W. Norman (1973) used L.P. to test various hypotheses regarding traditional farming in Dan Mahawayi, in Northern Nigeria. He derived from the description and analysis some implication for introducing changes, i.e. increasing and improving inputs such as fertilizers, seeds and animal traction technology.

Norman models the representative farm family in the region by splitting the sample families into two land per resident strata: small farmers with less than 1.5 acres per resident and large farmers with more than 1.5 acres. Norman found that the income level from crop production could be increased by about nine percent if family labor was cost free. The reallocation of resources did not have a very high potential income increase when Norman took into account the individual farm variations and the degree of uncertainty facing farmers in their actual farming operations.

E. S. Clayton (1963) studied peasant agriculture in Kenya with L.P. on a number of selected farms which are typical of important groups of holdings in the region. He computed maximum profit situations for these holdings under a wide range of postulated conditions, such as differing cash cropping possibilities and varying land and labor ratios. Clayton considered the distribution of the population (sample) which approximates a normal curve; then he selected the modal situation farm for closer examination. Clayton emphasized the importance of the land/labor ratio in peasant agriculture. High labor/land ratios, in the sense of employing extra labor on the family holdings, implied high productivity in Kenya because they allowed cash crop specialization. Clayton found that a high labor/land ratio could be a precursor of economic progress, a source of a valuable agricultural surplus and the provider of employment for the landless peasantry.

Additional resource allocation studies have been done by P.T. Fotzo (1983) and M. Kamuanga (1982). Fotzo found that seasonal family labor supply was critical in determining the maximum level of total gross margins attainable by farmers in Eastern Burkina Faso.

M. Kamuanga's analysis revealed that the optimum farm size was 3 to 7 hectares in a study conducted in the Office du Niger in Mali. He concluded that farm income could be increased if row-seeding and mechanical weeding were adopted .

Despite the criticism against using L.P.in the analysis of peasant farmers' behavior (C. Palmer-Jones, 1977), its strengh lies in its ability to handle a large number of interrelated variables (Low,1978). It permits researchers to cope with the high degree of interdependence which characterizes peasant farming systems. However, Odero-Ogwel et al (Agrarian Development Studies. Report No 5) argued that modifications of sophisticated models are necessary because of the fact that economic and social variables are not easily separable in subsistence agriculture.

4. Controversy in Resource Allocation Studies

4.1 Resource Allocation Efficiency and Analytical Tools

Most of the literature on small farmers argues for a better allocation of resources to improve productivity. The use of L.P. and other quantitative methods in analyzing traditional farming has provided some policy implications; but the problems faced in their use in developing countries are related to the nature of traditional agriculture. A few studies, e.g. W. P. Falcon (1964); E.O. Heady et. al. (1961); Narindar Radhawa et. al. (1964), indicate that farmers could increase their income if resources were combined differently. On the other hand, the opposite view is that farmers are "poor but efficient". This view claims that farmers combine enterprises so that the marginal value product of resources are equal in different enterprises and are equal to their marginal costs. This view is supported by T. W. Schultz (1964); Hoper (1964); John W. Mellor (1967).

T.W. Schultz (1964) argues that traditional agriculture is efficient. "There are comparatively few significant inefficiencies in the allocation of the factors of production in traditional agriculture "(Schultz, 1964 p. 37). He defined traditional agriculture as all poor agricultural communities which have not experienced any significant disturbance from outside intervention. A dam or irrigation canals may have a disequilibrium effect on an agricultural community. Such communities should be excluded from this definition. Schultz applies "the efficient but poor hypothesis" to the traditional agriculture as defined above. He explained that the implication of this hypothesis is that no appreciable increase in agriculture should come from the reallocation of the factors at the disposal of farmers who are bound in traditional agriculture. Also, an outside expert will not discover the efficiency in factor allocation in traditional agriculture. A very poor but efficient society is capitalist on a "microscopic scale". A careful observation of the behavior of people, prices and costs support strongly that they are remarkably efficient in allocating the factors at their disposol in current production.

J. W. Mellor (1969) found that the relatively inefficient use of resources in traditional agriculture is due to the fact that farmers are operating in a static environment. The criticism made by Mellor against the study of resource allocation in traditional agriculture is that the assumptions concerning factor costs, output prices and productivity are biased toward a conclusion of inefficiency. Error in assumption may lead to finding inefficiencies where none exist.

> Clearly the observation that there is labor capital formation potential available, the utilization of which could increase production, is no more a sign of disequilibrium in a traditional, low-income agriculture than in a modern high-income agriculture. The critical question is not whether added labor or capital would increase production but whether the incremental increase in value of production is greater than the incremental cost of added labor or capital. (Mellor, 1969)

Mellor suggests that a policy oriented research in peasant farming should consider "physical response" under wide range of conditions, "risk and uncertainty" and "prices and price policy" rather than proving a disequilibrium in traditional agriculture.

Following T.W. Schultz (1964); Lipton (1968); Mellor (1969); J.B. Hardaker

(1979) supports the contention that small farmers are efficient. They will always use their resources for what they see as their best advantage. Therefore an improvement in productivity cannot be achieved by simply recommending that farmers allocate their resources differently.

> The persistance of poverty in parallel with overall economic growth shows that policies aimed at generalized development have not corrected the gross inequalities existing in most developing countries. It is clear ... that growth with social justice will not result unless there is corrective bias in favor of the rural poor and unless the small farmers, who constitute the majority of the rural poor are brought into the mainstream of development through purposive intervention. (Hardaker, 1979, p.316)

He sees the choice of an appropriate decision criterion in modeling as an especially important and difficult issue in peasant farm management research. Complications come from the fact that several crops are grown with multiple cropping and intercropping. Reliable and avalaible data are often limited. Hardaker discusses the concept of "profit" in semi-arid subsistance farming. This concept can be practically irrelevant in areas where markets are not developed. The valuation in monetary terms of certain farm inputs may be inaccurate and depreciation inappropriate in the context of the small farm.

Hardaker concludes that the use of mathematical programming and related techniques can be expected to continue to be a challenge for small farm management reseachers. He points out that there is danger that accademic researchers will become increasingly remote from the reality of small farmers and that the modeling exercise will become an end in itself.

4.2 Price Response

Another issue of debate in peasant farming is whether or not traditional farmers respond to price changes. The extent of farmers response to price incentive is important if policy makers have to rely on market mechanisms for resource allocation. Even though a few authors have argued that farmers in subsistance farming respond to agricultural commodity price increases (Rex Daly, 1960; Raj Krishna 1963), a large number tend to believe that traditional farmers do not always respond to price increases.

Walter P. Falcon (1964) has argued that the disagreement about whether or not farmers respond to price signal comes from three main sources:

(1) the confusion between the elasticity of supply of all commodities and the elasticity of supply of one commodity.

(2) farmers' allocation of land and nonland resources in response to price, i.e. between acreage and yield responses.

(3) elasticities of supply between "cash" and "home" consumed crops.

In an example of a West Pakistan farm, W.P. Falcon showed that where there is a continual threat that farm production will fall below the minimal consumption requirement, small farmers produce a subsistance oriented cropping pattern to minimize uncertainty of survival. In a linear programming analysis, W.P. Falcon revealed that the value of net output in South West Pakistan can be increased 50% by changing the cropping pattern with a given set of prices, inputs and technology. Rainfall uncertainty, poor land, the lack of irrigation and water control facilities, the small farm size and marketing uncertainty for food crops are likely to outweigh the incentive effect cause by price increase. Falcon's work in West Pakistan reveals that there may be acreage responses to relative change in price - especially in the case of cash crops such as cotton and even in the case of food crops when climatic conditions are good. But price policy alone cannot stand as a basis for agricultural production increase. "Unless there is a throughgoing reform in the services and facilities available to farmers, (e.g., transportation, storage, credit, fertilizers, technical knowledge, etc.) price alone can have little effect on increasing yield per acre" (Walter P. Falcon, 1964). There is strong evidence that relative price change affect resource allocation; but "structural changes" are necessary if traditional agricultural production is to be increased (Christopher L. Delgado and John W. Mellor, 1984; Christensen and Wituki, 1982).

Concluding Remarks

In spite of the controversy regarding L.P. use in farm management reseach in traditional agriculture, the results of linear programs have the same function as other scientific research in that they provide a tool for problem solving and advisory service.

The literature review presented in this chapter is of value in the construction of the Boromo farm model. Previous research studies are helpful in defining the critical issue, developing the analytical model and interpreting the results for policy recommendations. The general interest of the previous studies in peasant farming has its value in identifying the magnitude and direction of adjustment and the expansion path in the improvement of the study region.

CHAPTER V

A FARM MODEL IN THE BOROMO REGION

Presented in this chapter is the linear programming tableau that describes the agricultural production model in the study area. The purpose is to describe the main constraints and revenue considerations that affect farmers' decisions on production and consumption activities.

The underlying assumption in this model is that farmers maximize profit, subject to meeting yearly consumption requirements. D.W. Norman has shown in a study of small farmers in Nigeria that profit maximization and security were not in conflict. While the provision of adequate food for the family was given top priority, it was found that the pattern of resource allocation was consistent with profit maximization objective. An attempt to introduce realism into the model was made by maximizing the objective function within the framework of consumption patterns, the mixed cropping system under hand tool and oxen traction cultivation and the constraints characteristic of farm production and farmers' behavior in the region.

1. Theoretical Aspects of the Model

This model is essentially conceived as a revenue maximizing model under two different technological packages: animal traction and hand tool cultivation.

In the context of the Boromo region the model is built for the average farm. The results generated by the linear program should be general enough for the whole survey area. The model comprises nine crop activities (five sole crops and four crop mixtures) cultivated with hand tool technology and seven crop activities cultivated with animal traction technology (five sole crops and two crop mixtures). The activities in the model are the most common sole and mixed crop systems actually practiced by the sample farmers.

Table 5.1 shows the distribution of each crop mixture in the cropping pattern. Mixed cropping of cereal is more common among manual farmers than animal traction farmers. Animal traction permits less intercropping with cowpeas because cowpeas lay between hills and makes weeding difficult. Table 5.1 also indicates that a large number of crop combinations are made by farmers. A maximum of three crop combinations will be considered in the model. All the enterprises and identification codes are presented in Appendix A.

The objective function is formalized as follows:

$$R = \sum_{j=1}^{n} C_j X_j$$

Subject to $\left(A \quad D\right) \left(x\right) \leq bi$

$X_j \geq 0$

where R is the net income

C_j is the net return per unit of the Jth activity expressed in CFA francs.

X_j is the Jth activity.

A = m x n matrix of technical coefficients for the activities.

x = n x 1 vector of activities level.

b = m x 1 vector of resource restriction.

The objective function is maximized subject to a set of 41 linear constraints. These are:

- three land constraints
- twelve monthly labor constraints
- one animal power constraint
- six constraints on the average yield permitted
- one fertilizer supply constraint
- three animal feed constraints
- one minimum subsistence requirement constraint
- fourteen capital constraints and/or transfer rows

Table 5.1
Percent Area Sown to Principle Cereal
Based Mixtures, Boromo Zone, 1981

Mixture		Sayero Manual	Sayero Traction
White sorghum	Sole	41	86
1. Maize		1	-
2. Cowpea		52	14
3. Cowpea-Maize		1	-
4. Sesame		5	-
Red sorghum	Sole	77	82
1. Maize		10	7
2. Maize-Sweet potatoe		-	8
3. Cowpea		2	1
4. Cowpea-Sesame		1	-
5. Sesame		4	-
6. Groundnut-Earthpeas		6	2
Millet	Sole	84	53
1. Cowpea		8	-
2. Cowpea-Maize		7	-
3. Cowpea-Groundnut		1	30
4. White sorghum		-	17
Maize	Sole	13	16
1. White sorghum		3	4
2. Red sorghum		39	39
3. Cotton		19	11
4. Rice		11	-
5. Sweet potatoe		-	12
6. Taro-Cotton		-	10
7. Others		15	8
Cotton	Sole	47	30
1. Maize		19	46
2. Groundnut		12	1
3. Cowpea		15	22
4. Earthpeas-Groundnut		4	-
5. Cowpea-Earthpeas		3	-
6. Earthpeas		-	1
Cereal	Sole	42	45
Mixed		26	14
Total	Sole	55	55
Mixed		45	45

Source: ICRISAT Annual Report 1982 p. G 19.

2. The Activities and the Objective Function Values

2.1 The activities

This section discusses the possibilities permitted by the model for the activities and the derivation of the objective function.

2.1.1 The Activities in the Model

Table 5.2 lists the 74 activities along with abbreviation used in the tableau (Appendix A).

The choice of possible cropping activities is determined by the technology, soil type, and crop mixtures. A distinction is made between cash crop (cotton) and food crop production activities including white and red sorghum, millet, and maize.

It is assumed that cotton mixed with any other crop is a cash crop production enterprise since cotton is usually the most important in intercropping with other crops.

Eight groups of activities are defined: food crop production activities and cotton production activities, both with hand tool and animal traction technologies; labor hiring activities, labor exchange activities, equipment hiring, capital transfers, consumption and borrowing activities.

2.1.2 Crop Production Activities

Cropping activities are defined in terms of sole or crop mixtures by combining the individual crop codes. For instance WS + MZ + CP will stand for a white sorghum, maize and cowpeas mixture. Only the most common mixtures found in the study area are presented in Appendix A.

2.1.3 Labor Hiring Activities

Labor hiring activities occur from May to December. Labor is hired any time during this period--especially from June to August for weeding and

Table 5.2

Linear Programming Tableau

ACTIVITIES	1 WSM	2 RSM	3 MLM	4 MZM	5 CTM	6 RS MZM	7 ML CPM	8 CT MZ CPM	9 RS MZ CPM
OBJECTIVE FUNCTION (1)	0	0	0	0	0	0	0	0	0
LAND CONSTRAINTS									
1 L1	1			1	1	1			1
2 L2	1	1	1	1	1		1	1	1
3 L3	1	1	1	1	1		1	1	1
FAMILY LABOR									
4 FLMY	102	73	16	189	38	78	9	92	332
5 FLJE	57	68	57	104	84	140	32	143	166
6 FLJY	252	292	202	522	272	226	148	438	520
7 FLAU	106	149	123	402	207	202	77	149	364
8 FLSE	33			345	14	78	22	86	110
9 FLOC	35	39		250		57	39	32	108
10 FLNO	83	73	93		15	32	123	28	223
11 FLDE	70		113		280		112	212	53
12 FLJA			34		253			246	16
13 FLFE			22		32			52	
14 FLMC	25	19	55		35	27	35	29	27
15 FLAP	37	24	57		42	31	37	38	36
16 ANTH									
PRODUCTION CONSTR.									
17 PWS	-415								
18 PRS		-736				-1000			-850
19 PML			-230				-230		
20 PMZ				-1720		-750		-700	-318
21 PCT					-1142			-800	
22 PCP							-55	- 24	- 90
INPUTS SUPPLY									
23 SUBR									
24 SFERT				82	136			136	
25 SFDJE									
26 SFDSE									
27 SFDFE									
OPERATING CAPITAL									
28 OPKMY				2255	3740			3740	
29 OPKJE				2255	3740			3740	
30 OPKJY									
31 OPKAU									
32 OPKSE									
33 OPKOC									
34 OPKNO									
35 OPKDE									
36 OPKJA									
37 OPKFE									
38 OPKMC									
39 OPKAP									
40 EOPK									
41 TEOPK									

ACTIVITIES	10 WSAT	11 RSAT	12 MLAT	13 MZAT	14 CTAT	15 CT MZ CPAT	16 RS MZ CPAT
OBJECTIVE FUNCTION (1)	0	0	0	0	0	0	0
LAND CONSTRAINTS							
1 L1	1	1		1			1
2 L2	1	1	1	1	1	1	1
3 L3	1	1	1	1	1	1	1
FAMILY LABOR							
4 FLMY	30	124	37	64	35		74
5 FLJE	65	63	67	283	99	72	76
6 FLJY	199	308	191	419	340	110	167
7 FLAU	43	81	66	132	77	42	54
8 FLSE	30			36	77	150	110
9 FLOC	25	58		253		170	130
10 FLNO	73	65	136			330	90
11 FLDE	65	27	110		350	270	37
12 FLJA			33		250	300	
13 FLFE		23			20	27	32
14 FLMC	25	25	43		35	40	39
15 FLAP	32	39	47		37	43	45
16 ANTH	7	70	8	61	17	31	25
PRODUCTION CONSTR.							
17 PWS	-460						
18 PRS		-780					-940
19 PML			-385				
20 PMZ				-1811		-700	-280
21 PCT					-1277	-827	
22 PCP						-54	-21
INPUTS SUPPLY							
23 SUBR							
24 SFERT		14		90	177	89	85
25 SFDJE							
26 SFDSE							
27 SFDFE							
OPERATING CAPITAL							
28 OPKMY		770		2475	4868	2448	2338
29 OPKJE				2475	4868	2448	2338
30 OPKJY	285	285	285	285	285	285	285
31 OPKAU							
32 OPKSE							
33 OPKOC	51	51	51	51	51	51	51
34 OPKNO	94	94	94	94	94	94	94
35 OPKDE							
36 OPKJA							
37 OPKFE	114	114	114	144	144	114	114
38 OPKMC							
39 OPKAP							
40 EOPK							
41 TEOPK							

ACTIVITIES	17 LHMY	18 LHJE	19 LHJY	20 LHAU	21 LHSE	22 LHOC	23 LHNO	24 LHDE
OBJECTIVE FUNCTION	-30 (1)	-30	-35	-35	-30	-30	-35	-35
LAND CONSTRAINTS								
1 L1								
2 L2								
3 L3								
FAMILY LABOR								
4 FLMY	-1							
5 FLJE		-1						
6 FLJY			-1					
7 FLAU				-1				
8 FLSE					-1			
9 FLOC						-1		
10 FLNO							-1	
11 FLDE								-1
12 FLJA								
13 FLFE								
14 FLMC								
15 FLAP								
16 ANTH								
PRODUCTION CONSTR.								
17 PWS								
18 PRS								
19 PML								
20 PMZ								
21 PCT								
22 PCP								
INPUTS SUPPLY								
23 SUBR								
24 SFERT								
25 SFDJE								
26 SFDSE								
27 SFDFE								
OPERATING CAPITAL								
28 OPKMY	30							
29 OPKJE		30						
30 OPKJY			35					
31 OPKAU				35				
32 OPKSE					30			
33 OPKOC						30		
34 OPKNO							35	
35 OPKDE								35
36 OPKJA								
37 OPKFE								
38 OPKMC								
39 OPKAP								
40 EOPK								
41 TEOPK								

ACTIVITIES	25 ELJY	26 ELAU	27 ELSE	28 ELOC	29 ATEOH	30 KTMY	31 KTJE	32 KTJY	33 KTAU	34 KTSE	35 KTOC
OBJECTIVE FUNCTION	0 (1)	0	0	0	-50	0	0	0	0	0	0
LAND CONSTRAINTS											
1 L1											
2 L2											
3 L3											
FAMILY LABOR											
4 FLMY					-1						
5 FLJE											
6 FLJY	1										
7 FLAU		1									
8 FLSE			1								
9 FLOC				1							
10 FLNO											
11 FLDE											
12 FLJA											
13 FLFE											
14 FLMC											
15 FLAP											
16 ANTH											
PRODUCTION CONSTR.											
17 PWS											
18 PRS											
19 PML											
20 PMZ											
21 PCT											
22 PCP											
INPUTS SUPPLY											
23 SUBR											
24 SFERT											
25 SFDJE											
26 SFDSE											
27 SFDFE											
OPERATING CAPITAL											
28 OPKMY					50	1					
29 OPKJE						-1	1				
30 OPKJY							-1	1			
31 OPKAU								-1	1		
32 OPKSE									-1	1	
33 OPKOC										-1	1
34 OPKNO											-1
35 OPKDE											
36 OPKJA											
37 OPKFE											
38 OPKMC											
39 OPKAP											
40 EOPK											
41 TEOPK											

ACTIVITIES	36 KTNO	37 KTDE	38 KTJA	39 KTFE	40 KTMC	41 KTAP	42 KT	43 SWS	44 SRS	45 SML	46 SMZ	47 SCT	48 SCP
OBJECTIVE FUNCTION	0	0	0	0	0	0	0	58	58	60	55	62	90
	(1)												
LAND CONSTRAINTS													
1 L1													
2 L2													
3 L3													
FAMILY LABOR													
4 FLMY													
5 FLJE													
6 FLJY													
7 FLAU													
8 FLSE													
9 FLOC													
10 FLNO													
11 FLDE													
12 FLJA													
13 FLFE													
14 FLMC													
15 FLAP													
16 ANTH													
PRODUCTION CONSTR.													
17 PWS								1					
18 PRS									1				
19 PML										1			
20 PMZ											1		
21 PCT												1	
22 PCP													1
INPUTS SUPPLY													
23 SUBR													
24 SFERT													
25 SFDJE													
26 SFDSE													
27 SFDFE													
OPERATING CAPITAL													
28 OPKMY													
29 OPKJE													
30 OPKJY													
31 OPKAU													
32 OPKSE													
33 OPKOC													
34 OPKNO	1												
35 OPKDE	-1	1											
36 OPKJA		-1	1										
37 OPKFE			-1	1									
38 OPKMC				-1	1								
39 OPKAP					-1	1							
40 EOPK						-1	1						
41 TEOPK							1						

ACTIVITIES	49 BWS	50 BRS	51 BML	52 BMZ	53 BCP	54 BFERT	55 BFDJE	56 BFDSE	57 BFDFE	58 CONSWS	59 CONSRS
OBJECTIVE FUNCTION (1)	-83	-83	-83	-80	-130	-55	-45	-45	-45	0	0
LAND CONSTRAINTS											
1 L1											
2 L2											
3 L3											
FAMILY LABOR											
4 FLMY											
5 FLJE											
6 FLJY											
7 FLAU											
8 FLSE											
9 FLOC											
10 FLNO											
11 FLDE											
12 FLJA											
13 FLFE											
14 FLMC											
15 FLAP											
16 ANTH											
PRODUCTION CONSTR.											
17 PWS	-1									1	
18 PRS		-1									1
19 PML			-1								
20 PMZ				-1							
21 PCT											
22 PCP					-1						
INPUTS SUPPLY											
23 SUBR										1	1
24 SFERT						-1					
25 SFDJE							-1				
26 SFDSE								-1			
27 SFDFE									-1		
OPERATING CAPITAL											
28 OPKMY											
29 OPKJE											
30 OPKJY											
31 OPKAU											
32 OPKSE											
33 OPKOC											
34 OPKNO											
35 OPKDE											
36 OPKJA											
37 OPKFE											
38 OPKMC											
39 OPKAP											
40 EOPK											
41 TEOPK											

ACTIVITIES	60 CONSML	61 CONSMZ	62 CONSCP	63 BRWMY	64 BRWJE	65 BRWJY	66 BRWAU
OBJECTIVE FUNCTION (1)	0	0	0	-1.155	-1.142	-1.130	-1.177
LAND CONSTRAINTS							
1 L1							
2 L2							
3 L3							
FAMILY LABOR							
4 FLMY							
5 FLJE							
6 FLJY							
7 FLAU							
8 FLSE							
9 FLOC							
10 FLNO							
11 FLDE							
12 FLJA							
13 FLFE							
14 FLMC							
15 FLAP							
16 ANTH							
PRODUCTION CONSTR.							
17 PWS							
18 PRS							
19 PML	1						
20 PMZ		1					
21 PCT							
22 PCP			1				
INPUTS SUPPLY							
23 SUBR	1	1	1				
24 SFERT							
25 SFDJE							
26 SFDSE							
27 SFDFE							
OPERATING CAPITAL							
28 OPKMY				-1			
29 OPKJE					-1		
30 OPKJY						-1	
31 OPKAU							-1
32 OPKSE							
33 OPKOC							
34 OPKNO							
35 OPKDE							
36 OPKJA							
37 OPKFE							
38 OPKMC							
39 OPKAP							
40 EOPK							
41 TEOPK							

ACTIVITIES	67 BRWSE	68 BRWOC	69 BRWNO	70 BRWDE	71 BRWJA	72 BRWFE	73 BRWMC	74 BRWAP
OBJECYIVE FUNCTION (1)	-1.105	-1.092	-1.08	-1.067	-1.054	-1.042	-1.029	-1.155
LAND CONSTRAINTS								
1 L1								
2 L2								
3 L3								
FAMILY LABOR								
4 FLMY								
5 FLJE								
6 FLJY								
7 FLAU								
8 FLSE								
9 FLOC								
10 FLNO								
11 FLDE								
12 FLJA								
13 FLFE								
14 FLMC								
15 FLAP								
16 ANTH								
PRODUCTION CONSTR.								
17 PWS								
18 PRS								
19 PML								
20 PMZ								
21 PCT								
22 PCP								
INPUTS SUPPLY								
23 SUBR								
24 SFERT								
25 SFDJE								
26 SFDSE								
27 SFDFE								
OPERATING CAPITAL								
28 OPKMY								
29 OPKJE								
30 OPKJY								
31 OPKAU								
32 OPKSE	-1							
33 OPKOC		-1						
34 OPKNO			-1					
35 OPKDE				-1				
36 OPKJA					-1			
37 OPKFE						-1		
38 OPKMC							-1	
39 OPKAP								-1
40 EOPK								
41 TEOPK								

ACTIVITIES	SIGNS (2)	RHS	ROW#
OBJECTIVE FUNCTION (1)			
LAND CONSTRAINTS			
1 L1	1	.90	1
2 L2	1	1.40	2
3 L3	1	2.50	3
FAMILY LABOR			
4 FLMY	1	135	4
5 FLJE	1	298	5
6 FLJY	1	635	6
7 FLAU	1	520	7
8 FLSE	1	304	8
9 FLOC	1	205	9
10 FLNO	1	185	10
11 FLDE	1	110	11
12 FLJA	1	80	12
13 FLFE	1	71	13
14 FLMC	1	90	14
15 FLAP	1	90	15
16 ANTH	1	50	16
PRODUCTION CONSTR.			
17 PWS	1	0	17
18 PRS	1	0	18
19 PML	1	0	19
20 PMZ	1	0	20
21 PCT	1	0	21
22 PCP	1	0	22
INPUTS SUPPLY			
23 SUBR	3	2340	23
24 SFERT.	1	0	24
25 SFDJE	1	0	25
26 SFDSE	1	0	26
27 SFDFE	1	0	27
OPERATING CAPITAL			
28 OPKMY	1	28830	28
29 OPKJE	1	0	29
30 OPKJY	1	0	30
31 OPKAU	1	0	31
32 OPKSE	1	0	32
33 OPKOC	1	0	33
34 OPKNO	1	0	34
35 OPKDE	1	0	35
36 OPKJA	1	0	36
37 OPKFE	1	0	37
38 OPKMC	1	0	38
39 OPKAP	1	0	39
40 EOPK	1	0	40
41 TEOPK	3	28830	41

NOTES:
(1) ALL ACTIVITIES ARE ON A PER HECTARE BASIS.
(2) RESTRICTION SIGN CODES: 1 = Less or Equal
3 = Greater or Equal

November to December for harvesting. The wage rates discussed earlier in Chapter II are 350 CFA francs/day (food included) for the peak period of weeding and harvesting and 300 CFA francs/day for non-peak periods.

2.1.4 Exchange Labor

Labor is exchanged during the peak labor demand periods of land preparation, weeding and tillage. Farmers participating in labor associations work for each other without any payment in monetary terms. Exchange labor is cost free in the model.

2.1.5 Equipment Hiring

Equipment is hired primarily during land preparation. Farmers may hire an oxen traction team for a work day. This activity may include a piece of equipment such as a plow.

2.1.6 Cotton Selling

All cotton produced is sold in February at the farm gate price to the SOFITEX marketing service. This price was 62 CFA francs/kg in 1982. It is assumed that all cotton will be sold at this price without any discount for quality.

2.1.7 Input Buying

Activities to buy inputs include fertilizers purchased at the subsidized price of 55 CFA francs/kg and animal feed on the quarterly basis discussed earlier in Chapter II.

Appendix C displays budget tables for all cropping enterprises in the model. Appendix C is important in the farm income analysis because the data help to explain the linear program tableau and the internal structure of the farm. Each table displays three main categories: the value of the output, the variable costs and the performance measures including the gross income and the gross margin.

The output section comprises the average physical output of all enterprises in a particular combination of crops as well as the value of production. Prices used to value production are the same as those used in the model. The value of the output represents the average gross revenue realized by a farmer who grows one hectare of the crop enterprise in question. In the case of mixed cropping, the output values of each crop are summed to provide the total value of the farm output.

Depending on the technology used to perform work on the farm, the variable costs section may include the hiring of farm equipment for animal traction. Fertilizer cost appears in the budgets only for cotton and maize in sole or mixed cropping. Non-wage payment such as drink and food provided by the household head to non-family workers are not in the budget because they are not usually paid in cash and these costs are repaid in kind when the farmer does exchange labor.

Each enterprise performance was evaluated in gross margin format by substracting the variable costs from the total value of output.

2.1.8 Capital Transfers

Monetary capital is transfered all year long from May to April, especially for animal traction farmers. From May to August the amount of capital used in farming increases because farmers pay for fertilizer and labor hiring activities which normally continue until December. Operating capital requirements are also modeled for animal maintenance costs, the wage rate and the average amount of fertilizer used. Capital was entered in the model on a monthly basis with a savings reserve starting in May.

2.1.9 Borrowing

It is assumed in the model that farmers could borrow from money lenders and from friends to supplement their personal cash to finance farming. Also, it is widely known in the survey area that SOFITEX provides short term loan to farmers using inputs in cotton. The official interest rate charged is 15.5% (World Bank, 1982 p. 172).

2.2 The Objective Function Values

Hiring activities for hand labor and the animal traction were entered in the objective function in each month as a cost (CFA francs/hour) estimated from the free market. The objective function value for income producing crops are based on CFA francs per kilogram of product sold. The selling activity for each crop was entered at the official farm gate price and the buying activity at the official market price. The same principle applies to the feed buying activities.

Borrowing is entered with an interest rate of 15.5% per year. This rate decreases by .0125% per month from May to March, assuming that the farmer can borrow at any time.

3. Resources Available and constraints

3.1 Land

The model includes 5.0 hectares for a mean household of 13 members for both hand tool and animal traction farmers. The land farmed by the mean household in the model is composed with .9 ha of "near the house" land, 1.4 ha of "in village" land and 2.5 ha of "in bush" land. Even though land seems to be "unlimited" and "free" its use in farming faces some constraints such as the trip from the village to the field, the level of fertility and the farming technology.

The number of fields per household in each class of land is quite variable. Usually farmers have fewer fields on land "next to house" than on any other land class. For instance, they may plow 2 fields "next to house"; 3 on "in village" land and 6 on "in bush" land.

3.2 Labor Available

3.2.1 Structure of the constraint

Michael Collinson (1983) suggested that the season be divided into periods in model building. The periods may be based on regular time intervals--weeks, fortnights, or months--or they may vary with the necessary timeliness of particular farm operations. Agricultural labor demand is related to rainfall, cropping pattern and the technology used. For our model, monthly intervals are used, justified by the labor intensive operations and the practice of staggered planting. The monthly interval is a matter of convenience and the interpretation of the results should allow some flexibility.

3.2.2 Estimation of Labor Available

The estimated number of hours of work available in each month is divided by the number of households in the sample. All labor categories were converted to a man-hour equivalent. Man and woman hours were considered to have the same values, whereas for children under 10 years old, hours were multiplied by .5 and converted to man hours (D.W. Norman,1971). Hired labor was not counted in household labor available. All labor in the model was used in farming; no off-farm employment of labor was considered.

The quantification of labor availability and use over the season is a major objective of investigation. Michael Collinson (1983) treats both availability and use of labor as flows which are meaningful only at points in time. The estimation of labor use is straightforward. On the other hand, its availability is more difficult to evaluate.

Among the techniques used for estimating labor availability, the constraint of observed usage at peak periods is accepted as a limit throughout the seasons (Michael Collinson, 1983 p. 197). The family is the main source of labor supply in peasant farming. Three factors that affect labor availability are: age, number of hours on a working day, and time spent on off-farm work. These factors give different bases for the amount of labor available and a wide variation in total farming hours. Another aspect which should be considered is the specialization by sex in the family. Woman labor and man labor are not perfectly substitutable.

The effect of climate or weather can be a limitation on work performed on the farm. Some farm activities such as plowing cannot be done for more than 6 hours a day; likewise, planting requires a certain minimum amount of rain.

In the Boromo region we are going to estimate labor availability with the assumption that men specialize in land preparation, weeding and thinning, whereas women sow and harvest.

3.3 Animal Power Available

All animal team hours were recorded. The constraint is found by adding up the animal time and by dividing the total by the number of equipped households. This gives a constraint of 50 hours per household. Animal traction is used mostly from June to August for preparation and weeding of fields, but it is aggregated as one constraint in the model.

3.4 Consumption Requirements

The FAO estimated that the average person in the country must consume 180 kg of cereals per year to meet the minimun requirement of 2,370 calories per person per day. For the average household of 13 persons the annual minimum cereal consumption should be 2340 kg.

3.5 Operating Capital

This includes all production expenses on fertilizers, hired labor and costs for animal maintenance. The model assumes that hand tool farmers have access to the same amount of capital as animal traction farmers.

3.6 Non-negative constraint

None of the activities discussed can be operated at negative levels.

4. Derivation of the Input-output Coefficients

The input-output coefficients (aij's) express the amount of input i needed for one unit of activity j. For instance in the case of labor input, a coefficient for the activity white sorghum (WS) with hand tool technology will tell us the hours of labor required per hectare for the production of one unit of white sorghum during the defined time period. The following section discusses some problems and the derivation of the technical coefficients in the model.

4.1 Land

The average farm land per household was used as the total land constraint. The constraint on each type of land was found from the area used for specific crops usually grown on the type of land in question. For instance, maize is usually grown on land "next to house". Therefore, all maize fields were cumulated and divided by the total number of households to estimate land "next to house". One hectare of each land type is allocated to the corresponding enterprise to estimate the net return from one hectare of each enterprise. The land coefficient is one for all corresponding enterprises.

4.2 Labor

The derivation of labor coefficients in an L.P. model can be done either with average coefficients, "synthetic coefficients" based on " subjective evaluation of the data"(Crawford,1980) or by using multiple regression technique as suggested by Balcet and Chandler (1981). The approach followed in this study is the average coefficients per hectare. The ratio obtained by dividing the total number of hours spent on an enterprise within a particular time period by the total area of land in hectares allocated to the enterprise in question, is the input-output coefficient.

The calculation for the labor usage coefficients can be illustrated as:

$$a_{ij} \text{ for labor is: } \sum_{j=1}^{n} T_{ij} / \sum_{j=1}^{n} F_{ij} \quad (j = 1...n) \text{ and } (i = 1...12)$$

where a_{ij} = input-output coefficient for labor during month i for 1 hectare of activity j.

T_{ij} = total number of hours spent in all fields of activity j during month i.

F_{ij} = total area in hectares allocated to crop production activity j during month i.

i = monthly time period

j = cropping activities

This calculation is done for all crop production activities under each production technology. Implicitly, it is assumed that all crops in the crop mixtures are produced with uniform technology, either hand tool or animal drawn technology.

4.3 Production Coefficients

These were found by dividing the total output in kilograms by the total area in hectares planted with the specific crop or crop combination.

4.4 Operating Capital

Fertilizer used per hectare of each crop enterprise times the subsidized price of 55 CFA francs/kg was entered in the model for each crop and combination of crop on which fertilizer was spread. The cost of hired labor is entered in May, June, September and October for non-peak periods at a wage rate of 30 CFA francs/hour; and in July, August, November and December for the peak periods of weeding and harvesting at a wage rate of 35 CFA francs/hour. Animal maintenance costs are entered quarterly for all crops under animal traction technology. The expenses during each quarter were divided by the number of activities performed with animal traction. This ratio was entered in the first month of each quarter for all animal plowed enterprises. It is assumed that the technology is evenly used on all enterprises.

Concluding Remarks

Three aspects of the farming in Boromo appear in this farm model tableau: 1) the technology used in farming; 2) the cropping pattern, either sole or mixed cropping; and 3) the utilization of land, labor and capital in both technological group of farmers. The main purpose is to determine the optimal farm plan. It is expected that this farm plan will indicate which technology is the most profitable for farmers and the competitve position of sole and mixed cropping. In addition, since there is a fixed supply of resources, the linear program will estimate the income generating potential of additional resources.

CHAPTER VI

RESULTS FROM THE BASIC MODEL AND SENSITIVITY ANALYSIS

> Economists of underdeveloped countries are beginning to realize that the farmer is no fool. A non-fool, in a static environment, learns to live 'efficiently': to optimize, given his value and constraints, and to teach his children to do the same. (Lipton, 1968)

The preceding chapters have provided the framework for analyzing the economics of resource use on farms in the Boromo region of Burkina faso. The specific farm problems being addressed were: 1) the relative profitability of single cropping versus mixed cropping systems, 2) the profitability of cropping systems under animal traction and hand cultivation, 3) the allocation of land, labor and purchased inputs between cotton and cereals.

This chapter will focus on the analysis of the model's optimal solution and sensitivity analysis of critical variables. The results must be interpreted with care, keeping in mind the context of the Boromo region farm environment and the main assumption of profit maximization. Sensitivity analysis will be performed on critical parameters to determine their impact on the optimal solution. The capital constraint will be increased to determine if credit availability affects decisions by farmers in the Boromo region. The fertilizer price will be increased in the objective function to observe the effect of subsidy suppression on farmers' decisions. Among the objective function values, the producer price will be increased to observe its effect on the optimal solution. The impact of an increase in the actual crop yields will also be analyzed.

1. The Optimal Solution

1.1 The Base Run

The objective function is maximized by three hand tool technology enterprises and one oxen traction enterprise: Single-cropped red sorghum; red sorghum and maize intercropped; and two enterprises of cotton-maize-cowpeas intercropped. Only one of the intercropped cotton-maize-cowpeas is under oxen plow technology. Table 6.1 displays the enterprises in the solution with the amount of land used.

The objective function is maximized at 27,540 CFA francs. All available land "next to house" and "in village" is utilized, whereas there still remains 1.1 hectare of unused "bush" land. The marginal value product of the first type of land is 93,707 CFA francs per hectare and 36,431 for the second type (see Table 6.2). The high MVP of "in village" land can be explained by the fact that it is very fertile and does not require any purchased input to grow crops. Table 6.1 and 6.2 show that only "in bush" land is left over and has a zero shadow price which indicates an excess supply of this land class at existing fixed resource levels.

All the estimated initial capital was exhausted. The farmer has to borrow 3,506 CFA francs.

Table 6.1

Results From the Basic Model:
Enterprises in the Optimal Solution

Activities	Enterprises label	Optimal level in ha	Upper limit imposed by constraints(ha)
Red sorghum * "in village" (manual)	RSm	1.12	1.4
Red sorghum and Maize "next to house"(manual)	RS+MZm	.90	.9
Cotton,Maize and Cowpea* "in village" (manual)	CT+MZ+CPm	.057	1.4
Cotton, Maize and Cowpeas "in bush" (traction)	CT+MZ+CPat	.22	2.5

Note:

1) Maximized objective function value is 27,540 CFA francs.
2) For details see Appendix B.
(*) Crops which could also be grown on "in bush" land. In this case, the constraint limit would be 2.5 ha.

Table 6.2 displays the shadow price of the resources in the optimal solution. A labor shadow price of zero at all time periods except in January, May6 and November reflects the fact that there is generally a labor surplus. The usual labor bottlenecks during planting (June) and weeding (July, August) have been removed with the flow of exchange labor. However, the January, May and November labor bottlenecks are due to simultaneous cotton harvesting, crop transport and land preparation.

The results indicate that hand tool technology is economically superior to animal traction technology, given the assumptions and structure as described previously. Likewise, intercropping seems to be more profitable than single cropping since mostly mixed crops appear in the optimal plan. However, Table 6.3 shows that cotton under oxen traction is the second most competitive activity, followed by hand plowed cotton, oxen plowed millet and oxen plowed maize, as suggested by their penalty costs on a per hectare basis.

1.2 <u>Consistency of the Optimal Solution with Reality</u>

The maximized objective function of 27,540 CFA francs is a realistic figure for the study region. It could however be somewhat over or underestimated depending on whether the market price of the commodities is above or below the official price used in the model. In any case, the net profit of 27,540 CFA francs per hectare remains in the range of likely figures for the peasant farmer in Boromo.

The amount of money borrowed to meet the capital requirement (3,506 CFA francs) is more likely to be underestimated because of the difficulties in finding an accurate figure for initial money available to an average farmer. Internal financing is common in traditional agriculture because at low technology levels, capital requirements are minimal. At the current stage of agricultural development in the region, the financial needs of animal traction farmers are

Table 6.2

Results From the Basic Model: Slack and Shadow Prices in the Optimal Solution

Row#	Resource	Shadow Prices (CFA francs)
1	L1	93,707
2	L2	36,431
3	L3	0
4	FLMY	60
5	FLJE	0
6	FLJY	0
7	FLAU	0
8	FLSE	0
9	FLOC	0
10	FLNO	25
11	FLDE	0
12	FLJA	132
13	FLFE	0
14	FLMC	0
15	FLAP	0
16	ANTH	0
28	OPKMY	1.029
29	OPKJE	1.029
30	OPKJY	1.029
31	OPKAU	1.029
32	OPKSE	1.029
33	OPKOC	1.029
34	OPKNO	1.029
35	OPKDE	1.029
36	OPKJA	1.029
37	OPKFE	1.029
38	OPKMC	1.029
39	OPKAP	1.029

Notes: Maximized objective function value is 27,540 CFA francs. See Appendix A for row identification.

Table 6.3

Results From the Basic Model: Cost of Forcing in Nonoptimal Enterprises

Column$	Activities	Enterprise label	Cost of forcing in (CFA francs)
1	White sorghum (Manual)	WSm	103,964
3	Millet (Manual)	MLm	30,387
4	Maize (Manual)	MZm	56,194
5	Cotton (Manual)	CTm	16,767
7	Millet and Cowpea (animal traction)	ML+CPat	21,284
8	Red sorghum Maize and Cowpea (Manual	RS+MZ+CPm	83,101
9	White sorghum (animal traction)	WSat	96,214
10	Red sorghum (animal traction)	RSat	96,239
11	Millet (animal traction)	MLat	26,101
12	Maize (animal traction)	MZat	45,089
13	Cotton (animal traction)	CTat	10,508
14	Red sorghum Maize and cowpea (animal traction)	RS+MZ+CPat	75,169

Notes: 1) Maximized objective function value is 27,540 CFA francs.
2) See Appendix B for all nonoptimal enterprises.

higher than those of hand tool farmers. A rapid expansion in animal traction technology and associated input use may necessitate more external financing.

The low and variable farm income because of weather uncertainty and associated crop failures leads to an increase in farm financial problems. The downside income risk created by added interest expense may lead to a decline in available funds and reluctance to adopt more capital intensive technology. For the Boromo farmers, the perceived risk of unprofitability of the new technology militates towards a low debt ceiling. Even with more credit available, farmers would probably not use as much credit as might be economically optimal in a static evaluation because of the high risk environment in which they are operating.

The optimal solution indicates that the minimum food requirement is met through the consumption of maize. The cereals consumed in the region include maize, millet, red sorghum, and white sorghum. Farmers usually prefer maize; but the quantity harvested is not sufficient to meet the entire year's food requirement. Furthermore, maize is harvested in September when the previous year's grain stocks are reduced to their lowest level. It plays the role of a security crop between previous and current harvest. If maize is consumed through the year, maize harvested from the field has to be supplemented with some quantity purchased as expressed by the optimal plan. For detailed data of computer results, see Appendix B.

Table 6.2 shows that the unutilized land is in the countryside, far from the village. This land has some disadvantages relative to other land classes due to: 1) travel time from the village to the fields; 2) risk of crop destruction by wild animals and birds; and 3) lower fertility. Land "in the village" and land "next to house" is more limited in terms of quantity. This aspect is expressed by the high shadow price.

The shadow price of labor does not show the labor shortage faced by farmers during some specific farm operations such as weeding and plowing. This may be caused by the monthly division of labor used in the model and the large amount of exchange labor used. However, a general excess of labor in the region is a reality. The slack of animal power is due to the fact that oxen are used in only a few farm operations: land preparation, plowing and crop transportation. This makes animal traction financially less attractive. Moreover, it reduces labor bottlenecks for some farming operation but may worsen them for others. For instance, if land under cultivation is expanded due to animal traction cultivation, more time may be required for harvesting.

One of the weaknesses of linear programming is that the assumption of factor divisibility may lead to unrealistic results in practice. Table 6.1 gives a figure of .22 ha of intercropped cotton, maize and cowpeas plowed with oxen in the optimal solution. Actually, this area is very small for oxen cultivation. A farmer who owns oxen will probably use his draft power on much larger land area. While a constraint could be added to reflect a minimum land required to make oxen cultivation profitable, there exists no empirical basis for estimating this constraint. Also, .22 ha is meaningful for certain commodities such as okra or cowpeas, but not for others such as cotton.

Sensitivity Analysis

D. R. Anderson et al (1982, p. 141) define sensitivity analysis as the study of changes in the optimal solution of the linear program, given changes in various coefficients of the problem. In this study, the sensitivity analysis will be performed in two sections. Discussed in this section are the results from a change of one or a group of coefficients under ceteris paribus condition. The purpose of this section is to determine the most effective agricultural development policy tools for increasing profitability in the study region. It will evaluate whether efforts should focus on economic tools (prices, interest rate, input price, agricultural commodities price) or technical tools (improved variaties, labor intensive or capital intensive technology). The results are intended to suggest the direction and magnitude of change in the objective function, resulting from a variation of a coefficient or group of coefficients, ceteris paribus.

The more sensitive the base solution is to a group of coefficients, the more efficient these coefficients are as policy tools if farmers' net returns are to be increased.

2.1 Economic Parameters

2.1.1 Producer Price:

Selected producer prices for a food grain (sorghum) and a cash crop (cotton) were increased from 15 to 60% above the base run price to observe their effect on the optimal solution. As shown in Tables 6.4 and 6.5, the objective function appeared to be very sensitive to sorghum price increase relative to cotton price increase.

A 15% increase in sorghum price led to 56% increase in net return in the optimal solution whereas a 15% increase in cotton price resulted in only a 7% increase in the optimal solution. The large sorghum price effect can be explained partially by the fact that both red and white sorghum prices were increased by the same percentage simultaneously. The sorghum price effect in the model did not change the activities in the solution relative to the base run because of the presence of two red sorghum activities in the base-run optimal solution. These activities cannot be increased because of land class one and class two constraint limits.

Beyond the 30% increase in cotton price, intercropped cotton-maize-cowpeas plowed with hand tools (0.56ha) is replaced by single crop oxen plowed cotton (.051ha) in the optimal solution. This result indicates that cotton produced with animal traction could be economically profitable if its price were increased by 30% above the base run price.

Table 6.4

Effect of Producer Price of Sorghum Increase on the Optimal Solution

Increase in Price (%)	White and Red Sorghum Price (CFA/kg)	Objective Function Value (CFA/ha)	Increase in Op. Sol. (%)
15	67	43,080	56
30	75	56,893	107
45	84	72,432*	163
60	93	87,972*	219

Notes: Base run price: 58 CFA francs
Base run optimal solution: 27,540 CFA francs

(*) Consumer price is raised by 30% above base run consumer price to avoid unboundness of optimal solution.

Table 6.5

Effect of Cotton Price Increase On the Optimal Solution

Increase in Price (%)	Cotton Price (CFA/kg)	Objective Function Value (CFA/ha)	Increase in Op. Sol. (%)
15	71	29,588	7
30	81	31,862	16
45	90	34,017	24
60	99	37,310	35

Notes: Base run price: 62 CFA francs
Base run optimal solution: 27,540 CFA francs

2.1.2 Release of Capital Constraint:

Where capital-intensive activities such as oxen traction are profitable and are employed, an increase of available capital should be expected to bring more oxen-traction activities into the solution. However, in this model of the Boromo region, optimal solution does not change when the capital constraint is relaxed. The more intensive capitalized cropping activities were not sufficiently profitable to encourage their adoption over hand-tool technology. In a high-risk substance style agricultural environment such as the Boromo region, farmers may not choose to borrow more money if available, because of increased risk exposure. The increase in potential profitability from using more purchased inputs may be viewed as also increasing the chance for financial failure. Table 6.6 shows that the optimal solution does not change when capital is increased 15 to 60% above the base run capital amount.

Table 6.6

Effect of Capital Constraint Release
on the Optimal Solution

Percent Increase	Capital Available (CFA/ha)	Objective Function Value (CFA/ha)
15	33,155	27,540
30	37,479	27,540
40	41,804	27,540
60	46,128	27,540

Notes: Base run capital: 28,830 CFA/ha
Base run optimal solution: 27,540 CFA

2.1.3 Progressive Fertilizer Subsidy Removal:

The actual fertilizer price use in the model is 55 CFA francs per kg. Without a subsidy from the government, fertilizer would cost 127 CFA francs per kg. Sensitivity analysis was performed assuming a progressive increase from 15 to 60% above the base run price.

The results suggest that the objective function is not very sensitive to an increase in fertilizer price. For instance, an increase of 15% above the base run price of fertilizer leads to a less than 1% decrease in the objective function value. Table 6.7 presents the objective function values that correspond to step increases in fertilizer prices. The activities in the solution remain unchanged relative to the base run optimal solution. The increase in fertilizer price does not affect the quantity used; it stays unchanged at 27 kg.

Table 6.7

Effect of Fertilizer Subsidy Removal on the Optimal Solution

Increase above Initial Price (%)	Fert. Price (CFA/kg)	Objective Function Value (CFA/ha)	Decrease in Objective Funct. Value (%)
15	63	27,322	.79
30	72	27,076	1.68
45	80	26,858	2.47
60	88	26,640	3.26

Notes: Base run price: 55 CFA francs
Base run Optimal Solution: 27,540

2.2 Technical Parameters

Selected yields for cotton, red sorghum, white sorghum and maize were increased for animal traction technology under ceteris paribus condition in the sensitivity analysis. The results show the yields increase required to make oxen drawn technology more profitable.

However, an increase in yield presuppose an increase in associated input costs. Therefore, the net return given by a yield increase under the ceteris paribus assumption is overestimated.

2.2.1 Change in Cotton Yield:

Table 6.8 shows that the objective function is sensitive to a cotton (oxen plowed single crop) yield inicrease. A yield increase of 30% bring this activity into the solution and implies an 8% increase above the base run net profit. Beyond a 30% increase, the results suggest that farmers with oxen traction technology will tend to drop mixed cropping enterprises and specialize in single cropping under the assumption of profit maximization (see Table 6.9).

Table 6.8

Effect of Oxen Plowed Cotton (Sole Crop) Yields Increase in the Optimal Solution

Increase above Initial Yields (%)	Cotton Yields (kg/ha)	Objective Function Value (CFA/ha)	Increase in Opt. Solution (%)
15	1,469	27,611	--
30	1,660	29,757	8
45	1,852	33,522	22
60	2,943	55,168	100

Notes: Base run yields: 1277 kg/ha
Base run optimal solution: 27,540 CFA francs

Compared to the base run, two hand plowed activities and one oxen plowed activity are in the optimal solution. One hand plowed red sorghum single crop, two red sorghum and maize intercropped activities (one hand plowed, the other oxen plowed) maximize profit at 45% and 60% yield increse.

At a 15% increase in cotton yield, hand plowed cotton-maize and cowpeas intercropped (.056 ha in base run solution) exits from the base solution. This activity is replaced by .051 ha of traction plowed cotton. Compared to the base solution, one additional animal traction activity comes into the solution whereas one hand plowed activity exits when cotton yield is increased by 15% above the base run yield. The activities in the solution are: hand plowed red sorghum (1.12 ha); hand plowed red sorghum and maize intercropped (.90 ha); traction plowed cotton (.05 ha) and traction plowed cotton, maize and cowpeas intercropped (.22 ha). The activities in the solution do not change at a 30% increase in cotton yield. However, the amount of land allocate to each enterprise in solution becomes 1.08 ha; .90 ha; .30 ha and .01 ha respectively. This suggests that more land is cultivated with oxen when cotton yields increases (.27 ha at 15% yield increase versus .31 ha at 30% yield increase).

From 45 to 60% cotton yield increase, traction plowed cotton-maize and cowpeas intercropped (.22 ha) exits from the solution. Three activities remain in solution: hand plowed red sorghum (1.08 ha); hand plowed red sorghum and maize intercropped (.90 ha) and traction plowed cotton-maize and cowpeas intercropped (.32 ha). Only one oxen plowed activity remains in the solution when cotton yield is increased from 45 to 60% above the base run cotton yield but more land is allocated to this activity (.32 ha) than the two oxen plowed activities combined in solution at 15 and 30% cotton yield increase (.27 ha).

These results suggest that animal traction technology becomes economically attractive when cotton yield is increase.

Table 6.9

Area of Cotton and Quantity of Fertilizer in Solution When Oxen Plowed Cotton Yields are Increased

Yields (kg/ha)	Object. Funct. (CFA/ha)	Area of Cotton (ha)		Fertilizer Used (kg/ha)
		Sole	Mixed	
1,277	27,540	--	.22*	27.31*
1,469	7,611	--	.22	28.93
1,660	29,757	.30	.01	54.99
1,852	33,522	.32	--	56.64
2,943	55,168	.32	--	56.64

Note: (*) indicates base run figures in optimal solution.

2.2.2 Change in Maize Yield:

Table 6.10 displays the changes in the objective function value of the optimal solution when maize yields are raised. A 30% increase in yields leads to an increase of the farm net profit by 9%. However, the activities in the solution remain the same as in the base run: hand plowed red sorghum; cotton, maize and cowpeas intercropped and oxen plowed cotton, maize and cowpeas intercropped. Beyond a 30% increase in maize yields, the crop combination of cotton, maize and cowpeas hand plowed drops out of the optimal solution and is replaced by oxen plowed maize. The quantity of fertilizer which maximizes profit goes up to 36 kg/ha leading to a 3% increase in money borrowed.

Table 6.10

Effect of Oxen Plowed Maize Yield
Increase on Optimal Solution

Increase on Initial Yields (%)	Yields (kg/ha)			Objective Function Value (CFA/ha)	Increase In Obj. F.[4] (%)
	a[1]	b[2]	c[3]		
15	2083	322	805	28,811	4
30	2354	364	910	30,082	9
45	2626	406	1015	32,124	17
60	2898	448	1120	39,653	44

Notes: 1) Maize Yield when single cropped. Initial yield: 1811 kg/ha. This yield is remarkably high in the region because of soil differences and field locations.

2) Maize yield when intercropped with red sorghum and cowpeas. Initial Yields: 280 kg/ha.

3) Maize yield when intercropped with cotton and cowpeas. Initial Yields: 700 kg/ha.

2.2.3 Change in sorghum Yield:

The objective function of the optimal solution was found to be insensitive to an increase in white sorghum yields (oxen and hand plowed. Even a 60% increase in white sorghum yields was not sufficient to make this enterprise more profitable than the ones already in the solution.

Concluding Remarks

This chapter provides answers to the questions highlighted in the introduction of this report.

1) Mixed cropping activities contribute more to the optimal solution than do single cropping activities. Among the four enterprises in the optimal solution, there is only one single crop enterprise (hand plowed red sorghum).

Enterprises in solution are: mixed crops, hand plowed red sorghum-maize; cotton-maize; cowpeas (one hand and one oxen plowed). These results indicate that the mixed cropping system actually practiced by Boromo farmers is consistent with a profit maximization objective.

2) The base-run results also indicate that hand tool technology is economically superior to animal traction technology since only one oxen plowed activity came into the solution in comparison with three hand plowed activities.

3) The base solution shows that purchased inputs are allocated mostly to cotton rather than cereals. The fact that the quantity of fertilizer which maximizes profit increases when more land is allocated to cotton may indicate that cotton gives a higher return to fertilizer relative to other crops. The quantity of land allocated to a particular crop depends very much on its yield level. The sensitivity analysis indicates that more fertilizer is allocated to cotton and maize when their yields are improved.

CHAPTER VII

CONCLUSION AND POLICY RECOMMENDATIONS

This study has employed static linear programming to investigate the most profitable cropping pattern in the Boromo region. It is the purpose of this chapter to draw conclusions, to present the policy recommendations and to suggest some areas for further research.

1. SUMMARY

The results of this study tend to support the following points:

(1) The scarcity of resources on traditional farms (mainly purchased inputs) encourages intercropping cultivation. The farm plan which maximizes net return is a combination of two and three crops enterprises. As revealed by D.W. Norman (1973), the decrease in individual crop yield in a crop mixture is more than offset by the yields of other crops present in the mixture. In addition, mixed cropping has merit, in farmers' opinions, as a method of yield risk protection against total crop failure when a single species is grown. Results of the study indicate that cereal production tends to dominate cash crop cotton production in the optimum farm plan. However, cotton intercropped with maize and cowpeas did enter the optimal farm plan.

(2) Within the existing resource base in the Boromo region, hand tool technology tends to be superior to oxen drawn technology. None of the enterprises cultivated with animal traction technology appear in the optimum farm plan at a significant level. Results suggest that given the assumed factor endowment, animal traction technology is inappropriate for Boromo farms. The main reason is that the net return from the yield of crops cultivated with animal traction cannot offset the increased operating costs associated with the use of oxen drawn cultivation. Yields are relatively higher for

animal traction farmers, but not very different from hand tool farmers' yields. These results suggest that at this point in time, innovative efforts should focus on biological technology rather than labor saving technology.

(3) Cotton benefits the most from purchased inputs. The amount of fertilizer used for cotton is about 130 kg per hectare of cotton for hand tool farmers and 170 kg for animal traction farmers. In both cases, maize benefits from cotton fertilizer residuals because it is commonly intercropped with cotton. Maize remains the only competing crop in terms of purchased inputs allocation, relative to cotton.

2. Policy Implications

The sensitivity analysis suggests that an increase in food crop prices, particularly sorghum would be an effective way to increase farmers' profit. However, raising the cotton price by a given percentage increases profits more than an equal percentage increase in yield (Tables 6.5 and 6.8). Therefore, it seems that both economic and technical parameters should be considered as agricultural development policy tools.

According to the results, an increase in cotton and maize yields by 30% is necessary to make animal traction economically attractive. As yields are increased, farmers tend to specialize in one crop. Agricultural production figures suggest that there is a high penalty for error in the Boromo region. A drop in production will not permit farmers to reach the minimum requirement for subsistence. The high risk in agriculture explains why farmers have an attitude "which emphasizes survival and maintenance of position rather than advancement of position" (Mellor, 1966, p. 240). This explains in part the low level of fertilizer used (27 kg/ha) in the optimal solution.

The price distortion created by the strong government intervention in the marketing system partially explains the results discussed in Chapter VI. The lack of competition described in Chapter II is the result of certain characteristics of production and marketing. An important unanswered question is how free market prices relative to government set prices would affect production and enterprise combinations. Most cotton produced in Burkino Faso is sold in the world market by SOFITEX. It is possible that the farm gate price for cotton is set below world price in order for SOFITEX to be competitive vis-a-vis other cotton exporting countries. Assuming a free market price that is 15% above the government price for all commodities, the sensitivity analysis describes the effect of upward price adjustment.

As presented in Tables 6.4 and 6.5, farmers' profit will increase by 7% above the base run profit if producer prices are increased by 15%. In the long run, the input suppliers will benefit from farmers' increased income. Also, the farm enterprise structure will become more specialized in the production of commodities which earn higher incomes relative to other commodities.

3. Areas for Further Research

The increase in food imports and the need for agriculture to play a greater role in the development of Burkino Faso have intensified interest in food production. New technologies such as animal traction, improved seeds and fertilizers provide potential instruments for agricultural development. However, they must be consistent with the country's resource endowment. A new technology should release the constraints of the limiting factor (labor, land or capital) which become relatively more abundant and/or increasingly productive per unit of limited resource.

For the particular case of the Boromo region, the description provided in Chapter II suggests that in addition to new technology adoption, an improvement in agricultural products and factors markets is necessary for agriculture development.

The farm model develop in this study has shown that land and labor are relatively abundant. The development of agricultural technology which makes more effective use of available resources - bush land and labor - should have a high pay off. The seasonal nature of farming leads to the underemployment of agricultural labor between peak demand periods. This implies that irrigation and water resources development is necessary for more labor and land utilization in agriculture. Animal traction technology releases labor, but unless this slack labor is mobilized for other productive activities, the impact will be minimal.

3.1 Agricultural Products Market

With the creation of the OFNACER, the marketing mandate of the ORD's and the regulation of trade through licences, the marketing functions in the agricultural sector in Burkina Faso have been transferred from the private to the public sector. Only government marketing agencies and few private traders are allowed to buy grain from the farmers.

Two problems are noticeable:

- It is expensive for the government to collect cereal all over the country. Surpluses are scattered in remote areas of the country, not always accessible with a four-wheel-drive vehicle all year around. It happens that some farmers cannot sell their surplus because of the marketing agencies' financial problems or inaccessibility of the surplus area.

- It takes a lot of human and financial resources for the administrative coordination of cereal marketing all over the country. The cumbersome operation of the ORD and the OFNACER implies an excessive subsidy burden to the government.

Research is needed to address: 1) the market processes linking individuals and firm through exchange and prices; 2) the efficiency of the market in transmitting information to producers. A study of these topics could guide public decision makers to determine the extent to which the government should intervene directly in the agricultural commodities marketing. It will also help the government in the establishment of farm prices, so that the price conveys accurate market information to farmers regarding the demand and supply situation.

3.2 Agricultural Factors Market

Much of the new technology needed to raise productivity per hectare and per person is in the form of mechanical or biological inputs which are produced by the non-agricultural sector of the economy. In Burkina Faso in general, and in the Boromo region in particular, improved seeds, fertilizers, pesticides and animal traction equipment are necessary to raise productivity.

> "If farmers are to employ the new biological and chemical inputs, they must have confidence that they will be available in sufficient quantity at the time when they are needed. It is also important that the price of the new input vary within sufficient narrow limits to permit reliable planning decisions". (Hayami and Ruttan, 1970, p. 269)

In the Boromo region, the inputs supply market is almost non-existant. The ORD or SOFITEX deliver fertilizer once a year at the beginning of the rainy season.

Research on the potential demand for inputs and their distribution will enable decision makers to determine the most appropriate input distribution system which satisfies the farmers needs.

3.3 Credit Institutions

Agricultural credits for input purchases is provided through the ORD's. Reimbursement of short term loans in the cotton zones, including Boromo, is exacted at the time of cotton purchase. Credit is usually allocated to farmers' associations for the account of individual farmers. The association assists in the distribution of credits among farmers and provides a moral pressure on recipients to repay.

The unavailability of credit sometimes results from the ORD's own financial problems rather than the farmers unwillingness to meet their obligation.

Research should be focused on the need and imput of improved credit delivery. Institutions of concern are the administrative framework at the ORD's levels and the farmers' associations which are the basic structure for the delivery of credit.

3.4 Irrigation and Water Resource Development

One of the constraints which prevents crops from reaching their potential yields is the physical constraint imposed by the environment in which the farmers operate. The individual farmer has relatively little control over factors such as soils, climate and water control. Since the Boromo farmer has limited capital, only appropriate public investment programs in irrigation and drainage can modify the constraint on yield imposed by the drought.

> Research on irrigation is particularly important and should be accelerated in the coming decades. The knowledge base for irrigation in Africa is meager . . . The cultivated land under irrigation is probably less than 5 percent in most other countries . . . Although irrigation will not be a panacea for the recovery of the Sahel nor for feeding Africa in the 1980's and 1990's, a long-term research program on the human, technical and institutional dimensions of irrigation should be initiated in the immediate future. (Eiker, C. K. and J. M. Staatz, 1984, p. 470)

Irrigation and water resources development suggest the need for important benefit cost study and engineering feasibility analysis. Such analysis requires more knowledge on irrigation system/infrastructure including water sources and distribution, crop production function response, and eventual impact on commodity prices.

There is a strong presumption that investments in transportation, communication, power, irrigation and related facilities are all missing in the Boromo region. However, research regarding labor-saving technology should recognize that such public or privately funded investments makes economic sense only if the labor released from agriculture could be used in some other activities of the economy. For the Boromo farmers, the most realistic reallocation of surplus labor is in dry season farming. Progress in drainage or irrigation should enable new areas to move into intensive system of cultivation.

4. Limitation of the Model and Critical Assumptions

Throughout the study several initial assumptions were made: maximization of profit in traditional agriculture, the use of official producer and consumer price in the model and the assumption that exchange labor is free. Each of these assumptions requires further comment in light of the conclusions reached.

4.1 Profit Maximization in Traditional Agriculture

D.W. Norman describes the farmers in the savanna areas of West Africa as being somewhere on the continuum between subsistence and fully commercialized agricultural production. The Boromo farmers' households are neither completely self-reliant on their own resources, nor tied to the market mechanisms.

Farms are organized as a group of jointly cultivated fields and a number of individual fields, privately owned by household members. Young men and women are often given autonomy in control over land and other fields such as rice and vegetable fields. As a result, the goals of individuals in the household may be different from those of the head of household. This may imply a mixture of goals in any farm household.

The issue raised by Norman is that the conventional framework of marginal analysis used in fully commercialized agriculture is not appropriate to analyze traditional farmers' multiple goals. Market forces in such systems do not completely determine behavior as suggested by the single goal of profit maximization.

The acceptance of animal traction technology by farmers in the Boromo region may be related to the aspect of "acceptability" rather than profitability (Collinson, 1983, p. 320). On adopting an innovation, the farmers might find that the change gives better satisfaction of their "nonmarket priorities", thus sustaining their adoption of the new technique even though it is not profitable financially. The Boromo farmers who adopt oxen drawn technology are found to have larger families than non-traction farmers, therefore the adoption of animal traction cannot be explained by the existence of a labor bottleneck. However, they may be more involved in off-farm employment than non-animal farmers, which justifies the use of animal traction. The manure obtained from keeping livestock is an important benefit which was not counted in the model, but may be a good reason for farmers to adopt animal traction.

The divisibility of animal traction technological package can partly explain why farmers accept the innovation despite the cost involved. Divisibility refers to the scale at which animal traction can be introduced. A farmer may decide to get first a pair of oxen and plowing equipment, then sowing equipment and any other equipment later. Divisibility permits the introduction of animal traction at a scale of adoption which is consistent with the farmers debt ceiling. It allows gradual progressive changes required in the management routine and reflects the farmers' risk preferences. This explains partly the circumstances in which animal traction is initially accepted by the Boromo farmers. But if yields improvement is not sufficient, the cost increase created by the increased scale of adoption may lead to its rejection.

The analysis suggests that the adoption of animal traction in the Boromo region requires the introduction of an appropriate yield-increasing technological package if farmers' confidence in the innovation is to be kept.

4.2 Price Assumption

Net return may be over estimated because of the assumption made about prices. The farmers may actually sell their commodities at a price below the official price, especially when they are sold to private traders. Likewise, they may buy at a price above the consumer price for the same reason. However, if farmers are trading with the OFNACER and the ORD's, the price assumption will not affect the model result. Also, it was assumed throughout the analysis that all cotton production was sold at 62 CFA francs per kilo without any discount for quality. Actually, SOFITEX grades all cotton purchase in three different qualities. The discount on quality would have probably reduced the net return if it had been entered in the model accordingly.

4.3 Exchange Labor Costs

With traditional crop farming systems, that have seasonal peak demands for resources, cash costs are usually associated with the hiring of labor and equipment services. Due to the fact that farming operations overlap during peak periods of labor demand, hired resources usually have high marginal value products. Hired labor is required when the labor demand exceeds the available family labor. But exchange labor is used before hired labor because the farmers do not give cash payments to the workers. The cost of exchange labor can be estimated by the forgone output in its best alternative use (Squire and van der Take, 1981, p. 78). The approach for estimating the foregone output is to estimate the marginal product of labor by the ongoing rural wage rate, when the relevant labor market is perfect. Excluding exchange labor cost from the model may lead to an overestimation of the net return per hectare.

APPENDIX A

Explanation of Abbreviations Used in L.P. Matrix

Resources		
Row No	Abbreviation Used	Complete Heading
1	L1	Next to house land
2	L2	In village land
3	L3	In bush land
4	FLMY	Family labor in May
5	FLJE	Family labor in June
6	FLJY	Family labor in July
7	FLAU	Family labor in August
8	FLSE	Family labor in September
9	FLOC	Family labor in October
10	FLNO	Family labor in November
11	FLDE	Family labor in December
12	FLJA	Family labor in January
13	FLFE	Family labor in February
14	FLMC	Family labor in March
15	FLAP	Family labor in April
16	ANTH	Animal team hours
17	PWS	Produce white sorghum
18	PRS	Produce red sorghum
19	PML	Produce millet
20	PMZ	Produce maize
21	PCT	Produce cotton
22	PCP	Produce cowpea
23	SubR	Minimum subsistence requirement
24	SFert	Supply fertilizer
25	SFdJE	Supply Feed in June
26	SFdSE	Supply feed in September
27	SFdFE	Supply feed in February
28	OPKMY	Operating capital in May
29	OPKJE	Operating capital in June
30	OPKJY	Operating capital in July
31	OPKAU	Operating capital in August
32	OPKSE	Operating capital in September
33	OPKOC	Operating capital in October
34	OPKNO	Operating capital in November
35	OPKDE	Operating capital in December
36	OPKJA	Operating capital in January
37	OPKFE	Operating capital in February
38	OPKMC	Operating capital in March
39	OPKAP	Operating capital in April
40	EOPK	End of operating capital
41	TEOPK	Transfer of end of operating capital.

Explanation of Abbreviations Used in L.P. Matrix

Activities		
Column No	Abbreviation Used	Complete Heading
1	WSm	White sorghum produced by manual farmers
2	RSm	Red sorghum produced by manual farmers
3	MLm	Millet produced by manual farmers
4	MZm	Maize produced by manual farmers
5	CTm	Cotton produced by manual farmers
6	RS+MZm	Red sorghum and maize produced by manual farmers
7	ML+CPm	Millet and cowpea produced by manual farmers
8	CT+MZ+CPm	Cotton,maize and cowpea produced by manual farmers
9	RS+MZ+CPm	Red sorghum,maize and cowpea produced by manual farmers
10	WSat	White sorghum produced with animal traction
11	RSat	Red sorghum produced with animal traction
12	MLat	Millet produced with animal traction
13	MZat	Maize produced with animal traction
14	CTat	Cotton produced with animal traction
15	CT+MZ+CPat	Cotton,maize and cowpea produced with animal traction
16	RS+MZ+CPat	Red sorghum,maize and cowpea produced with animal traction
17	LHMY	Labor hired in May
18	LHJE	Labor hired in June
19	LHJY	Labor hired in July
20	LHAU	Labor hired in August
21	LHSE	Labor hired in September
22	LHOC	Labor hired in October
23	LHNO	Labor hired in November
24	LHDE	Labor hired in December
25	ELJY	Exchange labor in July
26	ELAU	Exchange labor in August
27	ELSE	Exchange labor in September
28	ELOC	Exchange labor in October
29	ATEQH	Animal traction equipment hired
30	KTMY	Capital transfer from May to June
31	KTJE	Capital transfer from June to July
32	KTJY	Capital transfer from July to August
33	KTAU	Capital transfer from August to September
34	KTSE	Capital transfer from September to October
35	KTOC	Capital transfer from October to November
36	KTNO	Capital transfer from November to December
37	KTDE	Capital transfer from December to January
38	KTJA	Capital transfer from January to February

Explanation of Abbreviations Used in L.P. Matrix (continued)

Activities		
Column No	Abbreviation Used	Complete Heading
39	KTFE	Capital transfer from February to March
40	KTMC	Capital transfer from March to April
41	KTAP	Capital transfer from April to beginning of new season
42	KT	Capital Transfer
43	SWS	Sell white sorghum
44	SRS	Sell red sorghum
45	SML	Sell millet
46	SMZ	Sell maize
47	SCT	Sell cotton
48	SCP	Sell cowpea
49	BWS	Buy white sorghum
50	BRS	Buy red sorghum
51	BML	Buy millet
52	BMZ	Buy maize
53	BCP	Buy cowpea
54	BFert	Buy fertilizer
55	BFdJE	Buy feed in June
56	BFdSE	Buy feed in September
57	BFdFE	Buy feed in February
58	ConsWS	Consume white sorghum
59	ConsRS	Consume red sorghum
60	ConsML	Consume millet
61	ConsMZ	Comsume maize
62	ConsCP	Consume cowpea
63	BRWMY	Borrow money in May
64	BRWJE	Borrow money in June
65	BRWJY	Borrow money in July
66	BRWAU	Borrow money in August
67	BRWSE	Borrow money in September
68	BRWOC	Borrow money in October
69	BRWNO	Borrow money in November
70	BRWDE	Borrow money in December
71	BRWJA	Borrow money in January
72	BRWFE	Borrwo money in February
73	BRWMC	Borrow money in March
74	BRWAP	Borrow money in April

APPENDIX B

The Base Run Solution

```
AG. ECON. LINEAR PROGRAMMING PACKAGE -- VER.  2.20
LINEAR PROGRAMMING ANALYSIS -- LPKOHO

MATRIX SIZE -- ROWS =   41 COLS =   74

ROW    1  (1--          .9000)
     1        1.0000
     4        1.0000
     6        1.0000
     9        1.0000
    10        1.0000
    11        1.0000
    13        1.0000
    16        1.0000

ROW    2  (1--         1.4000)
     1        1.0000
     2        1.0000
     3        1.0000
     4        1.0000
     5        1.0000
     7        1.0000
     8        1.0000
     9        1.0000
    10        1.0000
    11        1.0000
    12        1.0000
    13        1.0000
    14        1.0000
    15        1.0000
    16        1.0000

ROW    3  (1--         2.5000)
     1        1.0000
     2        1.0000
     3        1.0000
     4        1.0000
     5        1.0000
     7        1.0000
     8        1.0000
     9        1.0000
    10        1.0000
    11        1.0000
    12        1.0000
    13        1.0000
    14        1.0000
    15        1.0000
    16        1.0000

ROW    4  (1--        95.0000)
     1      102.0000
     2       73.0000
     3       16.0000
     4      189.0000
     5       38.0000
     6       78.0000
     7        9.0000
     8       92.0000
     9      332.0000
    10       30.0000
    11      124.0000
    12       37.0000
    13       64.0000
    16       74.0000
    17       -1.0000
    29       -1.0000

ROW    5  (1--       289.0000)
     1       57.0000
     2       68.0000
     3       57.0000
```

4		104.0000	
5		84.0000	
6		140.0000	
7		32.0000	
8		143.0000	
9		166.0000	
10		65.0000	
11		63.0000	
12		67.0000	
13		283.0000	
14		99.0000	
15		72.0000	
16		76.0000	
18		-1.0000	
ROW	6	(1--	635.0000)
1		252.0000	
2		292.0000	
3		202.0000	
4		522.0000	
5		272.0000	
6		226.0000	
7		148.0000	
8		438.0000	
9		520.0000	
10		199.0000	
11		308.0000	
12		191.0000	
13		419.0000	
14		340.0000	
15		110.0000	
16		167.0000	
19		-1.0000	
25		1.0000	
ROW	7	(1--	520.0000)
1		106.0000	
2		149.0000	
3		123.0000	
4		402.0000	
5		207.0000	
6		202.0000	
7		77.0000	
8		149.0000	
9		364.0000	
10		43.0000	
11		81.0000	
12		66.0000	
13		132.0000	
14		77.0000	
15		42.0000	
16		54.0000	
20		-1.0000	
26		1.0000	
ROW	8	(1--	304.0000)
1		33.0000	
4		345.0000	
5		14.0000	
6		78.0000	
7		22.0000	
8		86.0000	
9		110.0000	
10		30.0000	
13		36.0000	
14		77.0000	
15		150.0000	
16		110.0000	
21		-1.0000	
27		1.0000	
ROW	9	(1--	205.0000)
1		35.0000	
2		39.0000	
4		250.0000	
6		57.0000	
7		39.0000	

8		32.0000	
9		108.0000	
10		25.0000	
11		58.0000	
13		253.0000	
15		170.0000	
16		130.0000	
22		-1.0000	
28		1.0000	
ROW	10	(1--	185.0000)
1		83.0000	
2		73.0000	
3		93.0000	
5		15.0000	
6		32.0000	
7		123.0000	
8		28.0000	
9		223.0000	
10		73.0000	
11		65.0000	
12		136.0000	
15		330.0000	
16		90.0000	
23		-1.0000	
ROW	11	(1--	110.0000)
1		70.0000	
3		113.0000	
5		280.0000	
7		112.0000	
8		212.0000	
9		53.0000	
10		65.0000	
11		27.0000	
12		110.0000	
14		350.0000	
15		270.0000	
16		37.0000	
24		-1.0000	
ROW	12	(1--	80.0000)
3		34.0000	
5		253.0000	
8		246.0000	
9		16.0000	
12		50.0000	
14		250.0000	
15		300.0000	
ROW	13	(1--	71.0000)
3		22.0000	
5		32.0000	
8		52.0000	
11		23.0000	
14		20.0000	
15		27.0000	
16		32.0000	
ROW	14	(1--	90.0000)
1		25.0000	
2		19.0000	
3		55.0000	
5		35.0000	
6		27.0000	
7		35.0000	
8		29.0000	
9		27.0000	
10		25.0000	
11		25.0000	
12		43.0000	
14		35.0000	
15		40.0000	
16		39.0000	

```
ROW   15   (1--         90.0000)
   1          37.0000
   2          24.0000
   3          57.0000
   5          42.0000
   6          31.0000
   7          37.0000
   8          38.0000
   9          36.0000
  10          32.0000
  11          39.0000
  12          47.0000
  14          37.0000
  15          43.0000
  16          45.0000

ROW   16   (1--         50.0000)
  10           7.0000
  11          70.0000
  12           8.0000
  13          61.0000
  14          17.0000
  15          31.0000
  16          25.0000

ROW   17   (1--          0.0000)
   1        -415.0000
  10        -460.0000
  43           1.0000
  49          -1.0000
  58           1.0000

ROW   18   (1--          0.0000)
   2        -736.0000
   6       -1000.0000
   9        -850.0000
  11        -780.0000
  16        -940.0000
  44           1.0000
  50          -1.0000
  59           1.0000

ROW   19   (1--          0.0000)
   3        -230.0000
   7        -230.0000
  12        -385.0000
  45           1.0000
  51          -1.0000
  60           1.0000

ROW   20   (1--          0.0000)
   4       -1720.0000
   6        -750.0000
   8        -700.0000
   9        -318.0000
  13       -1811.0000
  15        -700.0000
  16        -280.0000
  46           1.0000
  52          -1.0000
  61           1.0000

ROW   21   (1--          0.0000)
   5       -1142.0000
   8        -800.0000
  14       -1277.0000
  15        -827.0000
  47           1.0000

ROW   22   (1--          0.0000)
   7         -55.0000
   8         -24.0000
   9         -90.0000
  15         -54.0000
```

```
   16          -21.0000
   48            1.0000
   53           -1.0000
   62            1.0000

ROW    23   (3--        2340.0000)
   58            1.0000
   59            1.0000
   60            1.0000
   61            1.0000
   62            1.0000

ROW    24   (1--           0.0000)
    4           82.0000
    5          136.0000
    8          136.0000
   11           14.0000
   13           90.0000
   14          177.0000
   15           89.0000
   16           85.0000
   54           -1.0000

ROW    25   (1--           0.0000)
   55           -1.0000

ROW    26   (1--           0.0000)
   56           -1.0000

ROW    27   (1--           0.0000)
   57           -1.0000

ROW    28   (1--       28830.0000)
    4         2255.0000
    5         3740.0000
    8         3740.0000
   11          770.0000
   13         2475.0000
   14         4868.0000
   15         2447.0000
   16         2337.0000
   17           30.0000
   29           50.0000
   30            1.0000
   63           -1.0000

ROW    29   (1--           0.0000)
    4         2255.0000
    5         3740.0000
    8         3740.0000
   13         2475.0000
   14         4867.0000
   15         2447.0000
   16         2337.0000
   18           30.0000
   30           -1.0000
   31            1.0000
   64           -1.0000

ROW    30   (1--           0.0000)
   10          285.0000
   11          285.0000
   12          285.0000
   13          285.0000
   14          285.0000
   15          285.0000
   16          285.0000
   20           35.0000
   31           -1.0000
   32            1.0000
   65           -1.0000
```

```
ROW    31  (1--          0.0000)
   20          35.0000
   32          -1.0000
   33           1.0000
   66          -1.0000

ROW    32  (1--          0.0000)
   10          55.0000
   11          55.0000
   12          55.0000
   13          55.0000
   14          55.0000
   15          55.0000
   16          55.0000
   21          30.0000
   33          -1.0000
   34           1.0000
   67          -1.0000

ROW    33  (1--          0.0000)
   10          51.0000
   11          51.0000
   13          51.0000
   14          51.0000
   15          51.0000
   16          51.0000
   22          30.0000
   34          -1.0000
   35           1.0000
   68          -1.0000

ROW    34  (1--          0.0000)
   10          94.0000
   11          94.0000
   12          94.0000
   13          94.0000
   14          94.0000
   15          94.0000
   16          94.0000
   23          35.0000
   35          -1.0000
   36           1.0000
   69          -1.0000

ROW    35  (1--          0.0000)
   24          35.0000
   36          -1.0000
   37           1.0000
   70          -1.0000

ROW    36  (1--          0.0000)
   37          -1.0000
   38           1.0000
   71          -1.0000

ROW    37  (1--          0.0000)
   10         114.0000
   11         114.0000
   12         114.0000
   13         114.0000
   14         114.0000
   15         114.0000
   16         114.0000
   38          -1.0000
   39           1.0000
   72          -1.0000

ROW    38  (1--          0.0000)
   39          -1.0000
   40           1.0000
   73          -1.0000

ROW    39  (1--          0.0000)
```

```
  40         -1.0000
  41          1.0000
  74         -1.0000

ROW   40  (1--            0.0000)
  41         -1.0000
  42          1.0000

ROW   41  (3--       28830.0000)
  42          1.0000

OBJECTIVE VALUES
  17        -30.0000
  18        -30.0000
  19        -35.0000
  20        -35.0000
  21        -30.0000
  22        -30.0000
  23        -35.0000
  24        -35.0000
  29        -50.0000
  43         58.0000
  44         58.0000
  45         60.0000
  46         55.0000
  47         62.0000
  48         90.0000
  49        -83.0000
  50        -83.0000
  51        -83.0000
  52        -55.0000
  53       -130.0000
  54        -55.0000
  55        -45.0000
  56        -45.0000
  57        -45.0000
  63         -1.1550
  64         -1.1420
  65         -1.1300
  66         -1.1170
  67         -1.1050
  68         -1.0920
  69         -1.0800
  70         -1.0670
  71         -1.0540
  72         -1.0420
  73         -1.0290
  74         -1.1550

START L. P. SOLVE

OPTIMAL SOLUTION (    50)

OBJECTIVE FUNCTION=            27540.4735

ACTIVITIES IN SOLUTION
 ACTIVITY    2    IS         1.1231
 ACTIVITY    6    IS          .9000
 ACTIVITY    8    IS          .0568
 ACTIVITY   15    IS          .2201
 ACTIVITY   17    IS        62.4148
 ACTIVITY   30    IS     26206.5117
 ACTIVITY   31    IS     25455.4683
 ACTIVITY   32    IS     25392.7491
 ACTIVITY   33    IS     25392.7491
 ACTIVITY   34    IS     25380.6454
 ACTIVITY   35    IS     25369.4220
 ACTIVITY   36    IS     25348.7357
 ACTIVITY   37    IS     25348.7357
 ACTIVITY   38    IS     25348.7357
 ACTIVITY   39    IS     25323.6480
 ACTIVITY   40    IS     28830.0000
 ACTIVITY   41    IS     28830.0000
 ACTIVITY   42    IS     28830.0000
 ACTIVITY   44    IS      1726.6047
```

ACTIVITY	45	IS	.0000
ACTIVITY	47	IS	227.4585
ACTIVITY	48	IS	13.2475
ACTIVITY	49	IS	.0000
ACTIVITY	52	IS	1471.1729
ACTIVITY	54	IS	27.3147
ACTIVITY	61	IS	2340.0000
ACTIVITY	73	IS	3506.3520

SHADOW PRICES AND SLACKS

ROW	1	PRICE	93707.3247	EXCESS	0.0000
ROW	2	PRICE	36431.3176	EXCESS	0.0000
ROW	3	PRICE	0.0000	EXCESS	1.1000
ROW	4	PRICE	60.8700	EXCESS	0.0000
ROW	5	PRICE	0.0000	EXCESS	62.6576
ROW	6	PRICE	0.0000	EXCESS	54.5553
ROW	7	PRICE	0.0000	EXCESS	153.1472
ROW	8	PRICE	0.0000	EXCESS	195.9027
ROW	9	PRICE	0.0000	EXCESS	70.6690
ROW	10	PRICE	24.8380	EXCESS	0.0000
ROW	11	PRICE	0.0000	EXCESS	38.5342
ROW	12	PRICE	131.5295	EXCESS	0.0000
ROW	13	PRICE	0.0000	EXCESS	62.1031
ROW	14	PRICE	0.0000	EXCESS	33.9103
ROW	15	PRICE	0.0000	EXCESS	23.5231
ROW	16	PRICE	0.0000	EXCESS	43.1779
ROW	17	PRICE	83.0000	EXCESS	0.0000
ROW	18	PRICE	58.0000	EXCESS	0.0000
ROW	19	PRICE	60.0000	EXCESS	0.0000
ROW	20	PRICE	55.0000	EXCESS	0.0000
ROW	21	PRICE	62.0000	EXCESS	0.0000
ROW	22	PRICE	90.0000	EXCESS	0.0000
ROW	23	PRICE	-55.0000	EXCESS	0.0000
ROW	24	PRICE	55.0000	EXCESS	0.0000
ROW	25	PRICE	0.0000	EXCESS	0.0000
ROW	26	PRICE	0.0000	EXCESS	0.0000
ROW	27	PRICE	0.0000	EXCESS	0.0000
ROW	28	PRICE	1.0290	EXCESS	0.0000
ROW	29	PRICE	1.0290	EXCESS	0.0000
ROW	30	PRICE	1.0290	EXCESS	0.0000
ROW	31	PRICE	1.0290	EXCESS	0.0000
ROW	32	PRICE	1.0290	EXCESS	0.0000
ROW	33	PRICE	1.0290	EXCESS	0.0000
ROW	34	PRICE	1.0290	EXCESS	0.0000
ROW	35	PRICE	1.0290	EXCESS	0.0000
ROW	36	PRICE	1.0290	EXCESS	0.0000
ROW	37	PRICE	1.0290	EXCESS	0.0000
ROW	38	PRICE	1.0290	EXCESS	0.0000
ROW	39	PRICE	1.0290	EXCESS	0.0000
ROW	40	PRICE	1.0290	EXCESS	0.0000
ROW	41	PRICE	-1.0290	EXCESS	0.0000

COST OF FORCING IN NONOPTIMAL ACTIVITIES

ACTIVITY	1	IS	103963.9345
ACTIVITY	3	IS	30387.1729
ACTIVITY	4	IS	56193.8622
ACTIVITY	5	IS	16766.8328
ACTIVITY	7	IS	21284.2189
ACTIVITY	9	IS	83100.8236
ACTIVITY	10	IS	96214.2857
ACTIVITY	11	IS	96239.6919
ACTIVITY	12	IS	26101.8401
ACTIVITY	13	IS	45089.2432
ACTIVITY	14	IS	10508.3806
ACTIVITY	16	IS	75169.3573
ACTIVITY	18	IS	60.8700
ACTIVITY	19	IS	35.0000
ACTIVITY	20	IS	107.0300
ACTIVITY	21	IS	60.8700
ACTIVITY	22	IS	60.8700
ACTIVITY	23	IS	46.1770
ACTIVITY	24	IS	71.0150
ACTIVITY	29	IS	40.5800
ACTIVITY	43	IS	25.0000
ACTIVITY	50	IS	25.0000

ACTIVITY	51	IS	23.0000
ACTIVITY	53	IS	40.0000
ACTIVITY	55	IS	45.0000
ACTIVITY	56	IS	45.0000
ACTIVITY	57	IS	45.0000
ACTIVITY	58	IS	28.0000
ACTIVITY	59	IS	3.0000
ACTIVITY	60	IS	5.0000
ACTIVITY	62	IS	35.0000
ACTIVITY	63	IS	.1260
ACTIVITY	64	IS	.1130
ACTIVITY	65	IS	.1010
ACTIVITY	66	IS	.0880
ACTIVITY	67	IS	.0760
ACTIVITY	68	IS	.0630
ACTIVITY	69	IS	.0510
ACTIVITY	70	IS	.0380
ACTIVITY	71	IS	.0250
ACTIVITY	72	IS	.0130
ACTIVITY	74	IS	.1260

PRICE RANGE OVER WHICH OPTIMAL SOLUTION HOLDS

		ACTIVITY	PRICE	ACTIVITY	PRICE
		LOWER BOUND		UPPER BOUND	
ACTIVITY	2	7	-20560.6487	86	33414.5925
ACTIVITY	6	13	-45089.2432	0	9000000.0000
ACTIVITY	8	14	-9358.3747	84	6352.0647
ACTIVITY	15	84	-7746.4203	23	14401.5993
ACTIVITY	17	29	-70.5800	78	30.8700
ACTIVITY	25	****	-I	****	-I
ACTIVITY	26	****	-I	****	-I
ACTIVITY	27	****	-I	****	-I
ACTIVITY	28	****	-I	****	-I
ACTIVITY	30	103	-1.0290	63	.1260
ACTIVITY	31	103	-1.0290	64	.1130
ACTIVITY	32	103	-1.0290	65	.1010
ACTIVITY	33	103	-1.0290	66	.0880
ACTIVITY	34	103	-1.0290	67	.0760
ACTIVITY	35	103	-1.0290	68	.0630
ACTIVITY	36	103	-1.0290	69	.0510
ACTIVITY	37	103	-1.0290	70	.0380
ACTIVITY	38	103	-1.0290	71	.0250
ACTIVITY	39	103	-1.0290	72	.0130
ACTIVITY	40	74	-.1260	114	1.0290
ACTIVITY	41	0	-9000000.0000	115	1.0290
ACTIVITY	42	0	-9000000.0000	117	1.0290
ACTIVITY	44	59	55.0000	50	83.0000
ACTIVITY	45	60	55.0000	51	83.0000
ACTIVITY	46	****	-I	****	-I
ACTIVITY	47	86	20.4408	14	85.3003
ACTIVITY	48	62	55.0000	53	130.0000
ACTIVITY	49	10	-292.1615	43	-58.0000
ACTIVITY	52	59	-58.0000	14	-40.5020
ACTIVITY	54	23	-242.3899	99	0.0000
ACTIVITY	61	59	-3.0000	97	55.0000
ACTIVITY	73	72	-1.0420	103	0.0000

APPENDIX C

Appendix Table C.1

Average Budget per Hectare for
Hand Plowed White Sorghum, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of output				
A. Crop Yields	kg/ha			
White sorghum		415		
B. Unit Price	CFA/kg			
White sorghum		58		
C. Total Value of Output	CFA		24070	
II Variable Costs	CFA			
A. Fertilizer	CFA		0	
B. Hired Labor	CFA		0	
C. Total Variable Costs	CFA		0	
III Performance Measures	CFA			
A. Gross Income				24070
Less: Total Variable Costs				0
B. Gross Margin				24070
IV Number of Observations		12		

Appendix Table C.2

Average Budget per Hectare for Hand Plowed
Red Sorghum, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Red sorghum		736.0		
B. Unit Price	CFA/kg			
Red Sorghum		58.0		
C. Total Value of Output	CFA		42,688	
II Variable Costs	CFA			
A. Fertilizer	CFA		0	
B. Hired labor	CFA		0	
C. Total Variable Costs	CFA		0	
III Performance Measures	CFA			
A. Gross Income				42,688
Less: Total Variable Costs				0
B. Gross Margin				42,688
IV Number of Observations		9		

Appendix Table C.3

Average Budget per Hectare for Hand Plowed Millet, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Millet		230.0		
B. Unit Price	CFA/kg			
Millet		60.0		
C. Total Value of Output	CFA		13,800	
II Variable Costs	CFA			
A. Fertilizer	CFA		0	
B. Hired Labor	CFA		0	
C. Total Variable Costs	CFA		0	
III Performance Measures	CFA			
A. Gross Income				13,800
Less: Total Variable Costs				0
B. Gross Margin				13,800
IV Number of Observations		7		

Appendix Table C.4

Average Budget per Hectare for Hand Plowed Millet, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Maize		1,720		
B. Unit Price	CFA/kg			
Maize		55		
C. Total Value of Output	CFA		94,600	
II Variable Costs	CFA			
A. Fertilizer	CFA		4,510	
B. Hired Labor			0	
C. Total Variable Costs	CFA		4,510	
III Performance Measures	CFA			
A. Gross Income				94,600
Less: Total Variable Costs				4,510
B. Gross Margin				90,090
IV Number of Observations		8		

Appendix Table C.5

Average Budget per Hectare for Hand Plowed Cotton, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Cotton		1,142		
B. Unit Price	CFA/kg			
Cotton		62		
C. Total Value of Output	CFA		70,804	
II Variable Costs	CFA			
A. Fertilizer	CFA		7,480	
B. Hired Labor	CFA		256	
C. Total Variable Costs	CFA		7,736	
III Performance Measures	CFA			
A. Gross Income				70,804
Less: Total Variable Costs				7,736
B. Gross Margin				63,068
IV Number of Observations		17		

Appendix Table C.6

Average Budget per Hectare for Hand Plowed Red Sorghum and Maize Intercropped, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Red Sorghum		1,000		
Maize		750		
B. Unit Price	CFA/kg			
Red sorghum		58		
Maize		55		
C. Total Value of Output	CFA		99,250	
II Variable Costs	CFA			
A. Fertilizer	CFA		0	
B. Hired Labor	CFA		0	
C. Total Variable Costs	CFA		0	
III Performance Measures	CFA			
A. Gross Income				99,250
Less: Total variable Cost				0
B. Gross Margin	CFA			99,250
IV Number of Observations		9		

Appendix Table C.7

Average Budget per Hectare for Hand Plowed
Millet and Cowpeas Intercropped, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Millet		230		
Cowpea		55		
B. Unit Price	CFA/kg			
Millet		60		
Cowpea		90		
C. Total Value of Output	CFA		18,750	
II Variable Costs	CFA			
A. Fertilizer	CFA		0	
B. Hired Labor	CFA		0	
C. Total Variable Costs	CFA		0	
III Performance Measures	CFA			
A. Gross Income				18,750
Less: Total Variable Costs				0
B. Gross Margin				18,750
IV Number of Observations		19		

Appendix Table C.8

Average Budget per Hectare for Hand Plowed
Cotton, Maize and Cowpeas Intercropped, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Cotton		800		
Maize		700		
Cowpeas		24		
B. Unit Price	CFA/kg			
Cotton		62		
Maize		55		
Cowpeas		90		
C. Total Value of Output	CFA		90,260	
II Variable Costs	CFA			
A. Fertilizer	CFA		7,480	
B. Hired Labor	CFA		256	
C. Total Variable Costs	CFA		7,736	
III Performance Measures	CFA			
A. Gross Income				90,260
Less: Total variable Costs				7,736
B. Gross Margin				82,524
IV Number of Observations		14		

Appendix Table C.9

Average Budget per Hectare for Hand Plowed Sorghum, Maize and Cowpeas Intercropped Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Red sorghum		850		
Maize		318		
Cowpea		90		
B. Unit Price	CFA/ha			
Red sorghum		58		
Maize		55		
Cowpeas		90		
C. Total Value of Output	CFA		74,890	
II Variable Costs	CFA			
A. Fertilizer	CFA		0	
B. Hired Labor	CFA		0	
C. Total Variable Costs	CFA		0	
III Performance Measures	CFA			
A. Gross Income				74,890
Less: Total Variable Costs				0
B. Gross Margin				74,890
IV Number of Observations		11		

Appendix Table C.10

Average Budget per Hectare for Traction Plowed White Sorghum, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields (kg/ha)				
White sorghum		460		
B. Unit Price	CFA/kg			
White sorghum		58		
C. Total Value of Output	CFA		26,680	
II Variable Costs	CFA			
A. Fertilzer	CFA		0	
B. Hired Labor	CFA		0	
C. Hired equipment	CFA		0	
D. Total Variable Costs	CFA		0	
III Performance Measures	CFA			
A. Gross Income				26,680
Less: total Variable Costs				0
B. Gross Margin				26,680
IV Number of Observations		15		

Appendix Table C.11

Average Budget per Hectare for Traction Plowed Red Sorghum, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop yields	kg/ha			
Red sorghum		780		
B. Unit Price	CFA/kg			
Red sorghum		58		
C. Total Value of Output	CFA		45,240	
II Variable Costs	CFA			
A. Fertilizer	CFA		770	
B. Hired Labor	CFA		0	
C. Hired Equipment	CFA		0	
D. Total Variable Costs	CFA		770	
III Performance Measures	CFA			
A. Gross Income				45,240
Less: total Variable Costs				770
B. Gross Margin				44,470
IV Number of Observations		11		

Appendix Table C.12

Average Budget per Hectare for Traction Plowed Millet, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Millet		380		
B. Unit Price	CFA/kg			
Millet		60		
C. Total Value of Output	CFA		22,800	
II Variable Costs	CFA			
A. Fertilizer	CFA		0	
B. Hired Labor	CFA		0	
C. Hired Equipment	CFA		0	
D. Total Variable Costs	CFA		0	
III Performance Measures	CFA			
A. Gross Income				22,800
Less: Total Variable Costs				
B. Gross Margin				22,800
IV Number of Observations		16		

Appendix Table C.13

Average Budget per Hectare for Traction Plowed Maize, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Maize		1,811		
B. Unit Price	CFA/kg			
Maize		55		
C. Total Value of Output	CFA		99,605	
II Variable Costs	CFA			
A. Fertilizer	CFA		4,950	
B. Hired Labor	CFA		0	
C. Hired Equipment	CFA		0	
D. Total Variable Costs	CFA		4,950	
III Performance Measures	CFA			
A. Gross Income				99,605
Less: Total Variable Costs				4,950
B. Gross Margin				94,655
IV Number of Observations		9		

Appendix Table C.14

Average Budget per Hectare for Traction Plowed Cotton, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Cotton		1,277		
B. Unit Price	CFA/ha			
Cotton		62		
C. Total Value of Output	CFA	79,174		
II Variable Costs	CFA			
A. Fertilizer	CFA		9,736	
B. Hired Labor	CFA		256	
C. Hired Equipment	CFA		0	
D. Total Variable Costs	CFA		9,992	
III Performance Measures	CFA			
A. Gross Income				79,174
Less: Total Variable Costs				9,992
B. Gross Margin				69,182
IV Number of Observations		17		

Appendix Table C.15

Average Budget per Hectare for Traction Plowed Cotton, Maize and Cowpeas Intercropped, Boromo, 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Cotton		827		
Maize		700		
Cowpeas		54		
B. Unit Price	CFA/kg			
Cotton		62		
Maize		55		
Cowpeas		90		
C. Total Value of Output	CFA		94,634	
II Variable Costs	CFA			
A. Fertilizer	CFA		4,896	
B. Hired Labor	CFA		256	
C. Hired Equipment	CFA		0	
D. Total Variable Costs	CFA		5,152	
III Performance Measures	CFA			
A. Gross Income				94,634
Less: Total Variable Costs				5,152
B. Gross Margin				89,482
IV Number of Observations			7	

Appendix Table C.16

Average Budget per Hectare for Traction Plowed, Red Sorghum, Maize and Cowpeas Intercropped, Boromo 1982

	Unit		CFA/ha	CFA/ha
I Value of Output				
A. Crop Yields	kg/ha			
Red sorghum		940		
Maize		280		
Cowpeas		21		
B. Unit Price	CFA/kg			
Red sorghum		58		
Maize		55		
Cowpeas		90		
C. Total Value of Output	CFA		71,810	
II Variable Costs	CFA			
A. Fertilizer	CFA		4,676	
B. Hired Labor	CFA		0	
C. Hired Equipment	CFA		0	
D. Total Variable Costs	CFA		4,676	
III Performance Measures	CFA			
A. Gross Income				71,810
Less: Total Variable Costs				4,676
B. Gross Margin				67,134
IV Number of Observations		6		

Appendix Table C.17

Comparative Yields and Returns for all
Enterprise Budgets, Boromo 1982

Enterprise Label	Yields(kg/ha)		Gross Margin (CFA/ha)	
	Animal Traction	Manual	Animal Traction	Manual
WS	460	415	26,880	24,070
RS	780	736	44,470	42,688
ML	380	230	22,800	13,800
MZ	1,811	1,720	94,655	90,090
CT	1,277	1,142	69,182	63,068
RS+MZ				
RS	-	1,000	-	
MZ	-	750	-	
				99,250
ML+CP				
ML	-	230	-	
CP	-	55	-	
				18,750
CT+MZ+CP				
CT	827	800	-	
MZ	700	700	-	
CP	54	24	-	
			89,482	82,524
RS+MZ+CP				
RS	940	850	-	
MZ	280	318	-	
CP	21	90	-	
			67,134	74,890

Notes:
Enterprise codes are explained in Appendix A.

BIBLIOGRAPHY

Abbot, J.C., "The Role of Marketing in the Development of Backward Agricultural Economics," Journal of Farm Economics Vol. 44, p. 349-62, May 1962.

Aiyer, A.K.Y.N., "Mixed Cropping in India," Indian Journal of Agricultural Science Vol. 19 p. 442-95, 1949.

Allen, G.R., "Short-term Variations in Retailing Margins on Fruits in East Pakistan," Farm Economist Vol. 9 No. 6 p. 259-66, 1959.

Anderson, David R., Sweeney, Dennis J., Williams, Thomas A., "An introduction to Management Science: Quantitative Approaches to Decision Making," Third Edition West, 1982.

Atta-Konado, Yiadom Kwasi, "Economic Optima in Resource Allocation For Smallholder Subsistance Farming in Ghana," Unpublished Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University, 1974.

Barret, Vincent; Lassiter, Gregory; Wilcock, David; Doyle, Baker and Crawford, Eric, "Animal Traction in Eastern Upper Volta: A Technical, Econmic and Institutional Analysis," Michigan State University International Development Paper No. 4, 1982.

Bates, Robert H., "Markets and States in Tropical Africa: The Political Basis of Agricultural Policies," Berkeley University of California Press, 1981.

Bauer, P.T. and Yamny, "A Case Study of Response to Price in an Underdeveloped Country," Economic Journal 69 (276) p. 800-804, 1959.

Casley, D.J. and Lury, D.A., "Data Collection in Developing Countries" Clarendon Press Oxford, 1981.

Clark, C., "Economics of Subsistance Agriculture" MacMillan St. Martin's Press (New York), 1967.

Christensen, Cheryl and Witucki, Larry, "Food Problems and Emerging Policy Responses in Subsaharan Africa," International Agricultural Development, 1982.

Clayton, Eric S., "Economic Planning in Peasant Agriculture: A study of the Optimal Use of Resources by Peasant Farmers in Kenya," Economic Department, Wye College; August, 1963.

Clayton, Eric S., "Agrarian Development in Peasant Economies," Pergamon Press 1964.

Collinson, Michael, "Farm Management in Peasant Agriculture," A Westview Encore Edition, 1963.

Crawford, Eric W., "A Simulation Study of Constraints on Traditional Farming Systems in Nigeria," Michigan State University International Development Paper. Department of Agricultural Economics, 1982.

Delgado, Christopher L., "Livestock Versus Foodgrain Production in Southern Upper Volta: A Resource Allocation Analysis," Ann Arbor: Center for Research on Economic Development, University of Michigan, 1978.

Delgado, Christopher L. and Mellor, John W., "A Structural View of Policy Issues in African Agricultural Development," International Food Policy Research Institute, Washington D.C., July, 1984.

Eicher, Carl and Staatz, John, M., "Agricultural Development in the Third World," The John Hopkins University Press, 1984.

Falcon, Walter P., "Farmers Response to Price in a Subsistance Economy: The Case of West Pakistan" American Economic Review 54 (3) 580-591, 1964.

Haggblade, Steve, "An Overview of Food Security in Upper Volta," A Report Prepared for USAID/Upper Volta, July, 1984.

Hardaker, J.B., "A Review of Some Farm Management Research Methods for Small-Farm Development in LDCs," Journal of Agricultural Economics, Vol. 30, No,. 3, September, 1979.

Harrison, Kelly; Henley, Donald; Riley, Harold; Schaffer, James "Improving Food Marketing Systems in Developing Countries: Experiences From Latin America," Michigan State University, Latin America Studies Center. Research Report No. 6.

Hayami, Yujiro and Ruttan, Vernon W., "Agricultural Development: An International Perspective," The Johns Hopkins Press, Baltimore and London, 1971.

Heyer, J., "An Analysis of Peasant Farm Production Under Conditions of Uncertainty," Journal of Agricultural Economics, Vol. 23 p. 135-146, 1972.

Heyer, J., "A Linear Programming Analysis of Constraints on Peasant Farms in Kenya," Food Research Institute Studies in Agriculture Economics, Trade and Development. Vol. 10, No. 1, 1971.

Hirschman, Albert, O., "The Strategy of Economic Development," Yale University Press, Inc, 1958.

Hopper, David M., "Allocative Efficiency in Traditional Indian Agriculture," Journal of Farm Economics, 47: 611-624, August, 1965.

Holton, Richard H., "Marketing Structure and Economic Development," Quarterly Journal of Economics, Vol. 67 344-61, August, 1963.

ICRISAT, "Annual Report: Republic of Upper Volta, Ministry of Rural Development; Department of Agricultural Services. 1980.

------, "Rapport Annuel" Programme Cooperatif ICRISAT/Haute-Volta, 1981.

------, "Annual Report of ICRISAT/Upper Volta" Economic Program, 1982.

------, "Annual Report" ICRISAT/Upper Volta Cooperatif Program, 1983.

ILCA, "Animal Traction in Subsaharian Africa," Bulletin No. 14.

Kamuanga, Malumba, "Farm Level Study of rice Production System at the Office du Niger in Mali: An Economic Analysis. Unpublished Ph.D. Dissertation; Department of Agricultural Economics, Michigan State University, 1982.

Kennedy, J.O.S. and Francisco, E.M., "On the Formulation of Risk Constraints for Linear Programming," Journal of Agricultural Economics, 25 (2); 129-44, 1974.

Krishna, Raj., "Farm Supply Response in India-Pakistan: A Case Study of the Pundjab Region," Economic Journal, 73 (291): 477-487, 1963.

Lele, Uma J., "Market Integration: A Study of Sorghum Prices in Western India," Journal of Farm Economics, Vol. 49, 147-59, February, 1967.

Lipton, Michael, "The Theory of The Optimising Peasant," Journal of Development Studies, 4 (3): 327-352, 1968.

Low, A.R.C., "Linear Programming and The Study of Peasant Farming Situations - A Reply, Journal of Agricultural Economics, Vol. 24, No. 2, May, 1978.

Low, A.R.C., "Decision Taking Under Uncertainty: A Linear Programming Model of Peasant Farmers Behavior," Journal of Agricultural Economics, 25 (3): 311-22, 1974.

Matlon, Peter J., "The size, Distribution, Structure and Determinants of Personal Income Among farmers in the North of Nigeria," Unpublished Ph.D. Thesis, Cornell University, 1977.

McInerney, J.P., "Maximim Programming: An Approach to Farm Planning Under Uncertainty, Journal of Agricultural Economics, 18 (2): 279-90, 1967.

Mellor, John W., "The Economics of Agricultural Development," Cornell University Press; Ithaca, New York, 1966.

Mellor, John W., "The New Economics of Growth: A Strategy for India and the Developing World," Cornell University Press; Ithaca, New York, 1976.

Norman, D.W., "Economic Analysis of Agricultural Production and Labor Utilization Among the Haussa in the North of Nigeria," African Rural Employment Paper No. 4, Department of Agricultural Economics, Michigan State University, 1973.

Norman, D.W., Simmons, Emmy B. and Hays, Henry M., "Farming Systems Research in the Nigerian Savana: Research and Strategies for Development," A Westview Replica Edition, 1982.

Nuthall, P.L., "On the Analysis of Simplex Linear Programming Solution Tableau with Reference to Net Revenue Stability Limits," Journal of Agricultural Economics, Vol. 22 No. 1 49-69; January, 1971.

Ogunfowora, O. and Norman, D.W., "An Optimization Model for Evaluating the Stability of Sole Cropping and Mixed Cropping Systems Under Changing Resource and Technology Levels," Bulletin of Rural Economics and Sociology, Vol. 8, No. 1, 1973.

Odero-Ogwel and Clayton, Eric, "Regional Programming Approach to Agricultural Sector Analysis," Agrarian Development Studies, Report No. 5, School of Rural Economics, Wye College.

Palmer-Jones, C., "A Comment on Planned Versus Actual Farmer Performance Under Uncertainty in Underdeveloped Agriculture," Journal of Agriculture Economics, Vol. 28, 177-179, 1977.

Ruttan, Vernon W., "Agricultural Product and Factor Markets in Southeaast Asia," Economic Development and Cultural Change, Vol. 17, 501-519, July, 1969.

Sarimin T. and Bernsten R.H, "Agroeconomic Profile of an Old Transmigration Area in the Tidal Swamp Environment," International Rice Research Institute, Los Banos, 1984.

Schultz, Theodore W., "Transforming traditional Agriculture," New Haven and London; Yale University Press, 1964.

Shaffer, James D. with Weber, Michael; Riley, Harold and Staatz, John, "Influencing the Design of Marketing Systems to Promote Development in the Third World Countries," Department of Agricultural Economics, Michigan State University, East Lansing, 1984.

Sinaga, R.S., Bernsten, R.H., "Myths About Land Preparation Mechanization: Research Results in Indonesia," Paper Prepared for the 8th International Conference of Agricultural Economists, Jakarta, August 24-September 2, 1982.

Square, Lyn and van der Tak, Herman G., "Economic Analysis of Projects," A World Bank Publication, The John Hopkins University Press, Baltimore and London, 1981.

Tagne, Pascal Fotzo, "The Economics of Bas-Fond Rice Production in the Eastern Region of Upper Volta: A Whole Farm Approach," Unpublished Ph.D. Dissertation, Department of Agricultural Economics, Michigan State University, 1983.

Thomas, John W., "Food Problem and Emergency Policy Responses in Sub-Saharan Africa: Discussion," American Journal of Agricultural Economics, December, 1982.

Timmer, Peter C., Falcon, Walter P., Pearson, Scott R., "Food Policy Analysis," A World Bank Publication; The John Hopkins University Press, Baltimore and London, June, 1983.

Wharton, Clifton R., Jr., "subsistence Agriculture and Economic Developoment," Aldine Publishing Company, Chicago, 1965.

Wilde, de John C., "Experience de Development Agricole en Afrique Tropicale (Pays Divers)," Collection Techniques Agricoles et Productions Tropicales.

The World Bank, "Upper Volta Agricultural Issues Study," Report No. 3296-UV, West Africa Region, October 29, 1982.