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ECONOMIC EVALUATION OF AGRICULTURAL POLICY IN BURKINA FASO: A SECTORAL MODELLING APPROACH

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ABSTRACT

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Agricultural productivity in Africa has declined for two decades. Food aid imports and government policies emphasizing "cheap" food for urban consumers have lowered production incentives. Input subsidies, to compensate producers, have created government budgetary deficits. In 1980, the government of Burkina Faso was asked by the IMF and the World Bank to eliminate food aid, raise commodity prices and reduce fertilizer subsidies. This study provides an economic analysis of those policies.

A model of Burkina Faso's agricultural sector is constructed to simulate the effects of alternative policies on prices, quantities and trade. The model contains nine commodities, five supply regions, seven demand regions, domestic and foreign trade. Coexistence of private and official markets is explicit. In official markets, input supply and commodity marketings are based on government rations at fixed prices. Rations reflect government budgetary and market constraints. In private markets, prices and quantities are relatively unrestricted, but conditional on the institutional behavior of official markets.

Production and input use are estimated via linear programming, based on profit maximization given producers' expectations of private

and official market prices. Demand is estimated via Linear Expenditure Systems and the Frisch method. Linearized demand, foreign trade and price linkage equations are nested in a Linear Complementarity Problem to solve for private market prices, quantities demanded and trade. The model is solved recursively, permitting short and long term analyses of market dynamics and policy impacts.

Solution results show that eliminating food aid raises commodity prices, but increases commercial imports. Removing fertilizer subsidies causes minimal changes due to low current fertilizer rations. Removing fertilizer rations sharply increases fertilizer utilization and output. But, fertilizer imports outpace commodity exports, creating balance of payments problems.

With the addition of higher official commodity prices, cereal production decreases as incentives shift to cotton. Cereal production and consumption are still superior to base levels. Improved profitability of agricultural technologies increases fertilizer use. Balance of payments improve with higher cotton exports. The policy reform improves agricultural performance, but relies heavily on cotton for foreign exchange earnings to cover fertilizer imports--contrary to government food self-sufficiency objectives.

CHAPTER I

PROBLEM STATEMENT AND OBJECTIVES

Background

Sub-Saharan Africa is the only region in the world where agricultural productivity has declined over the past two decades (USDA, 1981). Between 1970 and 1979, agricultural output per capita fell at an average annual rate of 1.4 percent. High population growth (2.7 percent per year) combined with stagnant growth in agricultural production (1.3 percent annually) led to rising food imports (The World Bank, 1981a, pp. 167, 176). Cereals imports rose at an average annual rate of 9.5 percent despite slumping economic growth of many countries in the region. While Gross National Product (GNP) per capita for all developing and developed countries grew 2.5 percent per year during the 1970s, GNP per capita for all sub-Saharan Africa grew only 0.8 percent per year. If the growth of Nigeria is excluded, GNP per capita for low and middle income countries fell at annual rates of -0.3 and -0.5 percent, respectively. The result has been acute foreign exchange problems, fiscal crises and growing dependence on the rest of the world for development assistance.

Many complex factors have contributed to the continent's agrarian crisis. Studies by the Club du Sahel (1982), FAO (1977), USDA/ERS

(1981), DAI (1982) and the World Bank (1981a and 1981b) have comprehensively explored the underlying causes. From their analyses, four broad categories of factors appear to be common to most countries in the region:

1) Agriculture is based on subsistence farming methods. Increases in production have historically depended on extensive farming practices and area expansion. Fallowing and crop rotations have been the traditional means for conserving soil fertility. Rapid growth of population has increased land-use pressures in many areas, increasing the incidence of continuous cultivation and the decline of traditional land conservation practices.

2) Environmental and climatic factors, including drought, pest infestation and crop disease, severely constrain yields. Drought has been an especially important factor. Nicholson (in Kandel, 1984) estimates, based on long-run precipitation records from the early 1900s to present, that rainfall deficiency has existed in the Sahel every year since 1968. The drought of 1982-83 was possibly the worst on record.

3) Commercial inputs that might improve yields or offset declining land productivity receive limited application. Improved technological packages, like those developed for Asia, have evolved slowly. Reasons underlying low modern input use are: poor economic incentives to producers, constraints on supply and distribution of inputs, and poor extension services. These in turn reflect poor communications and transportation infrastructure, fiscal constraints on government expenditures and lack of foreign exchange for intermediate inputs and capital imports.

4) Agriculture and its support system tend to be geared more toward production of cash crops for export and less toward food crop production (Acharya, 1981; Tosh, 1980; USDA/ERS, 1981). Commodity price policies have been directed toward providing low food prices for the urban consumer, thereby offering inadequate incentives to agricultural producers.

Since the drought years of the early 1970s, considerable development assistance has flowed into the sub-Sahara to combat low agricultural productivity. External aid has been invested in irrigation and land reclamation projects, physical infrastructure and

projects designed to improve the productivity of crop and livestock systems. Agronomists, plant breeders and other scientists in the international research community are working to develop new agricultural technologies to redress technical problems of low agricultural productivity. Farming Systems Research and Extension (FSR/E) programs are identifying socio-economic constraints to increased agricultural production and problems of technology dissemination and adoption.

The problems facing the agricultural sectors of African countries, however, cannot be solved solely by technological and sociological changes. The importance of agricultural policy, and its effect on the performance of the agricultural sector cannot be ignored.

Agricultural Policy

Historically, the state has intervened extensively in sub-Saharan agriculture. Food and fiber policies may vary widely, but certain policies are commonplace: a) partial or complete control of commodity prices; b) heavy subsidization of inputs; c) export taxation; and d) food aid imports of "non-traditional" cereals.

Nearly all governments in the sub-Sahara act in some manner to control prices of agricultural commodities. Prices are administered through procurements and sales by government marketing boards or parastatal agencies in an official market. During the past decade, export crop producers have been heavily taxed and prices of food crops systematically set below world prices (World Bank, 1981a, p. 55).

Policies affecting producer and consumer prices have shifted incentives in favor of industrial and commercial sectors and against agriculture (Acharya, 1981).

Policymakers face constant pressure to maintain cheap food policies. Population in urban areas of sub-Saharan Africa is growing at rates of 5 to 6 percent per year (World Bank, 1981a, p. 179), creating highly visible problems of inadequate housing, infrastructure and under- and unemployment. The urban constituency is better organized politically than rural inhabitants, giving it a strong say in the policy making process. Governments are faced with a dilemma. They would like to provide adequate economic incentives to ensure "sufficient" food production, yet at the same time wish to keep prices low for urban consumers. Maintaining affordable consumer prices usually predominates.

To offset low producer prices, governments have relied heavily on input subsidies (USDA/ERS, 1981, pp.158, 159). Inputs are distributed to producers through state marketing agencies at prices below world market levels. World Bank (1981a,p. 60) estimates that 50 percent or more of the countries in the region place full control of procurement and distribution of modern inputs in the hands of state agents. If mixed government and private sector involvement is considered, the figure is well above 85 percent.

While input subsidies permit some compensation to producers for low commodity prices, benefits accrue only to the users of modern inputs. Higher official commodity prices would benefit users and non-users alike. Thus, subsidies are less effective than higher output

prices for stimulating supply response (Timmer, Falcon and Pearson, 1983, p. 135). Also, governmental costs increase as demand for modern inputs grows. To meet these costs, governments must either increase taxes (usually on agricultural exports), draw resources from existing allocations, or incur budgetary deficits. Budgetary constraints in turn limit government effectiveness in carrying out input distribution and commodity marketing programs.

Many governments have turned to foreign countries for food aid to augment food supply. In some cases, food is imported to support official price schemes. Governments would like to fill quotas with domestically purchased grain, but the bias towards low "producer" prices and marketing constraints often create procurement problems. Since food aid is usually sold through official channels at fixed "consumer" prices (Berg in CRED, 1977, p. 60), prices of domestic substitutes are depressed.

A large fraction of imports consist of maize, wheat, and rice. Millets and sorghums, however, are the staple crops of the region. Wheat is not generally produced in the Sub-Sahara, while rice production is socially unprofitable, except for interior countries which receive protection from high transport costs (Humphreys and Pearson, 1979). Wheat and rice are considered modern cereals that are consumed mainly in urban areas. In the short run, food aid dampens demand and price incentives for locally produced millets and sorghums. In the longer run, changes in consumer preferences may be expected, strengthening demand for imports and placing growing pressure on the country's reserve of foreign exchange for food purchases.

In recent years, international agencies (IMF and the World Bank) have pushed for reductions in subsidy levels and for a free market approach to commodity pricing. This was the case in the early 1980s, when the government of Burkina Faso, in West Africa, through negotiations with the World Bank (1981b, p. 18), was persuaded to remove input subsidies on fertilizer, increase producer prices of cotton and sorghum, and eliminate food aid imports. Proponents of the policy argue: 1) subsidies are inferior to higher commodity prices for attaining higher agricultural output; and 2) the cost of subsidies become increasingly difficult to pay with the technological evolution of agriculture. Opponents argue that higher fertilizer prices would lead to diminished fertilizer use with profound negative impacts on agricultural output. Thus, the policy runs counter to food security objectives and stifles efforts to technologically transform agriculture. These issues were intensely debated in 1983, the year in which the policy was to be implemented. Officials wanted to estimate the effect of removing the subsidy, especially its impact on food supply and on national food security. Lack of analytical tools within the planning ministry precluded a quantitative analysis of the issue.

Methodological Issues

Improving agricultural policy requires better knowledge and understanding of the projected impacts of policy alternatives. The complex relationships connecting production, consumption, prices and trade in the economy must be considered. For agricultural policy analysis in Africa, there are three futher considerations: a) acute

shortages, particularly at the national and regional levels; b) existence of parallel markets; and c) limits on model size to meet computer limitations and financial constraints of African planning ministries.

There have been useful applications of micro-models of household production and consumption to technology evaluation and policy analysis (e.g. Lau, Lin and Yotopoulos, 1978; Barnum and Squire, 1979; Ahn, Singh and Squire, 1981; and Strauss, 1984). Analyses are conducted by evaluating the effects of an exogeneous policy change on the farming system. Such analyses, however, do not permit evaluation of feedback effects on the rest of the economy, optimal allocation of resources at the sectoral level, or costs and benefits of policy alternatives from a societal viewpoint. These questions require a broader perspective on markets, regional production possibilities, resource endowments, urban-rural consumption characteristics, domestic and international trade, than is possible with micro studies. Further, policymakers desire aggregate measures of performance--regional supply and demand response, prices, resource utilization, and distributional impacts among urban and rural groups--when choosing among policy alternatives.

Sectoral modelling is ideally suited to addressing macro policy issues. Approaches to sectoral modelling have been varied, including input-output analyses, econometrics and mathematical programming. The latter has been particularly useful for policy analysis (McCarl and Spreen, 1980). Existing approaches, however, have several limitations. Large-scale economy wide models (as developed for Taiwan, Mexico and Nigeria) require considerable resources for model

development and operation. Smaller modelling applications, like Jabara and Thompson's (1980) model of the Senagalese agricultural sector, are more suited to resources of African ministries. The technological specification of supply, in sector models, is often weak. Demand systems are rarely estimated that have had imposed the theoretical restrictions of demand theory. The existence of parallel markets in Africa presents a special problem. Prices and quantities are unrestricted in private markets but are restricted in official markets. Current approaches rely heavily on the assumption of competitive market behavior, limiting their application in cases where market restrictions exist.

Objectives

This analysis uses agricultural policy in Burkina Faso, West Africa, as a case study for policy evaluation. It describes price and product policy in Burkina Faso and evaluates alternative policies being considered by the government. The analysis centers on the World Bank policy that recommends a more free market approach to input and commodity pricing. Policies pursued by the government are similar to those found on the continent, making the analysis applicable on a regional scale.

A sector modelling approach is developed which overcomes some of the limitations of existing approaches. The research makes several unique contributions. The sector model explicitly incorporates parallel markets into the analysis. Linear programming models estimating supply are linked with a Linear Complementarity Problem for estimating

prices, demand and trade. The model is solved in sequential fashion permitting both short and long term analyses of policy impacts. The model's sequential nature also permits solving large supply models, without excessively slowing calculation of the market equilibrium. Supply is estimated based on producers' price expectations, rather than market equilibrium rates, allowing broader and more realistic analyses of producers' response to policy change. Supply models have detailed specification, permitting evaluation of a wide mix of technological options. Demand is estimated via the Linear Expenditure System which satisfys the theoretical restrictions of demand theory. Demand model parameters were estimated from limited data using the Frisch procedure. All data for the analysis comes from secondary sources, making the approach applicable to other regions of Africa where data problems are acute. The model is a flexible analytical tool suitable for evaluating a broad array of agricultural policies.

The sectoral model is used to investigate four policy options:

1) the economic consequences of removing fertilizer subsidies;

2) the effect of removing food aid imports on price incentives for production of domestically produced cereals;

3) the economic impact of raising official 'producer' prices;

4) the economic impact of price policy on new technology and the allocation of commercial inputs in agriculture.

Organization

This study is organized as follows. Chapter II provides background on the agricultural sector and macro-economy of Burkina Faso. It also describes national objectives and the state of agricultural policy. Chapter III provides an overview of the theoretical model

developed for policy simulation and analysis. It describes the specification of a spatial, recursive and dynamic market equilibrium model of the agricultural sector of Burkina Faso. Supply and demand sub-models in the larger sector model receive only partial coverage in that chapter. The complete development of the theoretical supply sub-model is in Chapter IV. The empirical implementation of the supply model is covered in Chapter V. An aggregate commodity balance sheet, prices and trade linkages are elaborated on in Chapter VI. This chapter provides the limited price and quantity data for estimating demand in Chapter VII. Chapter VIII evaluates model performance using the 'base' model solution. It presents 'base' model results, examines shadow prices of scarce factors and validates results. This analysis provides the benchmark for Chapter IX, which evaluates specific policy alternatives. Chapter X contains conclusions, policy implications and suggestions for future research.

CHAPTER II

BACKGROUND ON THE AGRICULTURAL SECTOR AND MACRO-ECONOMY OF BURKINA FASO

Introduction

Burkina Faso[1/] is a small land-locked country in Sahelian West Africa.[2/] It is bordered on the east by Niger, on the north and west by Mali and on the south by the Ivory Coast, Ghana and Togo (Figure 2.1). The country covers an area of 274,000 km.^{2} (roughly equivalent to the state of Colorado) of which one-third is considered arable (Table 2.1). Its climate is hot and mainly dry, with an average annual temperature of 82°F. Rainfall varies from under 500 mm. (20 inches) in the north to over 1200 mm. (48 inches) in the southwest, spread over a four to five month rainy season.

1/ Burkina Faso was formerly Upper Volta.

2/ Several studies are noteworthy in their comprehensive review of the country's geography, climate, demography, macro-economy and particularly the structure and performance of the agricultural sector: Club du Sahel, Developpement des Cultures Pluviales en Haute-Volta, 1982; Development Alternatives, Inc., "Agricultural Sector Assistance Strategy for Upper Volta," 1982; FAO, Perspectives du Developpement Agricole a Long Terme de la Haute-Volta, 1977; Republique de Haute-Volta, Ministere du Developpement Rural, Rapport de Synthese de la 2e'me Conference des Cadres (1981); and the World Bank, "Upper Volta Agricultural Issues Study," 1981. This list is not exhaustive. These studies provide a broad overview of agriculture in perspective of the larger macro-economy of the country.

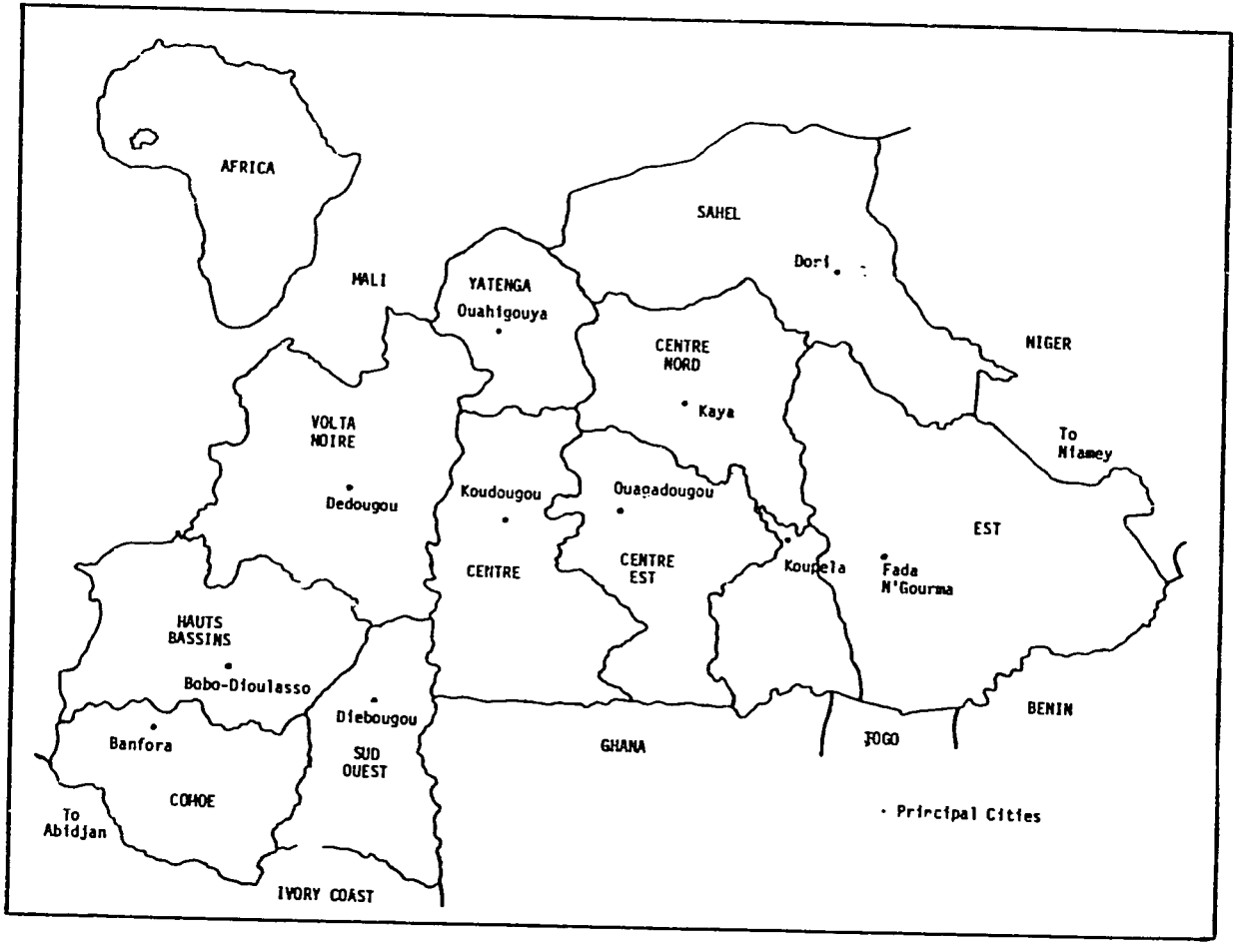

Figure 2.1. Map of Burkina Faso.

Table 2.1. General Country Charactersitics, Burkina Faso.

Total Surface Area: 274,200 km^2

Nation's Capital: Ouagadougou Population (1980): 247,877

Total Population: GNP/Capita (1980): $200
Census (1975): 5,638,203
Official Estimate (1980): 6,150,000

Population Growth:
Annual Birth Rate (1975-80): 47.8/1000 Natural Rate: 2.5%
Annual Death Rate (1975-80): 23.2/1000 Real Rate: 1.6-1.7%

Currency: 1 franc de la Communaute Financiere Africaine (CFA) = 100 centimes

Exchange Rates (francs CFA per US$) 1980: 211.3 1981: 271.7

GDP (Percent Distribution):		Labor Force (Percent Distribution):	
Agriculture (1979):	38%	Agriculture (1979):	83%
Industry:	20%	Industry:	12%
Services:	42%	Services:	5%

Principal Crops: sorghum, millet (more than 90% of area harvested)

Major Exports: cotton, shea nuts, livestock products

Minerals: Small deposits of manganese, gold, diamonds, uranium, and vanadium

Social Welfare:
People per physician (1980): 54,409
Percent enrolled in:
Primary school (6-11) 17% Secondary school (12-17): 2%
Adult illiteracy (1975): 91.2%
Population with safe water (1975): 25% Infant mortality: (before age 5) 31%
Daily Calorie Supply (1977): 1,875
Percent of requirement: 79%

Sources: From the World Bank, Accelerated Development in Sub-Saharan Africa: An Agenda for Action, 1981, pp. 143-181 and Europa Publications Limited, The Europa Year Book 1984, pp. 2638-2647.

Like many countries in Africa, Burkina Faso is experiencing rapid population growth. The size of its resident population is not accurately known, but estimates (Table 2.1) have placed it around 6.2 million persons in 1980. This population combined with low abundance of arable land make it one of the most densely settled areas of the Sahel (USDA/ERS, 1981, p. 278). The country's total population is estimated to be growing at a natural rate of 2.5 percent per year, increasing demands on the country's natural resource base. The effect in many areas has been severe degradation of land resources through deforestation, over-grazing and poor soil management, particularly on the Central Plateau where population settlement has historically been greatest.

The traditional means for alleviating pressures of overpopulation have been intra-regional migration and emigration from the country. Most migration within the country is from areas of high population on the Central Plateau to more land-fertile, less densely populated areas in the west and southwest.[3/] The country's rate of emigration is also significant. The World Bank (1981b, p. 24) estimates that as many as 0.7 million people, representing 20 to 25

3/ A 1975 population census found 5 percent of resident population working outside their district of birth. Most emigration was from the ORDs of Yatenga (Nord) and Centre-Ouest to the ORDs of southern Volta Noire and Haute Bassins. See Republique de Haute-Volta, Ministere du Plan et de la Cooperation, INSD, Principaux Resultats du Recensement de 1975, 1979, pp. 19, 20.

percent of the country's work force, may be employed abroad.[4/] This gives Burkina Faso the highest rate of emigration in West Africa and is the reason for the country's low real rate of growth in resident population (1.6 percent per year).

By most indices of welfare, Burkina Faso ranks among the poorest countries in the world (Table 2.1). Its population remains largely uneducated, health conditions are poor and low agricultural productivity contributes to low income and inadequate food availability. In 1975, less than 10 percent of the adult population were considered literate while only 1 in 6 children of primary school age attended school. Poor diets and lack of clean water curtail efforts to raise labor productivity and health standards. Per capita incomes of around $200 per year rank among the lowest in the world and provide little margin beyond subsistence for purchase of goods and services.

Regional Overview

The country is far from homogeneous. It possesses considerable regional variation in terms of natural resources, population, and land productivity. The extent of this heterogeneity is demonstrated in Tables 2.2 through 2.4, where information is provided on factor abundance and agricultural potential of each of the country's 11 ORDs

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4/ While most emigration abroad is from the Central Plateau, in particular from the ORDs of Centre-Ouest, Nord and Centre-Nord, all regions of the country are affected. Most emigrants are young (age 20 to 39), single men searching for work abroad. The rate of emigration is estimated to be increasing at 6 to 7 percent per year posing major demographic, economic and social problems for Burkina Faso and recipient countries alike. Ibid., p. 22.

Table 2.2. General Indicators of Climate, Land and Population by Region, Burkina Faso.

Region	O.R.D.	Ecological Zone[1/]	Total Surface Area (km^2)[2/]	Resident Population ('000,1980)[2/]	Density (Persons per km^2)[2/]	Potential Arable Land, (Percent)[3/]
North	Centre Nord	B	21,578	689	31.9	28 (12)
	Yatenga	B	12,297	578	47.0	28 (12)
	Sahel	AB	36,895	386	10.5	27 (6)
Central	Centre	C	21,952	1,029	46.9	34 (17)
	Centre Ouest	C	26,324	860	32.7	31 (11)
	Centre Est	CD	11,266	441	39.1	29 (15)
East	Est	BCD	49,992	443	8.9	31 (4)
West	Volta Noire	BCD	33,106	693	20.9	28 (8)
Southwest	Hauts Bassins	D	24,779	636	14.7	46 (7)
	Bougouriba	D	17,448	390	22.4	41 (9)
	Comoe	D	18,393			41 (6)
National	Burkina Faso	-	274,030	6,145	22.4	33 (9)

Sources:

1/ A=Sahelian zone (northern limit of crop cultivation at the 350 mm. to 600 mm. isohyet); B=Sahelo-Sudanian zone (600-800 mm. rainfall); C=Sudanian zone (800-1000 mm. rainfall); and D=Sudano-Guinean (south of 1000 mm. isohyet).

2/ Area, resident population and density are from Republique de Haute-Volta, Annuaire de Statistique Agricoles 1977, p. 5; and Republique de Haute-Volta, Bulletin de Statistiques Agricoles: Campagnes 1978/79, 1979/80, 1980/81, and 1981/82, p. 35. Resident population and density of Comoe are included in the data for Hauts Bassins.

3/ Data on arable land are from World Bank, "Upper Volta Agricultural Issues Study," 1981, p. 202. Figures in parentheses are the percent of total area actually cultivated in 1979/80 to 1981/82, calculated from area harvested figures in Table 2.4.

Table 2.3. Geographical Distribution of Agricultural Land and Labor Productivity, Burkina Fasc

Region	O.R.D.	Rural[1/] Population (1980,'000)	Density (Rur. Pop. per km Arable Land)	Production[2/] of Cereals per Rural Inhabitant	Yields (kg./ha.)[2/] 1979/80 - 1981/82			Cattle per[3/] Rural Inhabitant
					Millet & Sorghum	Cotton	Ground-nuts	
North	Centre Nord	682	113	152	459	371	426	0.5
	Yatenga	537	157	110	447	217	447	0.4
	Sahel	386	39	135	296	-	266	1.6
Central	Centre	830	111	214	495	424	442	0.3
	Centre Ouest	806	99	171	510	510	302	0.2
	Centre Est	438	134	180	488	373	415	0.3
East	Est	439	33	215	493	365	494	0.7
West	Volta Noire	689	75	254	752	899	517	0.5
South-west	Hauts Bassins	294	26	466	1,021	1,214	687	0.6
	Bougouriba	390	55	216	584	643	535	0.4
	Comoe	203	27	380	684	576	1,101	0.5
National	Burkina Faso	5,693	63	217	547	899	540	0.5

1/ Rural population (1980) is taken from rural population estimates (1975) by F.A.O., Perspectives du developpement agricole a long terme de la Haute-Volta, 1977, p. 20 and a growth rate of 1.72 percent. The 1975 population estimates are based on data sources estimated independently of the 1975 population census. Note: The use of a constant growth rate assumes no differential growth or unequal migration between regions from 1975 to 1980.

2/ Production of cereals (millet, sorghum, maize, rice and fonio) and yields are three year averages, 1979/80 to 1981/82 calculated from Republique de Haute-Volta, Bulletin de Statistiques Agricoles: Campagnes 1978/79, 1979/80, 1980/81, and 1981/82, pp. 61-69.

3/ From World Bank, "Upper Volta Agricultural Issues Study," 1981, p. 215.

Table 2.4. Total Area Harvested and Crop Mix by Region, Three Year Average,[a/] Burkina Faso

Region	O.R.D.	Total Area Cultivated (ha.)	Percent of Area Cultivated							
			Millet	Sorghum	Maize	Rice	Fonio	Ground-nuts	Cotton	Sesame
North	Centre Nord	255,102	38.6	43.7	4.5	0.7	-	9.0	1.7	1.7
	Yatenga	143,840	43.6	43.1	2.8	0.2	0.5	7.8	0.5	1.4
	Sahel	206,135	56.4	28.7	0.6	0.1	-	7.7	-	6.5
Central	Centre	374,598	43.8	48.3	2.2	0.6	-	4.5	0.6	-
	Centre Ouest	299,669	27.7	60.8	3.2	1.2	-	5.7	1.5	0.1
	Centre Est	168,965	40.5	35.9	6.0	4.9	-	12.7	0.1	-
East	Est	188,473	35.7	51.9	5.9	0.2	-	5.9	0.3	0.1
West	Volta Noire	275,812	26.7	47.9	4.8	1.6	0.5	4.3	11.3	1.2
Southwest	Hauts Bassins	166,230	12.1	42.0	13.6	4.1	4.9	7.8	13.4	2.3
	Bougouriba	154,622	24.9	57.8	6.1	2.0	-	4.7	4.4	0.1
	Comoe	111,623	21.7	26.7	27.0	4.2	-	11.2	0.2	9.0
AVV	AVV	8,207	3.9	54.4	7.5	-	-	1.5	32.6	-
National	Burkina Faso	2,353,276	34.8	46.0	5.6	1.5	0.2	6.3	3.5	1.6

Source: Adapted from Republique de Haute-Volta, Bulletin de Statistiques Agricoles: Campagnes 1978/79, 1979/80, 1980/81, and 1981/82 (various pages).

[a/] Average of 1979/80 to 1981/82.

(Regional Development Organizations). The ORD is an administrative-political structure that corresponds geographically with states or departments in the country.[5/] The ORDs are further grouped into sub-regions, based on similarities in precipitation, geography, infrastructure and agricultural potential, to facilitate comparisons. The rationale for choice of regions is given further elaboration in the discussion of methodology in Chapter III. The statistics in Tables 2.2 through 2.4 provide supporting documentation for the following regional descriptions.

North Region (Centre Nord, Yatenga and Sahel)

The northern region is the driest zone of the country. Most of the region lies north of the 700 mm. isohyet[6/] where low levels of precipitation and untimely rainfall severely constrain agricultural productivity. Returns to land and labor are low. Yields of staple cereals are only 300 to 460 kg./ha.[7/] while total cereals production

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5/ ORD is (in French) Organisme Regional de Developpement or Regional Development Organization. The ORDs were created in 1967 with the decentralization of economic development activities by the government. Eleven ORDs were formed corresponding to the country's 10 departments. One department is divided into two ORDs. Each ORD has considerable autonomy with respect to planning, project implementation, coordination of rural development activities, and use of resources within the policy guidance of the Ministry of Rural Development.

6/ Isohyets are lines on a map connecting areas of equal rainfall.

7/ It is argued in this study that yields reported in official statistics (Table 2.3) are overstated. Crop area and yield measurements are biased toward higher quality soils closer to the village and compound where yields are superior and crops such as maize and sorghum predominate. Fields cultivated in the outlying bush, where yields are typically lower and millet more prevalent, tend to be underestimated.

averages less than 150 kilograms per rural inhabitant.[8/] Millet, grain sorghum, and groundnuts are the major crops grown. Millet probably has greater representation in the crop mix than is reflected in official statisics (Table 2.4 and footnote 7). Various farm studies have independently reported millet to comprise upwards of 55 percent of area cultivated.[9/]

The ORDs of Centre Nord and Yatenga enclose the northern part of the Central Mossi Plateau, where population densities rank the highest in the country (32 to 47 persons/km.^{2}). The Central Plateau historically has been the country's most densely settled area. The Sahel, in contrast, has one of the lowest population densities, reflecting low productivity of land resources. A high proportion of its population are nomadic or semi-sedentary and livestock production plays a major role in the zone's economy. In 1980, stock levels in the Sahel ORD alone were 360,000 head of cattle and 800,000 small ruminants (Development Alternatives, Inc., 1982, p. 23).

High population pressure combined with low productivity per unit of land make this a major cereal deficit region in most years. Physical and social infrastructure are extremely poor. Roads are unpaved and frequently become impassable during the rainy season,

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8/ For sake of comparison, the FAO applies a norm of 180 kilograms of cereals per person per year in estimations of cereal needs of Burkina Faso's population. This is net consumption after post-harvest loss and seed requirements (estimated at 13.5 percent of annual production). Based on this criteria, the region incurs major food deficits.

9/ See M. Roth, (1986, forthcoming) for a synthesis of these data.

exacerbating the functioning of the cereals marketing network. Along with the eastern region, this is one of the least accessible areas of the country.

Central Region (Centre, Centre Ouest and Centre Est)

The central region occupies a band between the 800 and 1000 mm. ischyets of rainfall. The rainy season lasts only four months or less and there are few permanent water courses or bottomlands. Land productivity (yield/hectare) is higher than areas further north, due to higher precipitation, but low and untimely rainfall are still important constraints to agricultural production. Physical infrastructure is relatively better developed. A dense network of primary and secondary roads traverse the region with the country's major consuming center and capital--Ouagadougou--located at the hub.

The northern part of the zone encompasses the Central Plateau. The region's population density of 33 to 47 residents per km.^{2} is similar to that of the northern region, but several times higher than the extreme east, west, or southwest. High and increasing population density has increased land-use pressures and led to dimunition of the bush fallow system over time. Shifting cultivation, land fallow and manuring are traditional means for maintaining soil fertility in subsistence agricultural systems. High population pressures are decreasing the length of land fallow and increasing incidence of continuous cultivation. The effect has been severe soil degradation, which, in the absence of soil amending inputs (i.e., organic and inorganic fertilizers), has resulted in declining soil fertility.

Population pressures have also increased the incidence of forest overcutting and overgrazing by livestock. These are factors which contribute to desertification.

Farmers in the region plant over 90 percent of area cultivated in cereals, with about 5 percent in groundnuts. Sorghum is more prevalent than further north but farm studies suggest that millet still predominates. Grain production ranges from 171 to 214 kilograms per rural inhabitant, providing marginal marketed surplus in normal years. However, the region's large urban population, in Ouagadougou, reduces it to a food deficit area overall.

East Region (Est)

The eastern region lies to the east of the Central Plateau, between the 600 and 1000 mm. isohyets. It occupies 18 percent of Burkina Faso's land surface but less than 7 percent of its resident population. Except for the fringe along the border of the central region, it is one of the least densely populated areas of the country (8.9 persons/km.^{2}).[10/] Yields vary widely from north to south according to changes in precipitation and soil type (Lassiter, 1981, p. 17 and 1982, p. 1), but on average appear superior to those of the central region. Low population, abundant land resources and better surface water give the area a relatively large but unexploited

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10/ Reasons for this are not entirely clear. Several contributing factors are: a) high incidence of disease (malaria, onchocerciasis, and trypanosomiasis); b) lack of transport, communication and social infrastructure; and c) presence of wildlife preserves (Development Alternatives, Inc., 1982, p. 18).

potential. Realization of this potential, however, is hampered by poor transport, communications, and institutional infrastructure. These impose high real costs on the marketing of products, distribution of agricultural inputs and agricultural investment. With cereal production averaging around 215 kg. per rural inhabitant, the region produces a small marketed surplus in most years. But, due to high marketing costs and permeability of the country's eastern and southern borders, trade is as likely to take place with neighboring countries as it is with the rest of Burkina Faso.

Western Region (Volta Noire)

Like the eastern region of the country, the western zone encompasses a broad range of micro-climes from north to south (700 to 1000 mm. isohyets). Its population density is about the same as the national average (22 persons/km.^{2}), but agricultural land and labor productivity are higher due to greater abundance of comparatively more fertile soils. Yields of cereals average around 250 kg. per rural inhabitant[11/] making this a major food surplus region. The area around Solenzo in the southwest area of Volta Noire is frequently referred to as the "breadbasket" of the country.

Considerable private and public investment have transformed this region into the largest cotton producing area of the country. Some 31.5 thousand hectares of cotton are cultivated on average, most of

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11/ Statistics reported by the World Bank (1981b, p. 202) for 1975 show production to be considerably higher at around 300 kg. per rural inhabitant.

which is exported internationally. Farmers in these areas are more commercially oriented; they use more modern inputs and employ improved management practices. These investments have facilitated development of input distribution systems, product marketing and physical infrastructure (cotton mills, roads, etc.) but are largely limited to cotton growing areas. While the region is geographically closer to international markets (at Abidjan), the physical infrastructure within the region as a whole is inadequately developed.

Southwest Region (Hauts Bassins, Bougouriba and Comoe)

The Southwest region contains the country's second largest city, Bobo-Dioulasso, the former capital and a principal manufacturing center of Burkina Faso. The city and region's close proximity to Ivory Coast and to the seaport at Abidjan enable closer links with international markets and lower input to output price ratios for externally traded goods. Its endowments of physical infrastructure are superior to those of other regions. It also receives a high, disproportionate share of total capital investment. The zone has a relatively high proportion of rich vertisol soils, possesses several major water courses and has only a moderate population (15 to 22 persons/km.^{2}). Rainfall is generally in excess of 1000 mm., distributed over a five-month growing season. With these resources, this region probably has the greatest agricultural potential of any in the country.

The higher precipitation and more fertile soils permit a diversified agriculture. Sorghum is still widely cultivated, but maize and

tubers are relatively more important components of farming systems and consumer diets. Millet has less significance in the crop mix while cotton is a major cash crop for farmers. As with the western region, the institutions and infrastructure involved with cotton cultivation and export are relatively well developed, facilitating the supply of modern inputs. Much of the region's irrigation potential remains untapped but large irrigation schemes such as Vallee du Kou provide a significant portion of the commercial rice consumed in urban areas. With yields per hectare around 1.5 to 2.0 times those of the Central Plateau and production of 216 to 466 kilograms per rural inhabitant, this is a major grain surplus region in most years.

The threat of onchocerciasis or river blindness has historically prevented settlement of large tracts of land in the region, mainly in the river valleys. The disease is transmitted to humans by the female fly, *Simuleum damnosum*, which breeds in fast flowing streams or rivers. Currently, spraying programs are being carried out by the World Health Organization to control the vector of disease. Success of the program is expected ultimately to improve health and productivity of humans living in infected regions and permit resettlement of large areas which now remain unpopulated.

Agriculture in the Macro Economy

The economy of Burkina Faso is predominantly agricultural. More than 80 percent of the country's working population are farmers or livestock-raising nomads (Appendix 1, Table A1.14). Agriculture

contributes about 41 percent of Gross Domestic Product (GDP) (in 1977-79) (Appendix 1, Table A1.2)). The rest of the economy is mainly comprised of services and light industry.

With diversification of the economy over the past decade, agriculture's share in the national accounts has declined. Over the period 1970 to 1979, agriculture fell from 51.0 to 41.0 percent of GDP while the commerce, restaurants and hotels sector increased its share from 12.9 to 17.1 percent, non-market services from 7.4 to 13.8 percent and manufacturing from 11.3 to 12.5 percent (Appendix 1, Tables A1.2 and A.13). Most of the decline in agriculture came in the livestock (16.0 to 9.7 percent) and fishing and forestry (6.3 to 4.2 percent) subsectors while crop agriculture remained relatively constant.

Crop Production

Millet and sorghum are the most important crops cultivated nationwide. They constitute around 82 percent of total area cultivated, followed by groundnuts (5.8 percent), maize (5.5 percent) and cotton (3.4 percent) (1979-81 average; Appendix 1, Table A1.5). Yams and starches are also important food crops cultivated in areas of higher rainfall. Poor data, however, preclude estimation of their overall significance.

Agriculture for the most part is comprised of small farms (5 to 7 hectares) employing mainly traditional technologies. Modern inputs receive limited application, although their use has increased greatly over the past decade. Agricultural mechanization is used on only 7 to

8 percent of farms in the country. Less than 6 percent of total area cultivated receives chemical fertilization.[12/] Returns to both land and labor are low and highly variable. Yields of millet and sorghum average 490 to 590 kg. per hectare (1979-80 averages; Appendix 1, Table A1.5) ranking them, along with other West African countries, among the lowest in the world (Roth and Abbott, 1983, pp. 27 and 69). Cereal production per capita, as shown in Table 2.5, averages 184 kg. per resident (1972-81 average), creating food deficits and need for imports even in normal years. Allowing for post harvest losses and seed requirements (13.5 percent of production), net food production averages only 159 kg. per resident.

Besides low agricultural productivity, growth in food production, particularly staples, has been stagnant. Over the 1962-1981 period, production of grain sorghum and millet increased only 1.1 and 1.2 percent per annum, respectively, failing to keep pace even with resident population growth (Roth and Abbott, 1983, pp. 27 and 69). Most of the growth that was achieved was due to expansion of area cultivated by a growing rural population rather than higher productivity.[13/]

12/ Figures for animal traction are based on 21.2 thousand oxen units, 24.0 thousand donkey teams (Appendix 1, Tables A1.16 and A1.17) and 590 thousand farms (Republique de Haute-Volta, Ministere du Developpement Rural, "Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81 and 1981/82", p. 149. Figures for fertilization are based on 13.0 thousands metric tons of complex and Urea fertilizers (Appendix 1, Table A1.15), 2.35 million hectares cultivated (Table 2.4) and an estimated application rate of 100 kg./ha.

13/ The area of sorghum and millet from 1962 to 1981 increased at rates of 0.2 and 1.4 percent, respectively, while yields changed by 0.9 and -0.2 percent (Roth and Abbott, 1983, various pages).

Table 2.5. Gross Production and Availability of Grain for Food, Consumption, Burkina Faso.

Year	Total Cereal[a/] Production ('000 tons)	Cereal Production[b/] per Capita (kilograms)	Net Imports ('000 tons)		Gross Food[e/] Availability (kilograms)	
			FAO[c/]	INSD[d/]	FAO	INSD
1972	858.5	160	40.1		-	
1973	813.3	149	39.3		165	
1974	1068.7	193	74.1	107.7	160	166
1975	1243.4	221	21.2	29.4	193	195
1976	974.6	170	23.3	30.5	221	222
1977	1093.0	187	54.2	62.3	176	178
1978	1156.0	195	63.1	92.1	195	200
1979	1164.4	193	80.4	101.6	205	208
1980	1033.9	168	76.8		202	
1981	1254.3	201	48.0		173	

a/ Includes sorghum, millet, maize, fonio and rice.

b/ Total cereals per resident.

c/ From trade statistics published by FAO reported in Appendix 1, Table A1.8. Includes imports of millet and sorghum, maize, rice, and respective grain equivalents when flours are imported except for maize flour equivalents which are excluded from the data.

d/ From official government statistics reported in Appendix 1, Table A1.9. Maize flour equivalents are included in the data.

e/ Calculated as previous year production (Oct.-Nov. harvests) plus current year imports. No deductions are made for post-harvest losses and seed requirements (from Appendix 1, Table A1.6).

This situation has serious implications for the country's food security. As population in rural areas continues to grow, cultivation is pushed onto more marginal lands where soils are fragile and poorer in quality. Without the accompaniment of soil conservation practices or improved farm management techniques, soil fertility ultimately stagnates or declines. The deterioration of soils exacerbates problems of low and erratic rainfall, making production more precarious.

The series of droughts which occurred during the 1970s created major food security problems. As shown in Table 2.5, cereal production fell to 160 and 149 kg./capita in the severe drought years of 1972 and 1973 and later to 170 and 168 kg./capita in 1976 and 1980. For sake of comparison, the FAO and government of Burkina Faso use 180 and 215 kg./resident/year, respectively, net of post harvest loss and seed requirements, as norms for calculating cereals needs. If production is adjusted for post-harvest loss (13.5 percent), then the minimum consumption standard of 180 kg./capita for cereals was exceeded only once in the 1972-1981 decade.

Imports

To meet production shortfalls, the country has increasingly relied on food imports, in particular on food aid. Table 2.5 reports net cereals imports for the country based on FAO and INSD (official government) estimates. The latter includes maize flour (excluded by FAO) and higher imports of millet-sorghum. Imports of cereals are shown to have generally increased over the period of the 1970s, from

40,000 tons in 1972 to 80,000 tons in 1979 (FAO estimates). If INSD estimates including maize flour equivalents are considered, food imports were considerably larger. Based on the latter source, food imports would have represented nearly 8 percent[14/] of total cereals supply in 1979-81 (Appendix 1, Table A1.6).

Food imports tend to be highly cyclical, following climatic fluctuations. In years following droughts, as in 1974 and 1978, total cereal imports rose to over 100 thousand metric tons, of which 80 to 82 percent were contributed through food aid (Appendix 1, Table A1.9). In more normal years, food aid represented 35 to 47 percent of total cereal imports.

The level of cereals supply available for human consumption, reported in the last column of Table 2.5, is estimated from the commodity balance sheets presented in Table 2.6 and Appendix 1, Table A1.6. Estimates are computed by taking prior harvest production plus current year imports. No deductions are made for post-harvest losses or seed requirements, hence the figures represent gross availability of grain. Changes in stock levels and livestock utilization are assumed to be zero (for lack of data). Using the figures estimated with FAO trade data, average cereals availability over the period 1973 to 1981 was 188 kg./capita. Moreover, the lowest availability in any one year was 160 kg./capita in 1973. Since production in that year

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14/ Based on the ratio of FAO's estimates of imports (quantities) to INSD's estimates, calculated as 1.34 from data in Table 2.5. This calculation is necessary, because the INSD time series stops in 1979 and FAO estimates exclude maize flour, a sizable fraction of cereal imports.

Table 2.6. Cereals Production, Trade and Gross Food Balance, Burkina Faso, 1978 to 1981.

	1978		1979		1980	1981
Cereals Production ('000 tons)						
Millet	377.9		377.7		350.7	442.8
Sorghum	635.0		653.2		546.9	658.8
Maize	107.7		89.5		104.5	118.6
Fonio	9.6		3.5		5.7	4.7
Rice (paddy x 0.65)	25.8		30.5		26.1	29.4
Total	1156.0		1164.4		1033.9	1254.3
	FAO	INSD[a/]	FAO	INSD[a/]	FAO	FAO
Imports ('000 tons)						
Millet, Sorghum, Maize	29.2		20.4		19.8	8.7
Sorghum		(29.2)		(18.7)		
Maize		(24.7)		(18.4)		
Rice	10.2	(10.3)	25.5	(25.5)	30.3	15.0
Wheat	23.8	(26.0)	34.9	(36.4)	26.9	24.4
Other		(2.0)		(2.8)		
Total	63.2	(92.2)	80.8	(101.8)	77.0	48.1
Exports ('000 tons)						
Millet, Sorghum, Maize, Rice & Wheat	0.1		0.4		0.2	0.1
Total Cereals Available ('000 tons)[b/]			1,236.4		1,241.2	1,081.9
Resident Population ('000 tons)			6,040		6,145	6,251
Per Capita Cereals Availability (kg./person)			205		202	173

a/ Figures in parentheses are trade estimates by INSD.

b/ Total cereals available is previous year production (Oct.-Nov. harvests) plus current year net trade (FAO estimates). Imports exclude maize flour equivalents due to incomplete data (Appendix 1, Table A1.8). No deductions are made for post-harvest losses or seed requirements which normally represent 13.5 percent of supply.

Source: Data are taken from Appendix 1, Tables A1.6, A1.8, and A1.9.

was 149 kg./capita, imports provided a major supplement to food supply.

Food imports based on a high fraction of food aid, rather than with domestically generated foreign exchange, can increase food insecurity. Food aid often comes with conditional restrictions or may be terminated because of international politics, increasing uncertainty over its availability and cost.

There are two further potentially adverse effects from high, sustained levels of food aid imports. First, food aid depresses prices to producers of domestic substitutes, decreasing incentives in agriculture (World Bank, 1981a, p. 57). This effect would be negligible if aid were targeted towards drought afflicted populations whose effective demand were low. But, as Berg (in CRED, 1977, p. 60) points out, grain is usually sold through official channels at market prices.

Second, imports comprise a large fraction of maize, rice and wheat--not millet and sorghums, the staples of rural consumers. Cereal imports in Burkina Faso in 1977-1978 consisted of 22.2 percent maize, 18.5 percent rice, 32.2 percent wheat and only 24.7 percent millet and sorghum (Table 2.6: INSD estimates). Wheat is not produced domestically. The country is about 55 percent self-sufficient in rice (1979-81 average, Table 2.6). Wheat and rice are consumed mainly in urban areas.

In the short run, high sustained imports of these non-traditional cereals dampens demand and price incentives for locally produced millets and sorghums. Sustained imports over the long run may change consumer preferences, strengthening demand for wheat and rice through

an outward shift of their demand schedules, leading to further downward pressures on prices of domestically produced cereals.

Increasing urbanization and rising incomes have a related effect. Since income elasticities of demand for wheat (.51 to 1.46) and rice (.56 to .93) are higher than for sorghum and millet (.01 to .28), they incur proportionally larger increases in quantity demanded with increasing income (USDA/ERS, 1981, p. 36). Food imports then need to rise to meet demand, placing growing pressure on the country's reserve of foreign exchange for food purchases. To offset growing dependency on "expensive" cereal imports, governments often opt for less efficient production of import substitutes to secure supplies locally. This appears to be the case in Burkina, where experimentation is underway on production of irrigated wheat.[15/]

Exports

Exports of the country are primarily agricultural. Cotton is the most important export commodity, followed by livestock, hides and leather products and shea nuts, but trade shares have changed with time. Over the period 1972 to 1981, cotton revenues as a percentage of total export earnings increased from 20 to 41 percent and shea nuts from 3 to 15 percent, while livestock products saw a concommitant decline (from 41 to 18 percent) (Table 2.7). Exports of cotton were

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15/ Research experimenting with wheat cultivation has been underway for several years (since 1976) at Sourou Valley.

Table 2.7. Exports of Principal Commodities, Burkina Faso, 1972 to 1981.

Year	Total Value of Exports ('000,000 FCFA)	Percent				
		Cotton	Live Animals	Shea-nuts	Hides & Leather	Other
1972	5,141	19.9	40.8	2.6	4.1	32.6
1973	5.598	21.5	40.9	1.3	4.5	31.8
1974	8,702	17.8	35.2	4.1	2.4	40.5
1975	9,369	16.3	36.1	6.8	2.7	38.1
1976	12,690	45.6	11.7	16.5	3.1	23.1
1977	13,614	39.7	29.0	9.6	3.9	17.8
1978	9,600	31.3	36.8	9.5	6.0	16.4
1979	16,238	32.9	26.4	6.8	5.2	28.7
1980	19,066	43.9	23.7	8.1	3.9	20.4
1981	19,919	41.0	17.6	15.0	5.1	21.3

Source: Adapted from Appendix 1, Table A.11.

only 10.6 thousand tons in 1978, following years of drought, but rose to 27.9 thousand tons in 1980 (Appendix 1, Table A1.10). Since 1976, Burkina Faso has been the third largest cotton producer in West Africa.[16/] Similarly, exports of shea nuts rose from 21.5 thousand tons in 1978 to 43.6 thousand tons in 1981, making it the second most important export crop. Livestock was the major export earner in the early 1970s when liquidation of herds due to the drought pushed exports to around 30 thousand tons from 1972 through 1974. Livestock exports dropped sharply in 1976, to just over 7 thousand tons, increased to over 34,000 tons by 1979 and declined thereafter.

National Objectives

The single most important objective of Burkina Faso is food self-sufficiency. This has been a central theme of the country's development policy since the drought of the early 1970s and one common to most Sahelian countries. Rural development has been the cornerstone of these development strategies.

In the country's third five-year plan (1977-1981), priority was given to rural development, under the guidance of three national objectives: improved living conditions for the country's populace, especially for the poorest strata of the population; self-sufficiency in food; and, a reduction in under- and unemployment. The two major objectives set for the agricutural sector were replacement of food imports with greater domestic production and diversification into

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16/ From The Europa Year Book 1984, Upper Volta, 1984, p. 2639.

export (cash) crops. To achieve these objectives, the plan proposed to:[17/]

1) intensify production of cereals using improved farming practices and offering remunerative prices to producers. (The plan did not emphasize irrigation, but provided for limited expansion, with priority given to rainfed agriculture);
2) promote migration to redistribute the population according to productive capacity;
3) improve the productivity of labor through better communications, extension and other services;
4) develop economic infrastructure, particularly roads and communications, and promote integrated rural development;
5) safeguard the country's natural resource base, using soil conservation and natural resource measures; and
6) invest in human capital through improved social infrastructure, in particular improved health, education and water.

While providing broad directives for development, few guidelines were given for implementation.

In the early 1980s, attention was drawn even closer to issues of food self-sufficiency and security.[18/] By then, an entire decade of

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17/ This information is summarized from Counseil de l'Entente, "Agriculture Policies in the Entente Countries," 1979, pp. 96-104, and World Bank, "Upper Volta Agricultural Issues Study," 1981, p. 28.

18/ The 2e'me Conference des Cadres, which was held in June 1981, outlined the magnitude and dimensions of the food problem as it relates to food security issues (see RHV, MDR 1981).

heavy investment in the rural sector had passed without substantial improvement in agricultural productivity or improved well-being of the population. Food self-sufficiency came to be redefined not just as the quantity of food to meet the food needs of the population, but also an indispensable surplus to raise Burkina Faso out of a subsistence economy (RHV/MDR, 1983, p. 1). In a document prepared by the Ministry of Rural Development in early 1983, the following objectives were set for national food production:

Crop	1987[a/] Production (tons)	Percentage[b/] Increase Over 1979-81 Total
Millet-sorghum-maize	1,500,000	34
Paddy	72,000	59
Fonio	18,000	283
Cotton	120,000	77
Groundnuts	200,000	187

Sources: a) Republique de la Haute-Volta, Ministere du Developpement Rural, Memorandum Sur La Situation Actuelle et Les Grands Objectifs du Developpement Rural, 1983, pp. 6 to 8; b) Adapted from Appendix 1, Tables A1.6 and A1.7.

Priority was still to be given to the rainfed sector, but added emphasis was placed on development of swampland and irrigated agriculture for protection against catastrophies of major drought. The government set as an objective self-sufficiency in rice production by 1990 to replace rice imports (AGROPROGRESS AO Gmbh., 1982).

Meeting these objectives required increasing the efficiency of the agricultural sector. This was to be accomplished through better

supply and distribution of modern inputs--chemical and non-chemical fertilizers, pesticides, improved seeds, and animal mechanization--and more intense use of domestic resources. In particular, fertilizer use was to be increased from 20,000 tons in 1982 to around 50,000 tons by 1987 (RHV/MDR, 1983, p. 14).

More recent policies of the government, since the August 1983 revolution, have stressed the inequities created between urban and rural sectors and have sought to redress them. The sentiments of the new Sankara government were that development strategies of the past gave priority to investment in the most profitable sectors in expectation that "trickle down" effects would compensate the remaining economy.[19/] This, in the eyes of the government, led to disorientation of the economy and social inequities between urban and rural sectors. The government proposed: (1) to make agriculture the "motor" of development by increasing performance of the sector;[20/] (2) to attain self-sufficiency in food products and intermediate inputs; (3) to reorganize national markets in a manner to facilitate consumption of domestic goods; and (4) to eliminate the country's commercial and financial dependence on the rest of the world by restoring

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19/ From President Sankara's message to the people of Burkina Faso in Carrefoure Africain, "Le Burkina n'est pas un accident de l'histoire. Nous sommes les produits d'une situation generalisee," 1984, pp. 11-12.

20/ This is to be accomplished through concentration of investments and modernization efforts in crop and livestock sectors. Higher production would be based on: higher yields from improved farming practices; bringing potentially arable lands into cultivation; agrarian reform, including investments in human capital, integration of crop and livestock enterprises, and remunerative prices for producers.

economic equilibria. Many of the policies proposed were similar to rural development strategies of the past. However, new emphasis was given to policies aimed at protectionism and self-determination with greater weight given to more equitable income distribution.

Macro Economic Policy

Three types of economic policy instruments have historically been used to pursue the government's rural development objectives. The first involves funneling domestic and foreign resources into rural sector development projects. Funding is provided mostly through bilateral and multilateral aid, whose donors in collaboration with the government target investment activities.[21/] Another activity involves the participation of the government, through parastatal organizations, in activities of land reclamation, supply and distribution of inputs and marketing of agricultural commodities. The third involves government control over prices, subsidies and credit administered through various domestic and trade policies.

Public Sector Investment

Table 2.8 shows the cumulative investment in projects under course of execution as of December 1982. A total of 99.5 billion FCFA had been approved for investment with 33.6 billion FCFA actually disbursed. Most of the investment was allocated to development of

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21/ Donors frequently wield great influence over the types of rural development activities undertaken because of the dominance of external aid in financing these activities.

Table 2.8. Cumulative Investment in Projects in Course of Execution, Burkina Faso, as of 12/31/82.

Region	O.R.D.	Approved Financing (billion FCFA)	Actual Investment (billion FCFA)	Percent of Total Investment	Investment per Inhabitant ('000 FCFA/person)
North	Centre Nord	4.0	1.1	3.2	1.5
	Yatenga	5.5	2.4	7.1	4.0
	Sahel	3.8	1.0	3.1	2.6
Central	Centre	12.3	3.4	10.0	3.2
	Centre Ouest	5.8	0.7	2.2	0.8
	Centre Est	2.7	1.3	3.7	2.7
East	Est	8.9	1.2	3.7	2.7
West	Volta Noire	9.2	4.0	11.9	5.6
Southwest	Hauts Bassins	10.0	3.7	10.9	7.9
	Bougouriba	7.7	1.9	5.8	4.8
	Comoe	4.0	1.2	3.6	6.1
Nation	Burkina Faso	99.5	33.6	100.0	5.3

Source: Republique de Haute-Volta, Ministere du Developpement Rural, Bulletin d'information sur les projets en cours d'execution, 1983.

water resources, hydraulique (40.3 percent), followed by rural community development, Organisation du Monde Rurale (24.7 percent), crop production (22.0 percent) and livestock production (12.6 percent). Areas in the west and southwest received a high, disproportionate share of investment, largely reflecting the higher payoff in these areas. This has led in recent years to debate over growth versus equity issues on a regional basis.

Parastatal Institutions

Central to Burkina Faso's rural development strategies are the operation of its parastatal agencies. These have been a principal instrument through which the government has administered its agricultural policy. Among the more significant are:

1) AVV (Management Authority for the River Valleys, Autorite pour l'Amenagement des Vallees des Volta): has charge over reclaiming areas along major waterways which historically have remained unsettled due to presence of onchocerciasis. The program is responsible for controlled resettlement of about 300,000 km^2 of disease freed land. Many soils in these regions are among the most fertile in the country.

2) ARCOMA (Regional Workshop for Construction of Agricultural Equipment, Atelier Regional de Construction de Materiel Agricole): manufactures a complete range of parts for animal drawn agricultural equipment. The parts are assembled by decentralized units, COREMMAs (Regional Cooperatives for Assemblage of Agricultural Equipment, Cooperatives Regionales de Montage de Materiel Agricole) located at the ORD level.

3) CNCA (National Credit Association, Caisse Nationale de Credit Agricole): is responsible for funding and administering credit at a national level. ORD credit bureaus administer the credit for agricultural inputs at the regional level.

4) OFNACER (National Organization for Cereals Marketing, Office National des Cereales): is charged with collecting and marketing cereal production given three primary objectives--maintain support prices for farmers, maintain ceiling prices

for consumers and hold security stocks to support ceiling prices. Prices are established by the Council of Ministers. The agency is estimated to handle about 10 to 15 percent of total cereals trade.

5) SOFITEX (Fibers and Textiles Association, Societe des Fibres et Textiles): has a monopoly on the export of cotton. SOFITEX procures seed cotton from the farmer, operates the gins and markets the lint. Prices are established by the Council of Ministers. It also distributes modern inputs (mainly fertilizer and pesticides) in cotton growing areas. In "non-cotton" areas, SOFITEX sells modern inputs to the ORDs who handle the distribution.

6) CSPPA (Price Stabilization Association for Agricultural Products, Caisse de Stabilization des Prix des Produits Agricoles): has an export monopoly on groundnuts, sesame and shea-nuts. The commodities are purchased from intermediaries at fixed prices plus transport cost and commissions and are sold at market prices. Profits accrue to a stabilization fund to support producer prices when world prices are depressed.

7) UVOCAM (Voltaique Union of Agricultural and Vegetable Cooperatives, Union Voltaique des Cooperatives Agricoles et Maracheres): handles the marketing of fruits and vegetables for exports.

Commodity Price Policy

As shown above, the government of Burkina Faso intervenes extensively in commodity markets. For commodities such as cotton, sesame, and shea nuts, whose output is mainly exported, the government holds virtual monopoly control over prices. For cereals, the majority of grain is consumed locally and marketed through private trading channels. Private trade in cereals operates freely, although the goverment occasionally attempts to enforce official government prices in the Ouagadougou market (Berg in CRED, 1977, p. 37). These attempts have generally not been effective or long lasting.

In the official market, the government purchases grain from producers at fixed "producer" prices and sells grain to consumers at

set "consumer" prices. These prices are set uniformly around the country, irrespective of local supply and demand conditions. Between 1980-81 and 1982-83, OFNACER purchased locally about 19,000 tons of cereals on average from producers (Table 2.9). Assuming that 15 percent of domestic production is marketed surplus, then the official share of domestic cereals market was around 11 percent (based on total production figures in Table 2.6).

OFNACER also distributes the majority of food aid imports. Most of these are sold at official "consumer" prices, though a small quantity are given free to the needy. Some concessional imports are also distributed by private relief agencies, like CATHWELL. Historically, food aid has averaged around 43,000 metric tons/year, (1974-79 average, Appendix 1, Table A1.9). Hence, food aid is the largest component of OFNACER supplies. Given purchases of 19,000 tons and sales of 62,000 tons, it is argued that OFNACER's role in the market has been mainly to support low prices for the consumer rather than to improve producer returns.

The distribution of grain purchases and sales is explained in large by the uniformity of official prices. Grain purchases tend to concentrate in the west and southwest (regions of excess supply) where the ratio of official "producer" to private market prices is more favorable. Sales go to deficit areas in the north and urban cities of Ouagadougou and Bobo Dioulasso, where the ratio of private market to "consumer" prices are highest. It is normally the case that purchasing quotas set by the agency exceed actual purchases. The government

Table 2.9. Official Purchases of Cereals by OFNACER.

Region	O.R.D.	1979/80	1980/81	1981/82	1982/83
		(tons)			
North	Centre Nord	-	-	109	23
	Yatenga	7	-	2969	3731
	Sahel	110	93	160	-
Central	Centre	1167	138	1776	1768
	Centre Ouest	310	58	1563	753
	Centre Est	1125	92	685	87
East	Est	2310	1348	2602	1983
West	Volta Noire	1533	175	9515	9383
Southwest	Hauts Bassins & Comoe	656	320	8749	5882
	Bougouriba	1442	385	521	1141
National	Burkina Faso	8660	2609	28,649	24,751

Source: Ministere du Developpement Rurale, Bulletin de Statistique Agricoles, Campagnes 1978/79, 1979/80, 1980/81, and 1981/82, p. 114.

would like to see its market share of cereals trade raised, but perennially faces procurement problems due to insufficient funds, constraints on marketing infrastructure, unattractive "producer" prices and low operating margins between "producer" and "consumer" prices.

International Trade Policy

To meet production shortfalls, the country can either increase levels of imports or reduce stock levels. As for imports, the government has several policy options. It can formally request food aid from the international community, spend scarce foreign exchange on food purchases from foreign markets or encourage private imports by adjusting levels of quotas, tariffs and subsidies.

Over the past decade, food aid has been the largest component of 'official' imports. 'Official' is emphasized because some grain passes through clandestine markets which do not enter official accounts. Requirements of food aid are determined annually by the Direction des Services Agricoles (DSA) following assessment of the adequacy of food harvest. If food aid is desired, the government negotiates with international donors over quantity and terms. The determination of quantity is particularly difficult. On one side of the equation, production statistics are poor and the incentive rests (depending on the costs of aid acceptance) with the government to escalate deficits. On the other, differences exist between donors and the government on what is the acceptable minimum cereals requirement (i.e., 180 or 215 kg./resident).

Whether or not aid is desirable depends on restrictions accompanying its use. If aid is relatively condition-free, like donations under Title I of P.L. 480, then aid should be preferred to purchases with foreign exchange or borrowing from abroad. In LDCs like Burkina, where capital is scarce, the shadow price on foreign exchange is typically high. Likewise, borrowing is undesirable because of credit costs and ultimate need for repayment. However, if aid is tied with restrictions that impose high real costs in terms of reallocation of resources, then it may be rational to refuse aid and make direct purchases. An example of this is Title II donations under P.L. 480, where aid is given on condition that it be sold in the market to generate counterpart funds for support of development projects. As resources are drawn from existing use, the cost of lost efficiency can outweigh benefits of aid.

The process is made more confusing by the number of actors involved, including multiple government agencies, international donors and financial organizations. Certainly, the international community, in view of the country's need for food, can exercise power through "tieing" aid (e.g., power in choice and operation of development projects). Likewise, the government has flexibility to negotiate among donors for the most favorable terms and may choose rejection if it desires. Clearly, some set of rationing rules exists which optimizes the balance of aid, direct purchases, and borrowing, but the form and substance remains ambiguous.

Commercial imports are handled by large private importing agents. These deal in several commodities and are subject to licensing

restrictions by the Ministry of Commerce. Cereal imports are subject to tariffs, but appear to be relatively free of quantity restrictions. For rice, import fees amounted to 5,000 FCFA in 1980 (The World Bank, 1981, p. 153) although the Army imported large quantities without regulation or tariffs. Imports, at least of rice, appear price responsive. In the late 1970s, when the official price of rice was set higher than the border price, imports flourished.

There is also illicit trade in cereals. Depending on prices from year to year, grain moves across the border with Niger or through the southwest to or from Mali and the Ivory Coast. The government discourages exports of cereals, but the country's long frontier with deficit countries like Niger and Mali, combined with budgetary constraints, make the border permeable to trade.

Nominal rates of protection (NRP) measure the combined effect of various policies on commodity prices. The NRP is the ratio of financial or market price to economic price. A coefficient greater than 1 implies protectionist policies, where consumers are being taxed with transfers to the public treasury or producers. A coefficient less than 1 implies producers are taxed to the benefit of the treasury or consumers. Table 2.10 presents NRP estimates for various commodities estimated by the World Bank (1981, p. 52) for the period 1979-80. The results should be interpreted with caution, because of

Table 2.10. Nominal Rates of Protection for Various Commodities, Burkina Faso, 1979-80 Prices.[a/]

	Southwest	Center	East
Paddy	1.0	1.0	0.8
Sorghum	0.7	0.8	0.6
Millet	-	0.8	0.6
Maize	0.8	0.7	0.7
Cowpeas	1.0	1.0	1.0
Cotton[b/]	0.8	0.8	0.9
Shelled groundnuts	2.1	2.4	2.4
Sesame	0.9	0.9	0.8
Shea nuts[b/]	1.2	1.2	1.2
Soybeans	-	-	8.3

a/ Where production is for home consumption, an NRP greater than 1 does not result in income transfers.

b/ Official prices are used as financial prices in the analysis. All other commodity prices are based on locally observed market prices.

estimation error and methodological difficulties,[22/] but in general suggest producers have been extensively taxed. With the exception of three minor commodities, production was taxed by 15 to 25 percent. Rice was neither taxed nor subsidized.

Revised prices by the World Bank in 1980 raised the NRP for sorghum, maize and groundnuts by 0.2, eliminating most of the implicit taxation. With these revised prices, implicit taxation of cotton increased. The situation for oilseeds was less clear due to institutional arrangements in trade with Europe and the deficit position of the country in vegetable oils. Hence, with the exception of cotton and oilseeds, market distortions were not appreciable.

The geographical distribution of NRP coefficients is complicated. They largely reflect the flow of export trade through the Southwest, where economic prices are higher, and cereal imports from the southwest and east to the Central Plateau, where financial prices are greatest. They also reflect the difficulties of internal trade and the significance of transportation and marketing costs separating financial prices between regions. In general, producers on the Plateau tend to be most favored because of excess demand in the region, due largely to the influence of the Ouagadougou market, and

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22/ Estimates are subject to error in estimating foreign prices and choosing representative local prices where market data are exceptionally poor. With regard to methodology, the NRP measure: 1) does not measure the effect of policies which may support producers or consumers without affecting prices; 2) is not likely to reflect the impact of input price subsidies or other subsidies on producer costs. Moreover, divergences between internal and border prices may arise due to transportation costs and marketing margins that are not due to trade restrictions.

the limited capacity of the region to expand production. Producers in the east, where agricultural potential is high but poor infrastructure inhibits transport of marketed surplus, are the least favored.

Input Price Subsidies

The government practices an aggressive subsidization policy for nearly all modern inputs. Subsidy rates have been estimated by the World Bank (1981, p. 52) as 40 to 58 percent for improved seeds, 40 percent for Urea, 56 percent for cotton fertilizer, 66 to 72 percent for cotton insecticides and 0 to 45 percent for sprayers.[23/] In general, recurrent inputs are subsidized by one-half while producers receive no direct subsidization for capital goods except for credit financing. Official input prices in theory are uniformly set nationwide, but in practice marginal adjustments are permitted for transportation and handling cost differentials.

An earlier evaluation of NRP coefficients indicated that commodity prices in the private market are closely in line with world prices. Hence, price distortions in the private market appear to be minimal. In the official market, however, price distortions are appreciable. Low official "consumer" prices, relative to private market prices, create income transfers to consumers. Subsidization of inputs creates income transfers to producers. Depending on the government's market share of commodity marketing and input distribution, the level of distortions and income transfers can be sizable.

23/ Figures are the percent of subsidy to economic prices in 1980.

Criticism of the agricultural policies pursued by countries in sub-Saharan Africa has mounted in recent years. The region's poor agricultural performance has been attributed in part to policies which subsidize consumer prices while overly discouraging incentives to producers (USDA/ERS, 1981). Urban consumers are typically given special consideration in the policy arena. This is due to their political clout and the greater appearance and immediacy of urban welfare problems. Food prices are kept low to satisfy consumers but provide disincentives to producers and reduce incentives to invest in agriculture. To compensate producers, governments offer input subsidies to offset lower commodity prices. Subsidies, however, affect a narrower segment of the farm population and skew income distribution in favor of input users.

The question of who pays the subsidies is central to the policy issue. With rising modern input use, public expenditures have risen to support the subsidies. Budget deficits of the government have emerged as a result. Appendix 1, Table A1.4 outlines revenues and expenditures of the government. Between 1976 and 1978, the government operated with budget balances ranging from a 0.4 billion FCFA deficit to 2.8 billion FCFA surplus. By 1979, a budget deficit of 8.1 billion FCFA had emerged.

International financial authorities (IMF, World Bank) intervened in the early 1980s. They requested the government to pursue policies of better fiscal management by following a more market-oriented approach to agricultural policy. In November 1980, the government, through negotiations with the World Bank, agreed in principle to

remove the input subsidies on fertilizer and to the increase producer prices for cotton and sorghum. No time schedule was set, but complete subsidy removal within 5 years was given as a target date.

The arguments given by proponents of subsidy removals are (World Bank, 1981, p. 18): (1) gains from these inputs are realized only in more favorable regions, on more responsive crops by better farmers who employ complementary inputs;[24/] (2) raising output prices uniformly affects all producers and is preferred to subsidies when compared with possible negative externalities of fertilizer overuse; and (3) the government would become increasingly unable to pay the subsidies without external assistance, especially as the technological transformation of agriculture increases modern input demand in the longer run.

From the government's perspective, the impact of subsidy removal on food supply is the critical issue. This question was intensely debated in 1983 as the government was asked by the Bank to follow through with phasing out the subsidies.[25/] Opponents argue that, for an agricultural sector which only marginally meets food needs, subsidy removals would have a profound negative effect on food supply and consumer welfare. Moreover, rural producers already on the border of poverty are made worse off by the proposal. Also, fertilizer is

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24/ From this argument it is unclear whether input use in more favorable regions would continue even without the subsidies or that farmers in these regions are better off and thus do not need subsidy support.

25/ From observations made during the author's stay in the Ministry of Rural Development from May to December, 1983.

perceived as the remedy for problems of low agricultural productivity. Hence, its restricted use would set back the transformation of agriculture and stymie growth of the country. What was most exasperating to ministry officials was the lack of analytical tools to shed light on these issues and evaluate economic consequences of policy alternatives.

Trade Deficit and Balance of Payments

A related set of issues concerns problems with the country's balance of payments and foreign exchange earnings. Over the past decade, the country's trade balance has been consistently negative and growing. As shown in Table 2.11, imports have exceeded exports in all years since 1970 and the gap has widened over time. In 1970, the country's trade deficit was 8.6 billion FCFA and exports represented 36.9 percent of imports. By 1981, the trade deficit had reached 71.5 billion FCFA while the ratio of exports to imports had fallen to 21.8 percent.

Several factors underlie the rapid growth in imports (in value terms). First, private and public sector investment in the economy increased in response to the country's development strategies. Second, there was higher demand for foreign goods brought about through growth in private remittances from abroad and public sector salaries. The poor performance of agriculture in keeping pace with growth in food demand was another important factor. As shown in Table 2.12, the growth in imports from 1972-74 to 1981 was spread broadly through the economy. The largest absolute gains were in machinery and

Table 2.11. Trade Deficit, Burkina Faso, 1970-1981.

Years	Exports	Imports	Balance	Ratio Exports to Imports
	-----(millions of francs FCFA)-----			
1970	5,056	13,701	- 8,645	36.9
1971	4,408	15,611	-11,203	28.2
1972	5,141	17,269	-12,128	29.8
1973	5,596	21,690	-16,094	25.8
1974	8,702	34,664	-25,962	25.1
1975	9,368	32,386	-23,018	28.9
1976	12,690	34,423	-21,733	36.9
1977	13,614	51,357	-37,743	26.5
1978	9,600	51,075	-41,475	18.8
1979	16,238	63,916	-47,678	25.4
1980	19,066	75,614	-56,548	25.2
1981	19,919	91,443	-71,524	21.8

Source: Banque Centrale des Etats de L'Afrique de L'Ouest (B.C.E.A.O.), Statistiques, Economiques et Monetaires: Haute-Volta, 1983, p. 24.

Table 2.12. Composition of Imports, Burkina Faso, 1972 to 1981.

	Total Imports	Machinery & Transport Equipment	Manufactured Goods	Food Products[a/]	Gas & Petrol	Chemicals[b/]	Other
	billion FCFA						
1972-74	24.5	5.2	5.3	6.0 (2.3)	1.6	2.0 (0.3)	4.4
1975	32.4	8.7	4.0	5.9 (2.4)	2.9	4.2 (1.0)	6.7
1976	34.4	10.1	4.6	5.4 (2.4)	2.7	3.4 (0.3)	8.2
1977	51.4	17.0	7.[illegible]	8.7 (4.5)	4.4	4.8 (0.8)	9.1
1978	51.1	15.5	7.2	12.3 (6.5)	4.4	4.5 (1.0)	7.2
1979	63.9	18.2	8.8	10.9 (6.3)	7.2	(1.5)	
1980	75.6				10.0	(1.3)	
1981	91.4				14.2	(1.7)	

a/ Figures in parentheses are the value of cereals imports.
b/ Figures in parentheses are the value of manufactured fertilizer imports.

Source: From Appendix 1, Table A1.12.

transport equipment, followed by petroleum and food products. Cereal imports alone tripled from 1972-74 to 1979.

The balance of payments accounts record a country's economic transactions with the rest of the world. They include trade in goods and services, transfer payments, concessionary assistance (foreign aid) and exchange of assets.[26/]

The balance of payments accounts of Burkina Faso, from 1972 to 1979, are shown in Table 2.13. As shown there, the balance on trade in merchandise goods was consistently negative through the seventies. The trade deficit steadily rose from 16.5 billion FCFA and 21.4 percent of GDP in 1972-73 to 37.9 billion FCFA and 27.4 percent of GDP in 1979. Of nearly equal magnitude was the country's negative trade in services. Here too, trade balances have historically been negative, with deficits growing from 6.9 to 31.4 billion FCFA over the same period. By 1979, the trade deficit in goods and services combined had reached 69.3 billion FCFA or 28 percent of GDP (Table 2.14). Several points merit attention. One is the importance of the external sector to the total macro-economy of the country. Another is the persistence of trade deficits in the economy, reflecting the country's growing dependence on the rest of the world.

26/ The accounts are divided into the current account, capital account and official settlements. The current account measures transactions arising from the sale of goods and services and unilateral transfers. One of its major components is the merchandise trade balance which measures a country's trade in goods. The capital account records transactions in assets including private short and long term loans and financing by the central government. Official settlements denote the monetary authorities (central bank, treasury) financing of the external imbalance.

Table 2.13. Balance of Payments, Burkina Faso, 1972 to 1979.

	1972-73	1975	1976	1977	1978	1979
	billions of FCFA					
Current Account:	-0.5	-8.9	-7.8	-20.5	-13.5	-12.1
Merchandise Trade Balance	-16.5	-24.4	-20.1	-30.8	-33.2	-37.9
Services	-6.9	-15.4	-16.7	-24.2	-27.8	-31.4
Private Transfers	9.6	10.1	11.6	13.3	17.4	23.6
Foreign Aid	13.3	20.8	17.5	21.2	30.0	33.7
Capital Account:	2.2	7.4	4.5	13.7	6.0	14.7
Short and Long Term Loans	-0.1	2.7	0.1	6.4	2.2	2.1
Central Government	2.0	4.4	3.5	5.7	3.6	10.7
Other (Inc. errors and omissions)	.3	.3	.9	1.6	0.2	1.9
Official Settlements	-1.7	1.5	3.2	6.8	7.5	-2.6
Foreign Official Agencies	0.8	-	3.7	2.4	1.9	2.3
Change in Reserves	-2.5	1.5	-0.5	4.4	5.6	-4.8

Source: From Appendix 1, Table A1.13.

Table 2.14. Components of National Income, Burkina Faso.

	1972-73	1975	1976	1977	1978	1979
	billions of FCFA					
Gross Domestic Product (at market prices)	109.6	145.5	158.4	192.1	213.2	252.8
Government Purchases of Goods and Services	10.2	23.5	21.2	24.7	30.1	36.0
Personal Consumption Expenditure	98.1	126.9	133.7	180.6	197.0	240.3
Gross Domestic Investment	17.8	29.5	34.0	35.9	39.2	41.1
Inventory Adjustment	3.4	5.6	6.2	5.1	6.8	4.9
Exports of Goods	11.7	18.4	23.9	27.4	29.1	34.0
Imports of Goods and Services	-31.6	-58.5	-60.6	-81.5	-88.9	-103.6

Source: From Appendix 1, Table A1.1.

Offsetting the negative trade balance in goods and services in the current account were private transfers and foreign aid. Private transfers mainly comprised worker remittances from the country's large workforce abroad (Appendix 1, Table A1.13). These transfers totaled 23.6 billion FCFA in 1979 covering roughly one-third of the trade deficit in goods and services. Inflows of foreign aid, in accordance with development assistance programs, amounted to 33.7 billion FCFA or roughly half the deficit in trade balance. Hence, funds provided by private transfers and foreign aid enabled the large scale net importation of goods and services through the 1970s.

Even with these inflows of capital, however, the country ran a deficit on its current accounts in all years since 1970. These deficits remained particularly high through the latter 1970s, ranging from 12.1 to 20.5 billion FCFA between 1977 and 1979. These deficits were financed by the capital account, which includes private short and long term loans and financing by the central government, and official settlements.[27/] As shown in Table 2.13, the central government (through the central bank or treasury) intervened extensively between 1972/73 and 1979 to finance the external imbalance. Likewise, the country made use of its exchange reserves and official government borrowing abroad to offset the excess demand for foreign currency which emerged. The funds provided by private short and long term

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27/ Aid is normally put in the capital account, but is included in the current account in this analysis to remain consistent with reporting methods used by data sources.

borrowing, in contrast, were relatively insignificant.

Like many countries in West Africa, Burkina Faso has historically relied on external assistance for its development programs and food imports. The world recession of the eighties and politics of foreign aid highlight the tenuous nature of this dependence. In early 1985,upwards of 500,000 foreign workers were expelled from Nigeria because of the recession in its oil industry. With incidents such as these and the general downturn in the regional economy, reductions in repatriated earnings and re-entry of workers from abroad can be expected. Moreover, foreign aid can dissipate or incur rising implicit costs due to "tied-aid" arrangements.

At the heart of the food security issue lies the performance of the agricultural sector. Over the past decade, food imports have averaged over 60 percent of total export revenues (Tables 2.11 and 2.12) with food imports exceeding earnings in several years. Moreover, it raises questions of the capacity of the sector to generate scarce foreign exchange to purchase imported capital goods. These are needed for private and public sector investment for transformation of the agricultural sector in the longer run.

Conclusions

Burkina Faso, like many countries in sub-Saharan Africa, is experiencing problems with its agricultural sector. Per capita incomes in the country are low, food deficits are a perennial occurrence, growth in agricultural productivity is low and stagnating,

and the country's rate of emmigration, particularly of skilled manpower, is high. Several explanations for poor agricultural performance were offered in this chapter, with emphasis given to the role of agricultural policy. Three types of government policy were elaborated on: (a) use of official "producer" and "consumer" prices and regulation of commodity flows; (b) imports of food aid and non-traditional cereals (wheat and rice); and (c) provision of input subsidies to producers.

Governments require economic information on policy impacts to enable formation of better policy. This may lead to elimination of policies which currently run counter to national objectives or policies which increase efficiency and performance of the sector. The interrelationships among policies, however, are complicated and sometimes conflicting. What is required is a framework to facilitate analysis of these issues, yet is suitable to data limitations and technical constraints of planning ministries in Africa. The next chapter outlines a methodology suitable to this end.

CHAPTER III

METHODOLOGY

The previous two chapters focused on descriptive characteristics and policy issues pertinent to agriculture in Burkina Faso. Attention now shifts to methodological issues related to the development of an economic model of Burkina's agricultural sector and its application for policy simulation and analysis. First, there is a brief review of household and sectoral modelling approaches to policy evaluation. Next, a broad overview of the sectoral model is presented, followed by a detailed description of producer, consumer, international trade, private market and public market sub-components of the model. Each sub-model is described as if it were self-contained. Sub-models are then integrated into a spatial, recursive and dynamic model of Burkina Faso's agricultural sector. The chapter finishes with a brief statement on the application of the model for policy evaluation.

Household-Firm and Sectoral Models

Economic models of household production in Africa are common. Models have been estimated by Balcet and Candler (1981) and Crawford (1982) for Nigeria; Haswell (1953) and Niang (1980) for Senegal; Niang (1980) for Mali; and Delgado (1978), Jaeger (1984) and Roth, et al. (1984) for Burkina Faso. All these use linear programming, maximizing

profits subject to the firm's production function and resource endowments. Analyses may incorporate off-season labor employment and marketing activities (Delgado, 1978; Crawford, 1981), production risk (Niang, 1980; Jaeger, 1984) or multiple goals of producers (multiple goals programming (Barnett, 1979).

Production models are in some cases used to evaluate whole-farm impacts of new technology. Jaeger (1984) and Delgado and McIntire (1982) evaluated the economic performance of animal traction while Roth and Sanders (1984) evaluated fertilization, animal traction and water conservation technologies. Minimum or maximum constraints are sometimes imposed on production of a commodity or several commodities for consumption requirements (e.g., minimum protein, caloric or food requirements). However, producer behavior is generally treated independently of consumer decisions.

Studies by Raj Krishna (1962, 1963) and Jere Behrman (1966) were among the first to recognize the importance of incorporating the income elasticity of consumption in the estimation of household marketed surplus. A subsistence farmer responds differently than a 'pure' consumer to a price change, because production and consumption decisions in the household are simultaneously determined. Models of household production and consumption behavior have been estimated by Lau, Lin and Yotopoulos for rural households in Taiwan (1978); Barnum and Squire (1978) in Malaysia; Ahn, Singh, and Squire (1981) in Korea; and Strauss (1983, 1984) in Sierre Leone.

The above models of household production and consumption have a common structure. Each maximizes utility of consumers in the

household subject to a production function, time and budget constraints. Barnum and Squire use a three-commodity (paddy, non-food, leisure) Linear Expenditure System (LES) for demand and a Cobb-Douglas production function for paddy with the wage-rate endogenous. Ahn, Singh and Squire estimate a six commodity model (four foods, non-food, leisure). Like Barnum and Squire, they use an LES for demand, but estimate production via linear programming. Strauss' model of seven commodities (five foods, non-food, leisure) employs a quadratic expenditure system to overcome problems of linear Engel curves imposed by the LES. A constant elasticity of transformation function is used to specify outputs and a Cobb-Douglas function to specify inputs to production.

All are 'representative' household models estimated from primary cross-sectional and sometimes time-series data. They have been used to estimate impacts of migration, changes in input costs, output price intervention, technological change and structural adjustments on marketed surplus. While such models are suitable for micro studies, they do not easily accommodate resource and institutional constraints at the sectoral level, needed for evaluation of macro policy issues.

Micro-models, for example, do not permit evaluation of feedback effects on the rest of the economy, optimal allocation of resources at the sectoral level, or costs and benefits of policy alternatives from a societal viewpoint. These questions require a broader perspective on markets, regional production possibilities, resource endowments, urban-rural consumption characteristics and trade, than is possible with micro studies. Also, they do not provide the aggregate measures

of performance--regional supply and demand response, prices, resource utilization and distributional impacts--that policymakers desire when choosing among policy alternatives.

An alternative approach for agricultural policy analysis is sector modelling, either at the economy-wide level or at the agricultural sector sub-level. There have been numerous attempts to develop and apply agricultural sector models in developing countries. Egbert (1978) summarizes and evaluates agricultural sector models (in some cases total economy models) for Peru, Guatemala, Korea, Brazil, Portugal, Mexico and the Ivory Coast. McCarl and Spreen (1980) provide a survey of sectoral programming models in agriculture.

Various methodologies have been used to formulate these models. In instances where linkages between sectors of the economy are of interest, input-output analyses may be used. When the objective focuses on structural characteristics of the sector, econometric analyses may be applied. To simulate the impacts of policy upon a sector, however, mathematical programming has been found particularly useful (McCarl and Spreen, 1980). (Also see Blitzer, Clark and Taylor (1975) and Dervis, de Melo and Robinson (1982) for a review of the various approaches.)

Because of the complexity of an agricultural sector, Egbert (1978) suggests conceptualizing the economic system in four dimensions: sectors, degree of input-output transformation or processing, space and time. Sectors may be further disaggregated into commodities or products. The degree of model complexity depends largely on the level of disaggregation. Since there are a large

number of products, technologies, levels of processing, and economic agents in the economy, models can become large with small levels of disaggregation.

Large-scale economy-wide models like those developed for Taiwan, Mexico and Nigeria require considerable resources for model development, maintenance and computer requirements. These costs can exceed skilled manpower capabilities and financial resources of Ministries in poorer LDC's. Smaller modelling applications, like Jabara and Thompson's (1980a, 1980b) analysis of the Senegalese agricultural sector, appear to be a reasonable compromise between higher costs of model size and performance. Their model disaggregates the agricultural sector into regional demand functions (own-price and income effects) for agricultural commodities, linear programming models representing regional supply, processing activities, transport, import and export activities. The model's equilibrium is found by maximizing the sum of producer and consumer surplus.

The technological specification of supply, in sector models, is often weak. Supply models often lack detail on the technological diversity of traditional agricultural systems and on the substitution possibilities among traditional and modern technologies. Demand systems are rarely incorporated in the model that have had imposed the theoretical restrictions of demand theory. The existence of parallel markets in Africa presents special problems. Prices and quantities are unrestricted in private markets but are restricted in official

markets. Current approaches rely heavily on the assumption of competitive market behavior, limiting their application in cases where market restrictions exist.

Data poses an additional consideration for model specification in the case of Burkina Faso. National crop production estimates and income accounts data are poor in quality and unreliable. Price, consumption and trade data are severely limited, particularly time series information. Farming systems and experiment station research provide a relatively rich source of micro-level farm management data. This research must rely on empirical data reported in published studies, since data bases are generally not available or would involve large time requirements for analysis.

Data limitations, thus impose two further restrictions on the methodology. First, all data for empirical model development are taken from data or coefficients reported in the literature. This procedure avoids costly data collection techniques but assumes a minimal level of empirical research is available. Second, the methodology should exploit existing data strengths. Since, experiment station and farm management data are relatively abundant, production models should utilize these data as much as possible.

Model Formulation

The model of Burkina Faso's agricultural sector can be decomposed into five interrelated sub-problems: production, consumption, international trade, private market equilibrium and official market equilibrium. Sub-models associated with the sectoral model are the focus of this section. The next section integrates the sub-models

into a spatial, recursive and dynamic market equilibrium model of Burkina's agricultural sector. Before proceeding, an overview of the model is provided.

The sector model contains nine commodities--white and red sorghum, millet, maize, rice, wheat flour, groundnuts (shelled), cotton (ginned), and 'other' non-food goods and services--endogenous in prices and quantities.[1/] The market equilibrium involves determination of prices, quantity supplied, quantity demanded and domestic and international trade in two types of markets: a private, unrestricted market where prices are set by competitive market forces of supply and demand; and an official government-controlled market.

In the official market, the government sells modern inputs to producers (with monopoly control over income distribution) and buys commodities from producers at fixed input and output prices. However, input distribution and commodity procurements are normally limited (although not necessarily so) by institutional constraints. Grain procurements plus imports of food aid are distributed to consumers at fixed 'consumer' prices, but in rationed quantities because supplies are limited. Procurements of cotton and groundnuts by the government are exported abroad, earning export revenues. The official market equilibrium then determines commodity procurements from producers, based on fixed official prices, expected private market prices, and capacity constraints, then market rations to consumers.

[1/] Prices of the 'other' good are exogenous and fixed.

The private market equilibrium sets prices, quantity supplied, quantity demanded and trade in the private sector of the economy. Supply is determined via Linear Programming (LP) models estimated for five representative producing regions of the country. Producers make their planting decisions based on their expectations of prices at harvest time and output and input prices in the official market. Output may be sold to the government through the official market (but cannot exceed government procurement capacity) or sold to traders on the private market.

Demand is determined via a Linear Expenditure System (LES), estimated for seven regions of the country (five rural regions plus Ouagadougou and Bobo-Dioulasso). Consumers allocate their income--agricultural income from the producers' problem plus fixed non-farm income (exogenously set)--to purchases of the nine goods, given commodity prices.

Trade flows in the private market are determined via a competitive market equilibrium. Commodities from regions of excess supply are shipped to regions of excess demand based on cost minimization in a trade shipment problem. Trade flows in the official market are not explicitly incorporated in the model. The government buys from producers in one region and sells to consumers in another, but trade flows are handled exogenously. Commodities are sold on the official market via fixed rationing rules.

The complete sector model is solved sequentially:

1) Output is estimated via LP models of crop production in five regions of the country. Output is forecast based on producers' expectations of commodity prices in the private

market and government administered prices for inputs and commodities in the official market. In the initial period, private market prices are assumed to be equivalent to 'base' period private market prices.

2) Sales of output to the private or official markets in regional LPs constitute marketing activities of producers.

3) Commodity procurements by the government in the LPs plus food aid imports are used to set consumer rations in the official market.

4) With official market rations set, consumption, prices and trade are determined in the private market. The model is solved as a Linear Complementarity Problem (LCP). Output, food aid imports, income and market margins are right-hand-side constants to the LCP. Linearized parameters from regional LES systems, foreign trade equations and price linkages are nested in the LCP. Quantity demanded, prices and trade are solved endogenously in the LCP as a competitive market equilibrium.

5) Producers' price expectations are revised given updated prices from the LCP, then steps (1) to (4) are repeated. Price expectations of producers are revised based on a distributed lag model of long-term expected prices and previous period prices from the LCP. Steps (1) to (5) can be solved recursively for 'n' iterations.

Thus, quantities supplied in the private and official markets are set in (1) and (2), official market rations are determined in (3) and prices, trade and quantity demanded are computed in (4).

Steps (1) through (4) represent an annual model suitable for short term analyses of policy impacts. Revising producers' price expectations via step (5) and repeating steps (1) through (5) for 'n' iterations (for years), enable long term evaluations of policy shocks. Policies then which depress agricultural prices and income in the first year are captured by the annual model. The effect of price and income adjustment on prices and quantities in the longer run may be evaluated with the dynamic model.

The sector model makes several unique contributions to overcome limitations of existing approaches. It explicitly incorporates official markets for input supply and commodity marketing into the analysis. LPs estimating supply are linked with a LCP for estimating prices, demand and trade. The model is solved sequentially, permitting both short and long term analyses of policy impacts. The model's sequential nature permits solution of large supply models without excessively slowing the calculation of the market equilibrium. Supply models, estimated with producers' price expectations rather than market equilibrium prices, more accurately reflect the producers' decision making process. The LES for estimating demand satisfies the general restrictions of demand theory. Supply models have detailed specification, enabling evaluation of a wide mix of technological options. The models are estimated from experiment station and Farming Systems Research (FSR) data, exploiting data strengths. Thus, the sector model links FSR research with national policy making at the macro level. All data for the analysis comes from secondary sources making the approach applicable to other regions of Africa where data are perceived to be equally limiting. Finally, the model is a flexible analytical tool suitable for evaluating a broad set of policy issues. The structure of individual sub-models is explained below.

Production Problem

The production problem determines total agricultural output and sales by farmers in the official and private markets. Producers make their cropping decisions based on their expectation of harvest prices

and official prices announced by the government. All output is sold, earning agricultural income, which is allocated to purchase of goods in the consumers' problem.

Let aggregate agricultural output include production of h=1,...,H 'representative' households in the economy. Representative households are defined as groups of farms in a geographical region that possess similar climate, physical infrastructure and soils. The finest level of disaggregation in aggregate production statistics for Burkina Faso is by ORD.[2/] The development of household models for all 11 ORDS in the country would greatly enlarge the size of the sectoral model and increase costs in terms of computational requirements. As a compromise, ORDS were regrouped into five regions--north, central, east,west, and southwest (these regions were described in Chapter II)--based on physical similarities.

Output is represented by production (net of production losses and seed requirements) of k=1,...,s commodities including white and red sorghum, millet, maize, paddy, fonio, groundnuts, cotton, bambara nuts, soybeans, cowpeas, starchy tubers and straw (not all produced in

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2/ As noted in Chapter II (footnote 5), ORD stands for Organisme Regional de Developpement or Regional Development Organization. The ORD is an administrative-political structure, corresponding geographically to the country's state level departments.

all regions).[3/] Each 'representative' household has a semi-subsistence orientation. That is, some fraction of output, Q_{hk} (k=1,...,s) in region 'h', is consumed at home, the remainder sold as marketed surplus (stocks are assumed to remain constant). The household has two marketing options. It may sell commodity Q_{hk} to traders on the 'private' market and receive price P^m_{hk} (except for commodities controlled by government monopoly) or sell some output to the government, denoted by Q^*_{hk}, and receive an official 'producer' price, P^*_{hk}. Commodities Q_{hk} and Q^*_{hk} are identical goods, differentiated only by type of market.

The private market operates in an open, unrestricted manner where prices, P^m_{hk} (k=1,...,s), are set by forces of supply and demand. In the official market, 'producer' prices, P^*_{hk} (k=1,...,s), are announced by the government at harvest time (beginning of the buying season for private traders and government alike) and fixed uniformly nationwide. Government procurements of a commodity, Q^*_{hk}, are constrained by budget restrictions, capacity and institutional constraints. Price P^*_{hk} establishes a price floor that enables government procurements as long as P^*_{hk} exceeds P^m_{hk} and Q^*_{hk} is less than $\bar{Q}^*_{hk}$, where $\bar{Q}^*_{hk}$ is maximum government procurements of commodity 'k' in region 'h'.

3/ In hindsight, production models could have been developed with fewer commodities--excluding the minor crops--with resource endowments adjusted to compensate. Originally, production models were utilized for new technology evaluation where minor crops were potentially important in evaluating crop substitution possibilities. However, on a regional level, minor crops (fonio, bambara nuts, soybeans, starchy tubers, and straw) have little significance. Prices of these crops are fixed in the model and not solved for as part of the market equilibrium. Only prices of white and red sorghum, millet, maize, rice, groundnuts and cotton are solved for endogenously.

The production process employs i=1,...,m owned factors of production, W_{hi}, and d=1,...,r purchased factors, Z_{hd}. Owned-factors of production include land and labor, disaggregated by quality and seasonality characteristics, available in fixed quantities, b^{w}_{hi}. Purchased-factors of production include fertilizer, pesticides and animal traction units. The government holds monopoly control over modern input distribution. It allocates inputs among regions in fixed quantities, b^{z}_{hd}, and subsidizes input prices, ψ_{dh}, d=1,...,r. Assuming profit maximization as the producer's goal in maximizing utility, the optimization problem for the representative producer in region 'k' can be written as linear programming model of the form:

$$(1) \quad \max \pi_h = \sum_{k=1}^{s} (P^{m}_{hk}Q_{hk} + P^{*}_{hk}Q^{*}_{hk}) - \sum_{d=1}^{r} \psi_{hd}Z_{hd} \quad \underline{\text{Objective Function}}$$

subject to

$$(2) \quad - W_{hi} + \sum_{j=1}^{p} A_{hij}X_{hj} + \sum_{f=1}^{pp} A^{z}_{hif}X^{z}_{hf} = 0 \quad (i=1,\ldots,m) \quad \underline{\text{Owned Input Demand}}$$

$$(3) \quad - Z_{hd} + \sum_{f=1}^{pp} B^{z}_{hdf}X^{z}_{hf} = 0 \quad (d=1,\ldots,r) \quad \underline{\text{Purchased Input Demand}}$$

$$(4) \quad Q_{hk} + Q^{*}_{hk} - \sum_{j=1}^{p} Y_{hkj}X_{hj} - \sum_{f=1}^{pp} Y_{hkf}X^{Z}_{hf} = 0 \quad (k=1,\ldots,s) \quad \underline{\text{Production}}$$

$$(5) \quad Q^{*}_{hk} \leq \bar{Q}^{*}_{hk} \quad (k=1,\ldots,s) \quad \underline{\text{Official Market Capacity}}$$

$$(6) \quad - Q^{*}_{hk} + \sum_{d}^{r} C_{hd}Z_{hd} \leq 0 \quad (k=1,\ldots,s) \quad \underline{\text{Off. Mkt. Input Restrictions}}$$

(7) $W_{hi} \leq b^{w}_{hi}$ $(i=1,\ldots,m)$ Owned Resource Endowments

(8) $Z_{hd} \leq b^{z}_{hd}$ $(d=1,\ldots,r)$ Purchased Res. Endowments

(9) $Q_{hk}, Q^{*}_{hk}, Z_{hd}, W_{hi}, X_{hj}, X^{z}_{hf} \geq 0$ $(h=1,\ldots,H)$ Non-Negativity Conditions

The representative household in region 'h' maximizes profit, π_h, subject to constraints (2) through (9). Profit is defined as total value product, $\sum_{k=1}^{s} (P^{m}_{hk}Q_{hk} + P^{*}_{hk}Q^{*}_{hk})$, less expenditures for purchased inputs, $\sum_{d=1}^{r} \psi_{hd}Z_{hd}$. In the complete model of household production and consumption behavior, profit is incorporated into total income in the budget constraint of the consumers' utility maximization problem. More will be said on this in the next section.

Equations (2) and (3) are identities defining the derived demand for owned factors of production, W_{hi} $(i=1,\ldots,m)$, and purchased factors of production, $Z_{hd}(d=1,\ldots,r)$, respectively. The term X_{hj} $(j=1,\ldots,p)$, represents the area of crop enterprise 'j' cultivated with traditional hand-tillage technology. Similarly, X^{z}_{hf} $(f=1,\ldots,pp)$, represents the area of crop enterprise 'f' cultivated with 'modern' chemical and animal traction technologies.[4/] Together, $\sum_{j} X_{hf}$ and $\sum_{f} X^{z}_{hf}$ define cropping patterns under 'traditional' and

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[4/] The term 'modern' simply distinguishes technologies requiring animal traction services or fertilizer from traditional hand tillage technologies which do not. Animal traction and fertilizer are not truly modern, having been used in Africa for decades.

'modern' technologies within region 'h'. Coefficients A_{hij} and Z_{hif} define technical input-output requirements of 'traditional' and 'modern' technologies, X_{hj} and X^z_{hf}, respectively, for owned factors of production. The coefficients B^z_{hdf} defines input requirements of 'newer' technologies for purchased inputs.

Equation (4) is an identity relating crop yields, Y_{hkj}, and area, X_{hj}, under traditional technologies and crop yields, Y^z_{hkf}, and area, X^z_{hf} under modern technologies to total production $(Q_{hk} + Q^*_{hk})$. The term $\sum_j Y_{hkj}X_{hj}$ represents total production of commodity 'k' with traditional management practices while $\sum_f Y^z_{hkf}X^z_{hf}$ represents production with improved management practices.

Sales of commodities on the official market, Q^*_{hk}, are constrained in equation (5) to not exceed $\bar{Q}^*_{hk}$, the government's procurement capacity. If 'official' producer prices are 'low' (e.g., $P^*_{hk} < P^m_{hk}$), government purchases of Q^*_{hk} would approach zero. (It may not reach zero because of equation (6) described below.) Conversely, the government may expand its procurement quotas, $\bar{Q}^*_{hk}$, if producer prices P^*_{hk} (k=1,...,s) are made sufficiently high and capacity constraints are lessened.

The government's commodity marketing operations may not be independent of its input marketing activities. This would be the case if the government required its input sales to be repaid with commodity-in-kind. Restrictions of this sort are reflected by matrix C_{hd} in equation (6)

Conditions (7) and (8) state that levels of employment of owned and purchased factors of production, W_{hi} and Z_{hd}, cannot exceed endowments b^w_{hi} (i=1,...,m) and b^z_{hd} (d=1,...,r), respectively. Resource endowments are considered fixed in the short run and immobile across regions. Assuming resources are fully employed, equations (2) through (9) define the households' production possibilities frontier.

The linear programming model combines the producers' production and sales (marketing) activities. For any set of prices--P^m_{hk} and P^*_{hk} (k=1,...,s), and ψ_{hd} (d=1,...,r)--the producer produces output (Q_{hk} + Q^*_{hk}, k=1,...,s). Output may be sold to the official market (Q^*_{hk}) for price P^*_{hk} if prices there are higher, but capacity constraints $\bar{Q}^*$ may limit the level of sales. Alternatively, the producer sells to the private market (Q_{hk}), receiving price P^m_{hk}. Consumption decisions are treated separately in the consumers' problem where agricultural income is allocated to food and non-food purchases depending on consumer utility and prices.

Input-output coefficients for the regional LPs are estimated from farm-management data and experiment station research. Right-hand side resources are taken from farm-level and government census data. The models are solved with the MINOS solution package and validated with 1980 base period prices.

Consumers' Problem

The consumers' problem determines the allocation of income--agricultural income from the production problem plus non-farm income, exogenously fixed--and consumer demand, based on prices and utility. Goods may be purchased on the official market, where prices are fixed

and supplies are limited, or on the private market, where prices and quantities are set by competitive forces. The competitive market assumption appears to be a reasonable representation of consumer behavior in Burkina Faso, based on studies by Berg (in CRED, 1977), Sherman (1984), Bukowski (1986) and Savadogo (1986).

Let subscript g=1,...,G refer to groups of consumers in the economy and subscript k=1,...,s' to goods in the consumers' consumption bundle. As in the producers' problem, a 'representative' consumer refers to the aggregate demand behavior of a population within a geographical area. Seven 'representative' consumers are defined in the model. The five households, described in the previous section, are consumers as well as producers, accounting for rural demand (including small urban populations within these zones). Two additional consumers representing the population in the country's two largest urban centers, Ouagadougou and Bobo-Dioulasso, are also included. Thus, the model distinguishes between demand behavior of rural versus urban households in evaluating policy responses.

Commodities in the consumer sub-model include white and red sorghum, millet, maize, rice, wheat (flour), cotton (ginned), groundnuts (shelled), and an aggregate good, termed 'other', which accounts for other goods and services in the consumers' consumption bundle.[5/] Sorghums, millet and maize are purchased in kernel form

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5/ Minor crops in the supply problem are contained in the 'other' good in the consumer's problem, reducing the number of goods requiring solution in the model.

because 'pounding' or milling activities associated with their preparation (as toh, the staple preparation in diets) are generally performed by women within the household.

Let C_{gk} represent the total quantity of good 'k' demanded by the 'gth' consumer. Consumers have the choice of purchasing goods C_{gk} (k=1,...,s') on the private market referred to as G^m_{gk}) at price P^m_{gk}, or on the official market (referred to as C^o_{gk}) at the government's official 'consumer' price, P^o_{gk}. Prices and quantities demanded in the private market are unrestricted. In the official market, however, 'consumer' prices, P^o_{gk}, are uniformly fixed nationwide, usually at levels lower than P^m_{gk} to support 'cheap-food' policies. In practice, P^o_{gk} may exceed P^m_{gk} in surplus regions where private market prices are depressed, yet may be less than P^m_{gk} in deficit regions where private market prices are higher.

The amount consumers can buy is also constrained by government rationing of its fixed supplies, denoted as $\bar{C}^o_{gk}$ (g=1,...,G; k=1,...,s'). The total distribution of commodity 'k' on the official market $(\sum_k \bar{C}^o_{gk})$ is constrained by government procurements $(\sum_h Q^*_{hk})$ in the producers' problem plus imports of food aid, $A^o_{\ell k}$, from abroad. The regional distribution of commodities, however, is determined by political and institutional factors. When prices in the private market exceed fixed consumer prices in the official market (e.g., $P^m_{gk} > P^o_{gk}$), a rationing scheme $\bar{C}^o_{gk}$ (g=1,...,G; k=1,...,s') is required to allocate limited supplies.

Algebraically, the consumers' utility maximization problem can be written as:

(10) $\max U_g = U_g\ (C_{g1},\ldots,C_{gs'})$ <u>Consumers' Utility</u>

subject to

(11) $C^m_{gk} + C^o_{gk} \geq C_{gk}$ <u>Total Consumption</u>

(12) $C^o_{gk} \leq \bar{C}^o_{gk}$ <u>Official Market Ration</u>

(13) $\sum_k P^m_{gk}C^m_{gk} + \sum_k P^o_{gk}C^o_{gk} \leq \pi_g + Y^n_g$ <u>Budget Constraint</u>

$(g=1,\ldots,G;\ k=1,\ldots,s')$

Utility of the <u>gth</u> consumer, U_g, is shown to be a function of $k=1,\ldots,s'$ goods, C_{gk}. The optimization problem involves the maximization of consumer utility subject to the inequality constraints in equations (11) to (13). Constraint (11) says that total market demand, C_{gk}, is composed of demand in the private market, C^m_{gk}, and demand in the official market, C^o_{gk}. Constraint (12) states that the amount consumers purchase in the official market, C^o_{gk}, cannot exceed the government's ration, $\bar{C}^o_{gk}$, for the region.

Expression (13) is the consumers' budget constraint. It says expenditures on goods in the private market ($\sum_k P^m_{gk}C^m_{gk}$) plus expenditures in the official market ($\sum_k P^o_{gk}C^o_{gk}$) cannot exceed total income. The latter consists of profit, π_g, derived endogenously from the households' agricultural production problem (where h=g) and non-farm income, $\bar{Y}^n_g$, fixed exogenously. Urban income, by definition, contains no earnings from crop agriculture (e.g., $\pi_g = 0$). For rural producers

cum consumers, however, profit is the integral link between the households' production and consumption activities.

Assuming utility in equation (10) is of the Stone-Geary type, evaluation of Kuhn-Tucker conditions associated with the consumers' problem yields the demand system (refer to Chapter VI for the complete derivation and estimation procedure):

Private Market Demand Equation

$$(14)\quad C^m_{gk} = \gamma_{gk} + \frac{B_{gk}}{P_{gk}}\left(\pi_g + Y^n_g + \sum_k \bar{C}^o_{gk}(P^m_{gk} - P^o_{gk}) - \sum_j P^m_{gj}\gamma_{gj}\right) - \bar{C}^o_{gk}$$

$$(P^o_{gk} \leq P^m_{gk})$$

$$(g=1,\ldots,G;\ k=1,\ldots,s')$$

When official market demand is zero ($\bar{C}^o_{gk} = 0$, $k=1,\ldots,s'$), the system reduces to the widely applied Linear Expenditure System (LES). The term γ_{gk} corresponds to minimum consumption requirements of good 'h'; B_{gk} refers to marginal budget shares; and the expression $\sum_k \bar{C}^o_{gk}\ (P^m_{gk} - P^o_{gk})$ to levels of income subsidy associated with official market rations. The difference between income ($\pi_g + Y^n_g + \sum_k \bar{C}^o_{gk}(P^m_{gk} - P^o_{gk})$ and minimum subsistence expenditures ($\sum_j P^m_{gj}\gamma_{gj}$) is discretionary income which the consumer allocates to good C^m_{gk} in ratios of B_{gk}/P_{gk}. Demand in the private market (C^m_{gk}) is a function of all prices (P^m_{gk} and P^o_{gk}, $k=1,\ldots,s'$), total income (π_g plus Y^n_g plus subsidies) and demand for goods in the official market.

Demand in the official market ($\bar{C}^o_{gk}$) is fixed. In practice, the government distributes commodities (i.e., sets rations $\bar{C}^o_{gk}$) in regions

where private market prices, P^m_{gk}, are 'high' (as in the north and central regions and urban areas). Since the official market good is relatively cheaper, consumers will purchase good C^o_{gk}, but only up to the level of ration ($\bar{C}^o_{gk}$). Thereafter, goods must be bought on the private market. To operationalize this condition, rations can be set to zero if P^o_{gk} exceeds P^m_{gk}. If rations are kept constant, the restriction $P^o_{gk} \leq P^m_{gk}$ must be imposed.

Income is defined to include consumer subsidies, $\sum_k \bar{C}^o_{gk}(P^m_{gk} - P^o_{gk})$. As $\bar{C}^o_{gk}$ rises or P^o_{gk} falls (given $P^o_{gk} \leq P^m_{gk}$) consumer subsidies grow larger, increasing total market demand (C^m_{gk} plus $\bar{C}^o_{gk}$). If $\bar{C}^o_{gk}$ increases, demand in the private market may fall, however, due to the displacement of C^m_{gj} by $\bar{C}^o_{gk}$. Demand in the private sector thus acts as a residual market, increasing with consumer subsidies (lower official price, P^o_{gk}) but falling with expanded official market share.

Parameters γ_{gk} and B_{gk} ($k=1,\ldots,s'$) are derived, using the Frisch (1959) methodology, from 'base' period prices and quantities in private and official markets (P^m_{gk}, P^o_{gk}, C^m_{gk} and C^o_{gk}, $k=1,\ldots,s'$), income (π_g plus Y^n), estimates of income elasticities of demand (e^*_{ky}, $k=1,\ldots,s'$) and an estimate of the 'Frisch' parameter. A linear approximation of the LES is taken, using a first-order Taylor series expansion to incorporate private market demand in the model (note, the LES is linear in expenditures, not in quantities). This procedure is needed to maintain linearity of the LCP.

International Trade Problem

Both private and public sectors engage in international trade. In the private market, wheat and rice are imported from the rest-of-the-world at world prices (plus some government taxes) while livestock, shea nuts and various 'other' goods are exported. Cereals are also traded through clandestine markets with neighboring countries. The official market interacts with the rest of the world in three ways: international donors provide food aid imports augmenting government supplies; the government imports agricultural inputs, subsidizing their cost to producers; and, the government exports cotton and groundnuts, receiving export revenues. The government may also purchase food on the world market, paying international prices, though the availability of food aid or foreign exchange constraints limit the incidence of official commercial imports.

Let $E^m_{\ell k}$ represent private sector exports and $M^m_{\ell k}$ imports of commodity 'k' to and from country 'i'. Likewise, let $M^o_{\ell k}$ represent imports and $E^o_{\ell k}$ exports of commodity 'k' by the public sector. Food aid imports are normally distributed through official market channels (denoted as $A^o_{\ell k}$) at official 'consumer' prices. However, aid could also be distributed free-of-charge for charity, represented by the term $A^m_{\ell k}$.

Private international trade is permitted through three (L=3) trading channels: port of Abidjan via Bobo-Dioulasso; Niger via the 'east' region border; and Mali via the 'west' region border. The Bobo-Abidjan channel accounts for most of the country's external trade. However, trade flows with Mali (normally a net supplier in

Burkina Faso) and Niger (normally a net importer) are also incorporated in the model to account for clandestine movements in grain between neighboring countries.

From a global perspective, Burkina is a 'small' country trader. It is too small to individually affect world prices, although it can distort its own prices relative to the rest of the world through manipulation of exchange rates, tariffs, subsidies or quotas. From a regional perspective, however, Burkina may be viewed as a 'large' country trader which can influence prices. Transportation margins between internal countries (Burkina Faso, Mali and Niger) and coastal ports are sufficiently large. As a result, prices and trade may vary considerably among neighboring countries in the region without trade emerging with the rest-of-the-world.

In the small country case (Abidjan:Bobo), import and export elasticities with respect to price are expected to be elastic (though not 'highly' so due to constraints on transportation, foreign exchange and market information). In the large country case (Niger:'east'; Mali:'west'), where trade flows may influence prices, trade elasticities are expected to be relatively inelastic.

The grainshed hypothesis provides one explanation for the low elasticities in the large country case. The hypothesis says that as prices in Niger increase, the area of the grainshed selling grain to Niger expands further into Burkina Faso, increasing trade. As prices decrease, the area representing the vent for grain shrinks to areas closest to the border and trade declines (conversations with W.H.M. Morris).

The international trade problem for the official market can be written:

(15) $A^o_{\ell k} = \bar{A}^o_{\ell k}$ Food Aid

(16) $M^o_{\ell k} = \bar{M}^o_{\ell k}$ Official Imports

(17) $E^o_{\ell k} = \sum_h Q^*_{hk}$ Cotton and Groundnut Exports

$(\ell = L;\ k=1,\ldots,s')$

Government supplies may be supplemented through purchases of imports $M^o_{\ell k}$ at international prices or through receipts of aid, $A^o_{\ell k}$. Direct purchases by the government are insignificant, fixed at levels $\bar{M}^o_{\ell k}$. Imports of aid, $A^o_{\ell k}$, particularly food aid, are sizable and assumed fixed at levels $\bar{A}^o_{\ell k}$, although in practice levels vary with the international community's assessment of national cereals production (i.e., need). Official exports, $E^o_{\ell k}$, mainly of cotton and groundnuts, depend on domestic procurements, $\sum_h Q^*_{hk}$, in the supply problem. Commodities are sold at fixed international prices irrespective of official prices offered to producers.

Regarding the private market, the international trade problem can be written:

(18) $M^m_{\ell k} = a_{\ell k} + b_{\ell k} P_{\ell k}$ Net Import Supply Equation

(18') $M^m_{\ell k}(P_{\ell k} - P^m_{gk} - s^i_k - t_{\ell gk}) = 0$ Complementary Slackness Condition

(19) $E^m_{\ell k} = a_{\ell k} + b_{\ell k} P_{\ell k}$ Net Export Demand Equation

(19') $E^m_{\ell k}(P_{\ell k} - P^m_{gk} + s^e_k + t_{g\ell k}) = 0$ Complementary Slackness Condition

(20) $M^m_{\ell k} \leq \bar{M}^m_{\ell k}; \quad E^m_{\ell k} \leq \bar{E}^m_{\ell k}$ Quotas

(ℓ=1,...,L; k=1,...,s')

(g refers to regions adjacent to 'ℓ').

Equation (18) is the net import supply equation from country 'ℓ' of commodity 'k' defined as a linear function of border prices $P_{\ell k}$. The excess demand equation of country 'ℓ' for commodity 'k' is represented as a linear function of border prices $P_{\ell k}$ in equation (19). Equations (18') and (19') are complementary slackness conditions, connecting prices in country 'ℓ' with adjacent region 'g' in Burkina Faso. The border price ($P_{\ell k}$) is separated from the domestic price (P^m_{gk}) by a "wedge" comprised of specific taxes ($-s^i_k$ for imports, s^e_k for exports) and transfer charges, including transportation ($t_{\ell gk}$ for imports, $t_{g\ell k}$ for exports).[6/] Exchange rates are normalized at one because currencies of countries in West Africa are pegged to the French Franc (excluding Mali). If the border price ($P_{\ell k}$) equals the domestic price (P^m_{gk}) less total transfer costs ($s^e_k + t_{\ell gk}$), imports from country 'i' to region 'g' are possible (unless constrained by

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6/ Note, ad valorem taxes where they occur are expressed as specific tax equivalents. A subsidy can be written as the negative of a specific tax.

import quotas in (20)). Conversely, if the domestic price (P^m_{gk}) plus export and transfer charges ($s^e_k + t_{g\ell k}$) equal world prices ($P_{\ell k}$), exports are possible (unless constrained by export quotas).

The import supply and export demand functions in (18) and (19) are derived from base period prices, quantities and estimates of trade elasticities (intercept terms are computed from the point estimates). Excess supply elasticities are assumed to equal 0.4 in the small-country case and 3.0 in the large country case. For export demand equations, elasticities of -0.6 (small-country) and -3.0 (large-country) are assumed.

Private Market Trade Problem

Production, demand and international trade in the private sector were determined in the previous three sections, assuming a competitive market equilibrium. The private market trade problem also assumes competitive market operations. It handles transshipment of goods from regions of excess supply to regions of excess demand, minimizing transportation costs. It also handles processing of raw agricultural commodities into milled (wheat), shelled (groundnuts), or ginned (cotton) form required for final consumption. The presence of high marketing costs has contributed to notions that monopoly rents are taken by traders in the marketplace. Berg (in CRED, 1977) and Bukowski (1986), however, have shown that high margins result from poor infrastructure and high marketing costs, lending support for the competitive market assumption.

Production of commodities, Q_{hk} (h=1,...,H, k=1,...,s) on the private market are determined from the set of output prices, P^m_{hk} and P^*_{hk}, and input prices, ψ_{hd} (d=1,...,r), in the producers' problem. Demand for commodities, C^m_{gk} (g=1,...,G, k=1,...,s') are derived from prices, P^m_{gk} and P^o_{gk}, and income, $(\pi_g + Y^n)$ in the consumers' problem. Let the term 'ϕ^m' refer to marketing and storage losses and 'ϕ^p' to conversion rates for goods undergoing processing. Since only rice (not paddy), shelled groundnuts and ginned cotton (not seed cotton) are consumed, no restrictions are imposed on processing capacity. The net supply of goods in the private market, S_{hk}, can be obtained from the equation:

(21) $S_{hk} = (1 - \phi^m_k)(1 - \phi^p_k)Q_{hk}$ <u>Marketing Losses and Processing</u>

(h=1,...,H; k=1,...,s')

Given prices and income hence the determination of supply, demand and trade, the market problem in the private sector can be written as:

(22) $\min \sum_g \sum_\ell t_{g\ell k} T_{g\ell k}$ <u>Minimize Transport Costs</u>

subject to:

(23) $S_{gk} + M^m_{\ell k} - C^m_{gk} - E^m_{\ell k} = \sum_i^{G+L} T_{g\ell k} - \sum_j^{G+L} T_{\ell gk}$ <u>Commodity Balance Constraint</u>

(g≠1; k=1,...,s')
(g=1,...,G)
(ℓ=1,...,L)

For domestic regions, the term $t_{g\ell k}$ refers to the cost of transporting and transferring a unit of comodity, $T_{g\ell k}$, between g=1,...,G regions. Between domestic regions 'g' and border 'ℓ', however, the term $t_{g\ell k}$ also includes any import or export taxes which may be levied or border charges. The market problem involves minimizing total transfer costs $(\sum_g \sum_\ell t_{g\ell k} T_{g\ell k})$ of trade subject to the commodity balance equation (23). If supply exceeds demand $(S_{gk} + M^m_{\ell k} > C_{gk} - E^m_{\ell k})$, then net exports of magnitude $(\sum_i T_{g\ell k} - \sum_j T_{\ell gk} > 0)$ leave region 'g'. Conversely, if demand exceeds supply $(S_{gk} + M^m_{\ell k} < C^m_{gk} - E^m_{\ell k})$, then region 'g' is a net importer of commodity 'k' of magnitude $\sum_i T_{g\ell k} - \sum_j T_{\ell gk} < 0)$.[7/]

Official Market Problem

Official 'producer' and 'consumer' prices (P^*_{hk} and P^o_{gk}, k=1, ...,s') are fixed, set annually by the government. The government's procurement of commodities, Q^*_{hk} (k=1,...,s'), from producers depends on the set of relative prices (P^*_h/P^m_h) and institutional and capacity constraints, $\bar{Q}^*_h$. Let the term 'ϕ^m' again refer to marketing and storage losses and 'ϕ^p' to conversion rates in processing. With imports, exports and food aid shipments included, the public sector's commodity balance equation can be written as:

7/ Complementarity and non-negativity conditions insure at most one non-zero trade flow (either $T_{g\ell k}$ or $T_{\ell gk}$. As the direction of trade cannot be set a priori, both possibilities are allowed for in this specification.

(24) $S^*_{hk} = (1 - \phi^m)(1 - \phi^p)Q^*_{hk}$ <u>Off. Mkt. Losses and Processing</u>

$(h=1,\ldots,H;\ k=1,\ldots,s')$

(25) $\sum_h S^*_{hk} + (1 - \phi^m)(\sum_\ell M^o_{\ell k} + \sum_\ell A^o_{\ell k}) = \sum_g \bar{C}^o_{gk} + \sum_\ell E^o_{\ell k}$

$(h=g;\ h,g\neq\ell)$

$(h=1,\ldots,H;\ g=1,\ldots,G;\ k=1,\ldots,s')$

Demand (market rations) in the official market may be supported by the government through domestic procurements ($\sum_j S^*_{hk}$), purchases on the international market ($\sum_\ell M^o_{\ell k}$), or receipt of food aid ($\sum_\ell A^o_{\ell k}$). Cotton and groundnuts are exported ($E^o_{\ell k}$), earning export revenues.

When the private market price exceeds the official 'producer' price (e.g., $P^m_{hk} > P^*_{hk}$), an implicit income subsidy of magnitude $Q^*_{hk}(P^*_{hk} - P^m_{hk})$ is transferred to producers in region 'h'. Similarly, when the private market price exceeds the official 'consumer' price ($P^m_{gk} > P^o_{gk}$) an implicit income subsidy of magnitude $\bar{C}^o_{gk}(P^o_{gk} - P^m_{gk})$ is transferred to consumer 'g'.

The market problem facing the government involves two issues: 1) at what levels should prices, P^*_{hk} and P^o_{gk} $(h=1,\ldots,H;\ g=1,\ldots,g;\ k=1,\ldots,s')$ be set to achieve government objectives; and 2) how to allocate scarce supplies of goods, $\sum_g C^o_{gk}$ $(k=1,\ldots,s')$, given that official prices are fixed (and cease as a mechanism for allocation, assuming $P^m_{gk} > P^o_{gk}$). Clearly, if 'consumer' prices are cheaper, but the government has limited supplies, some rationing scheme, $\bar{C}_{gk}$, g =

1,...,G; k=1,...,s) is required to allocate goods. Historically, rationing schemes have been biased toward urban populations and severe food deficit areas.

Agricultural Sector Model

In this section, the producer, consumer, international trade, private market, and official market sub-models are integrated in a spatial, recursive and dynamic market equilibrium model of Burkina Faso's agricultural sector. Spatial dimensions of the model are represented by the determination of quantities (supply and demand) and prices in private regional markets, connected by inter-regional trade.

Recursive and dynamic dimensions refer to the manner in which supply, international trade and demand components are solved in arriving at a competitive market solution in the private market. Mathematical programming approaches which seek a competitive equilibrium in the economy (McCarl and Spreen) are not well suited to problems where quantities and prices are restricted in certain markets (i.e., official markets). The methodology below permits restrictions in the official market, but solves for a competitive equilibrium in prices and quantities in the private market. The model includes five sequential steps:

Stage 1: Production. Net production (Q_{hk} and Q^*_{hk}, h=1,...,H, k=1,...,s) and input demands (W_{hi} and Z_{hd}, h=1,...,H; d=1,...,r) are estimated via the producers' problem using producers' expectations of private market prices, (P^m_{hk}), and input and output prices, (ψ_{hd} and

P^*_{hk}) in the official market. The problem, summarized from equations (1) to (9), can be written

(26) $\max \pi_h = \sum_k (\bar{P}^m_{hk} Q_{hk} + \bar{P}^*_{hk} Q^*_{hk}) - \sum_d \bar{\psi}_{hd} Z_{hd}$ Producers' Obj. Fn.

subject to:

(26') $F_h[Q_{hk}:Q^*_{hk}:W_{hi}:Z_{hd}:Z_{hj}:X_{hj}:X^z_{hf}] = \bar{B}_h$ Production Poss. Frontier

$(h=1,\ldots,H;\ k=1,\ldots,s;\ i=1,\ldots,m;$

$d=1,\ldots,r;\ j=1,\ldots,p;\ f=1,\ldots,pp)$

For the annual model solution, producers' price expectations are assumed to equal 1980 base period prices in the private market. For subsequent solutions over time (years), price expectations are estimated as a function of the previous period's prices estimated by the Linear Complementarity Algorithm (described shortly in steps 4 and 5). Official market prices, $\bar{P}^*_{hk}$ $(k=1,\ldots,s)$ and $\bar{\psi}_{hd}$ $(d=1,\ldots,r)$ are current year official prices offered by the government. Given fixed prices ($\bar{P}^m_{hk}$, $\bar{P}^*_{hk}$, $\bar{\psi}_{hd}$) and resources ($\bar{B}_h$) and the households' production function, $F_h(--)$, output Q_{hk} for the private market, and Q^*_{hk} for the official market are determined.

Stage 2: Official Market Ration. The supply of official market commodities, S^*_{hk}, are derived from government procurements, Q^*_{hk}, in stage one and equation (24). The government's purchase of commodities abroad, $\bar{M}^o_{\ell k}$, and imports of food aid, $\bar{A}^o_{\ell k}$, are exogenously set in

equations (15) and (16). Government rationing of goods among domestic and foreign markets, then, is estimated by:

$$(27) \quad C^{o}_{gk} = \bar{\omega}_{gk}(\sum_{h} \bar{S}^{*}_{hk} + (1 - \phi^{m}) \sum_{\ell} (\bar{M}^{o}_{\ell k} + \bar{A}^{o}_{\ell k})) \quad \underline{\text{Off. Consumer Rations}}$$

$$(27') \quad E^{o}_{\ell k} = \bar{\omega}_{\ell k}(\sum_{h} \bar{S}^{*}_{hk} + (1 - \phi^{m}) \sum_{\ell} (\bar{M}^{o}_{\ell k} + \bar{A}^{o}_{\ell k})) \quad \underline{\text{Off. Export Rations}}$$

$$(h=1,\ldots,H;\ g=1,\ldots,G;\ \ell=1,\ldots,L;\ k=1,\ldots,s')$$

$$(\sum_{g} \bar{\omega}_{gk} + \sum_{\ell} \bar{\omega}_{\ell k} = 1)$$

where, $\bar{\omega}_{gk}$ and $\bar{\omega}_{\ell k}$, represent fixed rationing weights for allocating goods among regions. The weights sum to one since no carry-over stocks are allowed.

<u>Stage 3: Income Determination</u>. Total income (Y^{*}_{g}) for the consumers' problem is computed as:

$$(28) \quad Y^{*}_{g} = \pi_{g} + Y^{n}_{g} + \sum_{k} \bar{C}^{o}_{gk} (\bar{P}^{m}_{gk} - \bar{P}^{o}_{gk}) \quad \underline{\text{Derivation of Income}}$$

$$\bar{P}^{m}_{gk} \geq \bar{P}^{o}_{gk}$$

$$(g=1,\ldots,G;\ k=1,\ldots,s')$$

Agricultural income, π_{g}, including 'producer' subsidies, $\sum_{k} Q^{*}_{hk}(P^{*}_{hk}$ -

P^m_{hk}), is estimated from dual prices associated with the right-hand-side, ($\bar{B}_k$), of the supply problem in stage one.[8/] Non-agricultural income, $\bar{Y}^n_g$, is fixed exogenously. Consumer subsidies, $\sum_g \bar{C}^o_{gk}(\bar{P}^m_{gk} - \bar{P}^o_{gk})$ are computed from market rations in stage two and constant prices. If in evaluation of prices the condition holds that $P^o_{gk} > P^m_{gk}$, consumer losses are avoided by imposing the restriction $P^o_{gk} = P^m_{gk}$. Large infractions, however, suggest market rations $\bar{C}^o_{gk}$ are improperly set and weights ω_{gk} and $\omega_{\ell k}$ in stage two should be readjusted toward regions where private market prices are higher.

Stage 4: Competitive Market Equilibrium, Private Market. Quantities demanded (C^m_{gk}), prices ($\tilde{P}^m_{gk}$), trade flows (T_{ijk}), imports ($M^m_{\ell k}$) and exports ($E^m_{\ell k}$) in the private market are solved endogenously given predetermined values for supply and income. The net supply of commodities, $\bar{S}_{hk}$ (k=1,...,s') are determined from stage one and equation (21). Estimates of income ($\bar{Y}^*_g$) are determined in stage three. The market problem is formulated as a Linear Complementarity Problem (LCP) (see Hanson and Manne, 1977) solving directly for prices and trade flows (private market demand falls out indirectly from prices and fixed income):[9/]

8/ Alternatively, income could be taken from the objective function value in the model solution. However, calculating income from dual prices and right-hand-side values, enable the distribution of income according to ownership of scarce factors of production. Since all income in rural areas is distributed to producers in those regions, the objective function value could have been used instead.

9/ The computer algorithm to solve the Linear Complementarity Problem was developed by Paul Preckel, Purdue University.

(29) $T_{ijk}(\tilde{P}^m_{ik} + \bar{t}_{ijk} - \tilde{P}^m_{jk}) = 0$ <u>Complementary Slackness Condition</u>

<u>Commodity Balance Constraint</u>

(29′) $C^m_{gk}(\tilde{P}^m_i, \ldots, \tilde{P}^m_{s'}, \bar{Y}^*) + E^m_{\ell k}(\tilde{P}^m_{\ell k}) - M^m_{\ell k}(\tilde{P}^m_{\ell k}) + \sum_i T_{ijk} - \sum_j T_{jik} = \bar{C}^o_{gk} + \bar{S}_{hk} + \bar{A}^m_{\ell k}$

$(g=h\neq\ell;\ g=1,\ldots,G;\ h=1,\ldots,H;$

$\ell=1,\ldots,L;\ k=1,\ldots,s').$

Private market demand (C^m_{gk}), import supply ($M^m_{\ell k}$) and export demand ($E^m_{\ell k}$), written in implicit form in (29′), are linear in prices (from equations (14) and (17)). The market equilibrium refers to the set of prices ($\tilde{P}^m_{ik}$, $i=1,\ldots,G+L$; $k=1,\ldots,s'$) and trade flows, T_{ijk} ($i=j=1,\ldots,G+L$), which satisfy the complementary slackness conditions in expression (29) and commodity balance equations in (29′).

For trade flows in (28) to be positive ($T_{ijk} > 0$), price differentials between regions must equal total transfer costs ($\tilde{P}^m_{ik} - \tilde{P}^m_{jk} = \bar{t}_{ijk}$). Otherwise, trade is too expensive ($\tilde{P}^m_{ik} - \tilde{P}^m_{jk} < \bar{t}_{ijk}$) and trade flows are zero ($T_{ijk} = 0$). The complementary slackness condition assumes commodity prices are always greater than or equal to zero. Expression (28′) says total private market demand (C^m_{gk}) minus import supply ($M^m_{\ell k}$) plus export demand ($E^m_{\ell k}$) plus net imports ($\sum_i T_{ijk} - \sum_j T_{jik}$, $i=j=1,\ldots,G+L$) (negative implies net exports) must equal fixed endowments of supply ($\bar{S}_{hk}$) plus private market food aid ($\bar{A}^m_{\ell k}$) ($g=1,\ldots,G$; $\ell=1,\ldots,L$, $h=1,\ldots,H$; $k=1,\ldots,s'$).

Stage 5: Dynamics with Revised Prices. Stages (1) through (4) represent an annual model suitable for short-term evaluations of policy. Longer term effects may be evaluated by taking prices ($\tilde{P}^m_{hk}$, h=1,...,H; k=1,...,s') from the market equilibrium solution in stage (4), updating prices in the producers' problem in stage (1) and repeating the process. The cycle can be repeated in 'n' iterations (or years), permitting evaluation of dynamic adjustments to policy in the longer term.

Producers' price expectations are formed from the equation

$$P^m_{hk(t)} = \lambda \bar{P}^m_{hk} + (1 - \lambda) \tilde{P}^m_{hk(t-1)}$$

where, P^m_{hk} are producers' expected prices in the LPs, $\bar{P}^m_{hk}$ are producers' long run prior expectations of prices which remain constant, and $\tilde{P}^m_{hk}$ are private market prices generated by the LCP. The coefficient, λ, represents the price adjustment factor. When λ=1, expected prices of producers remain constant, equaling long run price expectations, regardless of price levels $\tilde{P}^m_{hk}$. When λ=0, price expectations of producers equal the previous period's prices. The use of expected prices in this manner more accurately reflect the producers' decision making process (as opposed to using long term market equilibrium prices). It also permits greater flexibility in evaluating producers' response to a policy change.

Thus, steps (1) through (4) represent an annual, short term model. Revising producers' price expectations via step (5) and

solving the model recursively over time, enables a dynamic evaluation of policy impacts.

Policy Evaluation

This methodology offers a flexible and highly disaggregated analytical tool suitable for a variety of policy applications:

Input Subsidies. Input subsidies to producers can be evaluated through manipulation of the price term, ψ_{hd}, in the producers' objective function and through adjustments to b^{z}_{hd}, the government's allocation of modern inputs, on the right-hand side of the producers' problem (equations (26) and (26')). The total cost of government input subsidies can be computed as

$$\text{Cost of Input Subsidies:} \quad \sum_h \sum_d Z_{hd} (\psi^{w}_{hd} - \bar{\psi}_{hd}) \qquad (h=1,\ldots,H;\ d=1,\ldots,r)$$

That is, total input subsidies equal the difference between the economic (undistorted) price (ψ^{w}_{hd}) and the official price ($\bar{\psi}_{hd}$) times levels of input usage (Z_{hd}) summed over 'r' modern inputs. Benefits of subsidies accrue to producers through lower input costs, $\sum_d \psi_{hd} Z_{hd}$, in equation (26). Subsidies are passed on to consumers through lower commodity prices (from expanded agricultural production).

Commodity Output and Price Policy. The effects of official price policy at the producer level may be evaluated through exogenous

changes in prices, P^*_{hk}, and capacity constraints, Q^*_{hk}, in the producers' problem. The impact of consumer policies may be simulated through adjustments in prices, P^o_{gk}, and market rations, $\bar{C}^o_{gk}$ (k=1,...,s') in the consumers' problem. Total subsidies--$\sum_h \sum_k \bar{Q}^*_{hk}(P^m_{hk} - P^*_{hk})$ for producers and $\sum_g \sum_k \bar{C}^o_{gk}(P^m_{gk} - P^o_{gk})$, $P^m_{gk} \geq P^o_{gk}$, for consumers--influence private market demand through income in stage (3). The government's gross revenue from running the program is

Gross Revenues from Commodity Programs: $$\sum_g \sum_k P^o_{gk}\bar{C}^o_{gk} - \sum_h \sum_k P^*_{hk}Q^*_{hk}$$

but, the combination of low margins $(P^o_{gk} - P^*_{gk})$ (g=h) and high average costs normally result in OFNACER operating in the red. Transport and marketing costs could also be included to calculate net-government revenues, but these costs have been excluded due to the lack of information.

The benefits to the program are higher prices to producers, increasing producer surplus, and lower costs to consumers, raising consumer surplus. The result is higher agricultural output and demand in the economy.

Alternatively, the government may import goods, $M^o_{\ell k}$, from abroad at prices $P_{\ell k}$ with earnings of foreign exchange from exports, $E^o_{\ell k}$ (k=1,...,s'). Revenue and disbursements associated with government programs can be computed as:

$$\sum_k (\sum_g P^o_{gk}\bar{C}^o_{gk} + \sum_\ell P_{\ell k}E^o_{\ell k} + \sum_\ell s^e_{\ell k}E^m_{\ell k} + \sum_\ell s^i_{\ell k}M^m_{\ell k}$$
$$- \sum_h P^*_{hk}Q^*_{hk} - \sum_\ell P_{\ell k}M^o_{\ell k})$$

That is, government gross revenue equals total official consumer sales ($\sum_g P^o_{gk}\bar{C}^o_{gk}$) plus official export revenues ($\sum_g P_{\ell k}E^o_{\ell k}$) plus export and import taxes ($\sum_* S^e_{\ell k}E^m_{\ell k} + \sum_\ell S^i_{\ell k}M^m_{\ell k}$) less payments for procurements from producers ($\sum_h P_{hk}Q_{hk}$) and official imports ($\sum_\ell P_{\ell k}M_{\ell k}$). An examination of the full budget effect would further require comparison of gross revenue with government operating costs. However, lack of data on government marketing costs precludes this calculation. By exporting goods in which the country has a comparative advantage and importing goods in which it is at a comparative disadvantage, the country's welfare can be improved.

Food Aid. Private imports of food aid provided free to consumers may be evaluated through adjustments in the term $\bar{A}^m_{\ell k}$ in equation (29′). Food aid distributed through the official market, sold at official prices, P^o_{gk}, are incorporated in official market rations, $\bar{C}^o_{gk}$, in (29′) and derivation of consumer subsidies in stage (3).

Technology. Traditional and modern crop technolcgies may be evaluated through crop enterprises, X_{hj} and X^z_{hf}, respectively in equation (26′). The profitability of existing technologies is indicated by the presence of activities and activity levels in the model solution. New technologies are evaluated by expanding the activity set, X^z_{hf}. The

effects of official market prices on economic returns may be considered through changes in P^*_{hk} and ψ_{hd} in the producers' objective function (26 and 26'). The impacts of changing resource endowments may be considered through changes in b^z_{hd} in the right-hand-side of the LPs. Evaluation of technical characteristics of the technology involve the modification of input-output requirements in the firm's production function (terms A^z_{hif}, B^z_{hdf} and Y_{hkf} in equations (2) to (4); implicit in equation (26')).

Dynamic Resource Adjustment. The effects of land resettlement schemes and resource adjustment in agriculture may be evaluated through changes in fixed resources, B_h, of the supply problem. Over the longer term, domestic resources (B_h) are expected to vary with economic profitability of the sector. Resources, B_h, may be made endogenous, determined by agricultural prices, to study longer effects of policies on resource issues (migration, land allocation, investment in animal traction and chemical inputs) through stage (5).

This completes the general overview of the agricultural sector model. Attention now shifts to the theoretical specification and empirical implementation of supply sub-models in Chapters IV and V.

CHAPTER IV

REGIONAL SUPPLY MODELS

This chapter describes the methodology for estimating agricultural supply response in the sectoral model. The methodology draws on the household-firm model of agricultural production, extended to accommodate regional resource endowments. Production and consumption decisions are simultaneously determined; profit from production affects consumption through the income elasticity of demand. Adjustments in consumption in turn affect prices which alter production decisions. This chapter concentrates on the supply model. Demand is covered in Chapter VII. The integration of production and consumption decisions in the agricultural sector model was explained in Chapter III.

This chapter is layed out as follows. First, a general overview of farming systems in Burkina Faso is given. This provides background on the structure of the agricultural sector and determinants of production. Next, several considerations are discussed which impact on choice and design of methodology. Finally, the theoretical supply model is formally specified. The empirical application of the theory to construction of the regional supply models and data sources follow in Chapter V.

Overview of Farming Systems

The food producing sector of Burkina Faso is based largely on smallholder agriculture. Farms are typically small, around 4 to 8 hectares in size (Table 4.1), but vary depending on the size of the family's work force. Agriculture is based on traditional methods with few modern inputs used. Most of output is consumed on the farm; the marketed surplus for cereals has been estimated at 10 to 15 percent of total production (SAFGRAD/FSU, 1982, p. 10; Delgado, 1978, p. 100; and McMillan, 1983, p. 157). This figure likely underestimates marketed surplus in the west and southwest, where productivity is higher, and for peanuts and cotton, 60 to 100 percent of which are normally sold (SAFGRAD/FSU, 1982, p. 10; McMillan, 1983, p. 157).

Millet and sorghum are the dominant cereal crops, accounting for about 90 percent of crop area over most of the country. As one moves from the arid north to humid southwest, rainfall increases and dominant cereals in the crop mix shift from millet to sorghum to maize. A similar effect is seen to the east, west, and southwest where soils are more fertile, leading to greater sorghum and maize and less millet in cropping patterns.

Livestock have been the traditional means for investing any surpluses from crops, wages or gifts (McMillan, 1983, p. 165). Smaller livestock--sheep, goats, chickens, and guinea hens--are supervised by the owner and paddocked in the compound at night. Larger animals are typically entrusted to the care of Fulani herdsmen. Livestock provide one of the main sources of year-around income on the

Table 4.1. Structural Characteristics of the Agricultural Sector, 1980.

Region	O.R.D.	Number of Villages 1/	Number of Farms ('000) 3/	Agricultural Population ('000, 1980) 2/	Persons per Household 2/	Area Cultivated per Farm 4/
North	Centre Nord	705	74.4	669	4.0	3.4
	Yatenga	685	68.8	550	8.0	2.1
	Sahel	n.a.	48.6	369	7.6	4.2
Central	Centre	893	109.7	878	8.0	3.4
	Centre Ouest	662	64.1	808	12.0	4.7
	Centre Est	545	41.8	418	10.0	4.0
East	Est	652	57.6	426	7.4	3.3
West	Volta Noire	797	59.3	652	11.0	4.7
Southwest	Hauts Bassins	365	33.9	305	9.0	4.9
	Bougouriba	1105	33.7	371	11.0	4.6
	Comoe	202	18.6	186	10.0	6.0
National	Burkina Faso	6611	610.5	5,632	9.2	3.9

1/ From C & I Associates, "Etude Sur la Situation Financiere des Organismes Regionaux de Developpement, Annexes Par O.R.D.," Vol. IV, September 1982.

2/ Data on agricultural population and persons per household were compiled by Republique de Haute Volta, Ministere du Developpement Rural, Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81, and 1981/82 from 1975 population census data and O.R.D. annual reports, respectively.

3/ Number of farms is computed from estimates of agricultural population and persons per household.

4/ Represents total area cultivated in 1979-1981 (from Table 2.4) divided by number of farms.

farm. Moreover, they complement cropping systems by providing investment opportunities and a "store of value." The latter two are particularly important in rural economies where investment and savings institutions are poorly developed.

Cultivation with a hand hoe, daba, still provides the major source of agricultural power. Most labor on the farm is provided by family members. Direct hire or exchange labor generally accounts for less than 10 percent of total labor inputs, coming mostly during slack periods of labor demand (McMillan, 1983, p. 139; Barret, et al., 1982, p. 65; ICRISAT, 1980, p. 112; Delgado, 1978, pp. 137-160). During peak labor periods, hiring of labor nears zero as farmers cum laborers concentrate their energies toward work on their own fields.

Land distribution is generally governed by local tribal customs and traditions which establish land-use rights (Saunders, 1980, p. 9, 10). It is never privately owned, but belongs to the patrilineal family, its ancestors and future generations (Hammond, 1966, p. 102). Land has long since been a scarce commodity in many areas of the densely populated Central Plateau, although elsewhere in Burkina Faso land is relatively more abundant. Labor migration, particularly of young adult men, has been the traditional safety valve for relieving population pressures. The earnings generated from more prosperous regions of the country or from abroad provide a major source of capital back to the village economy.

Two types of fields with different managerial control can be distinguished: "collective" fields farmed by the entire family for benefit of the household, and "private" fields cultivated for gain of

individual household members. The collective fields are under the control of the household head, who decides which crops are planted and when crop operations are performed. Any income or sale of crops from these fields belong to him. The household head's major responsibilities are to ensure there is sufficient grain to meet consumption needs of the family for the coming season plus adequate cash to pay taxes. As for private fields, each "active"[1/] within the household has the right to cultivate a small amount of land for his personal needs (McMillan, 1983, p. 131). The household head allocates these fields to family members and permits time to work on them, but cropping decisions are made by the individual in charge. Estimates of the fraction of private fields vary between 13 percent (Swanson, 1981, p. 44) and 28 to 38 percent (McMillan, 1983, p. 388) of total area cultivated.

The cultivation of collective fields takes priority over private fields. All members of the household work on communal fields during the major portion of the day. Work on the private fields is reserved for remaining hours (generally an hour or two in the morning before work on communal fields and again in the evening before returning home). Occasionally, the household head sets aside several days to cultivate private fields (McMillan, 1983, p. 131; Lallemand, 1977). Communal fields are predominantly planted in cereals while personal

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1/ "Active" comes from the French word actif which is common in the French literature on labor. In the context here, it refers to the number of workers who contribute to agricultural production (as opposed to dependents). While its exact definition varies on the source, in general it includes able bodied workers between 10 and 55 years of age.

fields tend to be planted in cash crops, particularly groundnuts, bambara nuts, and vegetables (Singh, 1983, p. 25; McMillan, 1983, p. 389). In the households studied by Lallemand (1977), young men usually planted cotton while women planted groundnuts and bambara nuts.

The traditional means for maintaining overall productivity of the farming system are manuring and shifting cultivation. Fields near the compound and within the village are more or less permanently cultivated until they become exhausted. Then, if land is abundant, the household is moved to a more fertile site while the exhausted land is retired to fallow (for as much as 15 years) (Saunders, 1980, p. 10). Where land is restricted in supply, land fallow becomes less feasible. Then, fertility declines or greater use must be made of organic or inorganic fertilizers or improved land management practices.

Manuring is an important component of the farming system. Animal manure, collected from livestock paddocks, is applied mostly to compound areas, where maize is normally grown, and less to outlying village and bush soils (McMillan, 1983, p. 394 and Bonkian, 1980, p. 14) due to constraints on manure supply and additional work for manure transport. Occasionally, contracts are formed with Fulani cattle herders to graze their herds on village fields to augment manure supply. Plant residues are rarely used as "green" manure because of their value as fodder, fuel, etc. (Hammond, 1966, pp. 33 to 36).

Modern inputs such as inorganic fertilizers or animal mechanization receive limited use in Burkina Faso (Table 4.2),

Table 4.2. Intensity of Modern Input Use, Burkina Faso, 1980.

Region	O.R.D.	Fertilizer[1/] per Total Area Cult.	Nat. Phosphate[2/] per Total Area Cult.	Number of[2/] Farms per Oxen Team	Number of[2/] Farms per Donkey Team
		(kg./ha)			
North	Centre Nord	1.7	26.5	30.0	10.5
	Yatenga	7.9	8.0	11.0	17.4
	Sahel	-	-	n.a.	n.a.
Central	Centre	1.2	0.7	43.7	8.1
	Centre Ouest	3.1	40.3	56.0	9.4
	Centre Est	0.3	17.4	n.a.	n.a.
East	Est	1.1	155.5	60.0	25.0
West	Volta Noire	13.4	13.8	6.2	18.5
Southwest	Hauts Bassins	28.5	-	6.0	53.3
	Bougouriba	4.2	2.3	112.8	210.6
	Comoe	7.3	-	63.6	n.a.
National	Burkina Faso	5.6	24.1	20.9	17.2

1/ Fertilizer includes the sum of N-P-K cotton fertilizer (14-25-14), Urea (46-0-0), and Simple and super phosphate. Information on consumption of fertilizers and natural phosphates were taken from Appendix 1, Table A1.17. Total area cultivated is taken from Table 2.4.

2/ The stock of animal traction teams (Appendix 1, Table A1.18) is assumed to grow at an annual rate of 15 percent over the period 1979/80 to 1980/81. Data on number of farms are taken from Table 4.1.

although demand has been growing rapidly.[2/] In cotton growing regions of the west and southwest (Volta Noire and Hauts Bassins), fertilizer use spread over total area cultivated averages 13.4 and 28.5 kg./ha., respectively. Outside these areas, fertilizer intensity averages less than 7.9 kg./ha. These statistics represent broad aggregate averages. At the farm level, studies by ICRISAT (1980, p. 111), Lassiter (1981, pp. 27-41), Singh, et al., (1983, p. 55), Whitney (1981, p. 155), and McMillan (1983, p. 392) show that not only is fertilizer use rare, but application rates are generally less than 30 kg./ha. (compared with more moderate rates of 100-200 kg./ha. used in experiment station research).

As for animal mechanization, only 1 in 17 or 1 in 21 farmers on average possesses a donkey or oxen team, respectively (Table 4.2). Rates of donkey traction ownership are highest in the north, central and east regions where soils are sandier and easier to till. Donkey mechanization predominates in these regions because of its lower investment costs, financial constraints of farmers, poorly developed credit markets, lack of adequate forage for oxen, institutional factors and cultural tillage practices which emphasize mechanized weeding and not plowing. Plowing is one activity where oxen traction has an advantage over donkey mechanization. Oxen teams are more

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2/ Total imports of fertilizer (metric tons) from 1965 to 1978 has grown at a rate of 30 percent per year (World Bank, 1980, pp. 72 and 73), starting from a low base of 500 m.t. Growth rates for oxen teams have been roughly estimated at 20-25 percent (World Bank, 1980, p. 97) over the same period.

prevalent in the west and southwest where soils are heavier, requiring greater strength to work.

Land quality and labor supply are the major determinants of cropping patterns (SAFGRAD/FSU, 1982, p. 13). Sorghums possess ceteris paribus superior yield response but less drought resistance than millet. Hence, it is typically planted on more fertile soils with better water retention. Millet is normally planted on poorer soils where, because of its superior drought resistance and yield stability,[3/] its yields are superior to sorghum in normal rainfall years. Farmers plant as much millet as their labor supply permits once they have allocated land to other crops (SAFGRAD/FSU, 1982, 1983). Hence, while sorghum is constrained by availabilities of high quality land, the area of millet is constrained by the supply of labor at critical periods of labor demand.

For most areas of the country, planting of maize is limited to highly manured plots (like soils surrounding the compound) where soils are relatively fertile and possess better water absorption capacity. With good rainfall, maize yields on these soils are superior to other crops. Also, because maize is harvested early, it helps supplement the household's food supply during the "hungry season". This is the

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3/ This relationship is complicated by rainfall. As one moves toward the southwest where rainfall is higher, sorghum tends to substitute for millet on these poorer soils due to better water supply. Inversely, in more arid regions, millet tends to substitute for sorghum on higher quality soils due to water constraints. The relationship depends on the production functions of sorghum and millet (by quality of land) to levels of fertility and water.

period prior to harvests of the main sorghum and/or millet fields when grain stocks can be low or depleted. Where rainfall is poor, maize may be cut-yielded by other cereals, but still be grown due to the "hungry season" constraint. In areas to the west and southwest, this constraint becomes less important since food supplies are larger and maize begins to substitute for sorghum on outlying fields.

Factors underlying cultivation of groundnuts, the principal cash crop, are more complicated. On the collective fields under the direction of the household head, groundnuts are planted because they can be harvested and sold nearest to the time when taxes are due (tax payments are the responsibility of the household head) (SAFGRAD/FSU, 1982). On women's private fields, the predominance of groundnuts may be explained by returns being maximized per unit of land (private fields are constrained in area) and cultural factors which allot to women control over groundnut marketings.

Methodological Considerations

For sectoral problems, assumptions are typically made concerning behavior of producing agents in the economy (McCarl and Spreen, 1980). Producers are assumed to operate in competitive markets for both output and factors of production, producing some number of homogeneous goods. No one firm can exert market power and influence factor or product prices. Each producer has a finite set of production processes where each process is assumed to be technically efficient.

For exemplary purposes, the generalized optimization problem of the h<u>th</u> producer can be written as:

(1) $\text{Max } U_h = U_h(\pi_h, Z_h)$ <u>Objective Function</u>

subject to

(2) $F_h(X_h) \leq B_h$ <u>Production Possibilities Set</u>

(3) $X_h \geq 0$ <u>Non-Negativity Conditions</u>

where U_h is producer h's utility gained from farming; π_h and Z_h refer to profit and other goals and objectives, respectively; $F_h(X_h)$ is an implicit function relating the transformation of inputs into outputs of the h<u>th</u> producer's production process; and B_h are producer h's endowment of resources. In the optimization framework, producer 'h' is assumed to maximize utility subject to his set of production possibilities in equation (2).

Because of the "large" number of micro-firms existing in agriculture, the producer problem is typically redefined to represent the collective behavior of 'n' producers in some sector or region 'h' of the economy. $F_h(X_h)$, then, represents the "average" transformation of inputs into outputs by 'n' producers in region 'h'; B_h contains the sum of resources of 'n' producers; and prices entering profit π_h in the objective function are weighted average prices for region 'h'. Resources are assumed mobile and move costlessly within the region but are immobile between regions. Given that B_h is fully employed, equation (2) defines the production possibility surface of region 'h'. Supply by region then is represented by a model of "representative" firm behavior with 'n' identical sets of producers' resources at its disposal.

Producer utility is shown to be a function of multiple goals and objectives. These include profit, π_h, and a term, Z_h, which encompasses other goals and objectives. The latter may include minimizing production risk, achieving minimum food or nutrient requirements, or minimizing financial risk associated with purchase of cash inputs. In sector analyses, the producer is typically assumed to maximize profits while objectives, Z_h, are excluded from the objective function (because of data limitations or requirements for specialized solution algorithms).[4/] However, minimum or maximum constraints may be imposed on production processes in $F_h(X_h)$ to account for certain objectives like food self-sufficiency or caloric requirements.[5/]

Two special problems related to the functioning of land and labor markets in Burkina Faso complicate the modelling of representative firm behavior:

1) Land is allocated by social custom, not in the marketplace where explicit rents are formed. Producers have at their disposal different types of land of different qualities which they in turn allocate among competing crops. How crops are allocated among land types depends on net returns of the enterprise. Land prices are a cost of production which should

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4/ For an application of multiple goal programming to studying resource allocation questions of an extended family household in the Sine Saloum region of Senegal, see Barnett (1981).

5/ These constraints act as terms in the objective function through their LaGrange multipliers, in the dual solution. This procedure provides an alternative way of handling objectives in the primal problem.

be accounted for in net return calculations. In the absence of formal markets for land, land prices are non-existant. The value of land is determined implicitly within the system of household production as a function of output prices, crop enterprises suited to soil types, production technology, yields and soil fertility. Land prices then are difficult to set a priori without assessing the relationship among these variables.

2) The market for farm labor in Burkina Faso is "thin", existing mainly during relatively slack periods of the agricultural season. During the peak periods of labor demand at first weeding of major cereals, labor is nearly impossible to hire as whole families are fully employed on their own fields. The absence of functioning labor markets at this time inhibits explicit wage rate formation. As with land, wage rates are required to estimate the cost of labor and in turn profitability of competing crop enterprises. The value of labor varies throughout the agricultural season with the highest value accompanying peak periods of labor demand. Use of wage rates observed during slack periods underestimates the value of labor at periods of peak demand. The appropriate labor costs for computation of net returns are labor flows of a crop enterprise through the agricultural season weighted by corresponding shadow prices of labor. These are difficult to set a priori because they depend on levels of output prices,

labor requirements of competing crop enterprises by period, supply of labor and production technology.

The treatment of these two problems are crucial to the analysis, since land and labor are the two most important factors in the production process.

Mathematical programming is ideally suited to handling problems of this nature. To demonstrate this, equations (1) through (3) need to be rewritten to incorporate prior assumptions and to add more detail to the production possibilities set. Let,

X_j = the level of the jth production process ($j=1,\ldots,p$).

Q_{kj} = yield of the kth output from the jth production process ($k=1,\ldots,s$; $j=1,\ldots,p$).

Z_{dj} = use of the dth purchased factor in the jth production process ($d=1,\ldots,r$; $j=1,\ldots,p$).

W_{ij} = use of the ith owned factor in the jth production process ($i=1,\ldots,m$; $j=1,\ldots,p$).

b_i^w = endowment of the ith owned factor available to the producer.

P_k = market price per unit of the kth output ($k=1,\ldots,s$).

ψ_d = market price of the dth purchased input.

A_{dj} = quantity of the dth purchased factor required by the jth production process ($d=1,\ldots,r$; $j=1,\ldots,p$).

B_{ij} = quantity of the ith owned factor required by the jth production process ($i=1,\ldots,m$; $j=1,\ldots,p$).

C_{kj} = quantity of the kth output yielded by the jth production process ($k=1,\ldots,s$; $j=1,\ldots,p$).

As shown by McCarl and Spreen (1980), the optimization problem for the "representative" producer, maximizing profit in region 'h' can be represented as:

(4) $$\max \pi = \sum_{j=1}^{p} \left(\sum_{k=1}^{s} P_k Q_{kj} - \sum_{d=1}^{r} \psi_d Z_{dj} \right)$$ Objective Function

subject to

(5) $$- Z_{dj} + A_{dj} X_j = 0 \qquad (d=1,\ldots,r;\ j=1,\ldots,p)$$

Purchased Input Demand

(6) $$- W_{ij} + B_{ij} X_j = 0 \qquad (i=1,\ldots,m;\ j=1,\ldots,p)$$

Owned Input Demand

(7) $$Q_{kj} - C_{kj} X_j = 0 \qquad (k=1,\ldots,s;\ j=1,\ldots,p)$$ Production

(8) $$\sum_{j=1}^{p} W_{ij} \leq b_i^w \qquad (i=1,\ldots,m)$$ Owned Resource Endowments

The "representative" producer in region 'h' maximizes profits π in equation (4) subject to constraints representing the derived demand for purchased inputs (Z_{dj}) in equation (5), demand for non-purchased inputs (W_{ij}) in equation (6), production (Q_{kj}) in equation (7); and endowments of non-purchased inputs (b_i^w) in equation (8). Given values for commodity prices (P_k), purchased input costs (ψ_d), technical requirements sets (A_{dj}, B_{ij} and C_{kj}) and endowments of non-purchased resources (b_i^w), the problem can be solved via linear programming.

Writing the Lagrangian for the problem makes explicit the derivation of land rents and labor costs implicit to the problem:

$$(9) \qquad L = \pi + \sum_{k=1}^{s} \sum_{j=1}^{p} v_{dj}(Z_{dj} - A_{dj}X_j) \quad \underline{\text{LaGrangian of Producers' Problem}}$$

$$+ \sum_{i=1}^{m} \sum_{j=1}^{p} w_{ij}(W_{ij} - B_{ij}X_j)$$

$$+ \sum_{i=1}^{m} \lambda_i(b_i^w - \sum_{j=1}^{p} W_{ij})$$

$$+ \sum_{k=1}^{s} \sum_{j=1}^{p} \sigma_{kj}(- Q_{kj} + C_{kj}X_j)$$

Kuhn-Tucker conditions provide the necessary and sufficient conditions for a constrained optimum at Z_{dj}^o, X_j^o, W_{ij}^o, Q_{kj}^o, v_{kj}^o, w_{ij}^o, λ_i^o, and σ_{kj}^o. The Lagrangian multipliers v_{dj}, w_{ij}, λ_i and σ_{kj} are prices imputed to purchased factors of production, owned factors of production, endowments of owned factors and output, respectively.

Of main interest here are the terms w_{ij} and λ_i. The coefficient w_{ij} is the marginal value imputed to the i<u>th</u> owned factor in the j<u>th</u> production process. λ_i is the marginal value imputed to the availability of the i<u>th</u> owned factor. Hence, $w_{ij} \leq \lambda_i$. The term λ_i, $i=1,\ldots,m$, would define the relevant implicit prices for land and labor. To capture the "appropriate" implicit prices in the analysis requires disaggregating constraints (6) and (8) into land of different qualities and labor demand and supply into periods of the agricultural

season. How closely the imputed prices approximate the "true" value of land and labor depends on the type and level of disaggregation used and yields, labor flows, production technology and structure of the farming system assumed in the model.

Model Specification

The supply model for the "representative" producer in each region 'h' encompasses cereal crops and cash crop activities. It excludes price endogenous crop-livestock interactions except where animal traction activities are concerned.[6/] Crops may be cultivated with three types of tillage technology: strictly manual labor, manual labor in conjunction with donkey mechanization; and manual labor in conjunction with oxen cultivation. Crop activities in the model include sole crops and prevalent crop mixtures.

Modern chemical technologies and irrigation are also incorporated in the model. Production functions for fertilizer permit adjustments in supply response to alternative levels of fertilizer application. Three models of irrigation are included to evaluate different regimes of water control.

Within each region 'h', four types of resources are available to the "representative" producer: land of various qualities, family labor, animal mechanization and modern inputs. For traditional

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6/ This implies that shifts in labor allocation among crop and livestock enterprises due to changes in price relatives is prohibited. Livestock activities are implicitly accounted for in land and labor parameters, however. For example, time spent on crop activities is exogenously constrained so that time is allotted for care of livestock during the day.

dryland agriculture, five types of land are defined: swampy land, high quality land encircling the family compound, higher quality village and bush fields, lower quality village fields, and outlying bush fields. Four additional types of land are incorporated in the model to accommodate land in modern irrigation schemes and AVV land reclamation projects. Stocks and flows of family labor are disaggregated into ten periods of the agricultural season to capture variations in the shadow price of labor. Periods corresponding to peak period labor demands are of weekly duration.

The "representative" producer is assumed to be a profit maximizer. However, other goals or objectives are included in the constraint set. These include sufficient maize for the "soudure" (hungry season), sufficient grain to meet annual cereals consumption needs and various bounds on minor crop activities.

Output prices in the model are defined for both private and official markets. On the private market, prices are those the producer expects to receive in the future for sale of output. Prices on the official market are those announced by the government prior to the growing season. The producer has liberty to sell to whichever market offers the best price, except where payment of officially controlled modern inputs is tied to output sales. Input prices are official prices on government controlled inputs.

A schematic diagram of the theoretical supply model is illustrated in Figure 4.1. Details on the theoretical structure of the model are outlined below. The subscript 'h' for regions is dropped

	Production			Hand Tillage Technologies				Animal Mechanization Technologies				Modern chemical and Irrigation Technologies												RHS
	Private	Official	Swp	CPD	HQ	LQ	Bush	Swp	Cpd	HQ	LQ	Bush	Swp	Cpd	HQ	LQ	Bush	IRR	AVV	Land	AT Teams	Manure	Chemicals	Credit	Male Wrkrs.	Female Wrkrs.	Child Wrkrs.	
	Q_k k=1...s	Q_k k=1...s*		X_j^m, j=1...p				Donkey: X_j^d, j=1...p Oxen: X_j^o, j=1...p					X_j^f, j=1...pp															
Obj. Fnctn.: Max π	$P_k^m Q_k$	$P_k^* Q_k^*$		$-\psi_j^{sm} X_j^m$				$-\psi_j^{sd} X_j^d$				$-\psi_j^{so} X_j^o$	$-\psi_j^{sf} X_j^f$							$-\psi$		$-\psi$	$-\psi$					≤ 0
Human Labor i = 1 ⋮ 10				A_{ij}^m				A_{ij}^{md}				A_{ij}^{mo}	A_{ij}^{mf}											-MHR	-FHR	-CHR		≤ 0
Donkey Labor i = 1 ⋮ 10				A_{ij}^d									A_{ij}^{df}								-DHR							≤ 0
Oxen Labor i = 1 ⋮ 10												A_{ij}^o	A_{ij}^{of}								-OHR							≤ 0
Crop Yields k = 1 ⋮ s	1	1		$-Y_{kj}^m$				$-Y_{kj}^d$				$-Y_{kj}^o$	$-Y_{kj}^f$															≤ 0
		1																										
			1																									
Swampy lowland			1					1					1															
Compound land				1					1					1														
Higher Quality					1					1					1													
Lower Quality						1					1					1					-I							≤ 0
Bush							1					1					1											
Irrigation																		1										
AVV Land Recl.																			1									
Land Fallow						-c	-c 1					1					1											= 0
Marketing		-c....-c																			c	c						≤ 0
Consumption (+)	1	1																										
or (-)																												$\gtrless G_k$
			1																									
Chemical Input													(d_j^u, d_j^f, j_j^p)									-I						≤ 0
Land																				1	-c							
AT Teams																					I							$\leq b$
Manure																					-c	I						$\leq b$
Chemicals																							I					≤ 0
Credit																							c	-1				$\leq b$
Male Workers																									1			≤ 0
Female Workers																										1		$\leq b^m$
Child Workers																											1	$\leq b^f$
																												$\leq b^c$

Figure 4.1. Schematic Representation of the Regional Supply Model.

for sake of readability, but the theory underlies empirical estimation of supply in all regions, except where caveats are given.

Let,

P_k^m = farm gate price producers expect to receive for commodity 'k' on the private market;

P_k^* = official producer price for commodity 'k' offered through government controlled markets;

Q_k = quantity of the kth commodity produced at expected price P_k;

Q_k^* = quantity of the kth commodity produced at official market price P_k^*;

X_j^m = hectares of land allocated to the jth crop enterprise farmed with strictly manual cultivation techniques;

X_j^d = hectares of land allocated to the jth crop enterprise cultivated with donkey mechanization (no chemical inputs);

X_j^o = hectares of land allocated to the jth crop enterprise cultivated with oxen mechanization (no chemical inputs);

X_j^f = hectares of land allocated to the jth crop enterprise cultivated with modern chemical inputs and/or irrigation using either strictly manual or animal traction technologies;

DK = number of donkey traction teams (single donkey) at an annualized cost of ψ^d per team;

OX = number of oxen traction teams (pairs of oxen) at an annualized cost of ψ^o per team;

FERT = quantity of cotton manufactured fertilizer (14-23-15) costed at ψ^f per ton;

UREA = quantity of Urea costed at ψ^u per ton;

PEST = quantity of cotton pesticide (Nuvacron) costed at ψ^p per kilo-liter;

CDT = credit extended to producers for purchase of modern inputs at interest rate r;

ψ_j^s = seed costs per hectare for the j<u>th</u> enterprise plus charges for land clearing (on land taken out of fallow) where appropriate.

Producers are assumed to maximize net returns of the household, represented by the objective function:[7/]

$$(10) \quad \max Z = \sum_{k=1}^{s} (P_k^m Q_k + P_k^* Q_k^*) - \sum_{j=1}^{p} (\psi_j^{sm} X_j^m + \psi_j^{sd} X_j^d + \psi_j^{so} X_j^o) - \sum_{j=1}^{pp} \psi_j^{sf} X_j^f - \psi^d DK - \psi^o OX - \psi^f FERT - \psi^u UREA - \psi^p PEST - rCDT$$

<u>Maximization of Profit</u>

Equation (10) implies that producers in aggregate seek to maximize the value of output, $P_k^m Q_k + P_k^* Q^*_k$, (k=1,...,s), less variable costs for seeds ($\psi_j^s X_j$) (subscripts denoting technology are dropped), donkey mechanization ($\psi^d DK$), oxen mechanization ($\psi^o OX$), fertilizer ($\psi^f FERT$), Urea ($\psi^u UREA$), pesticide ($\psi^p PEST$) and credit (rCDT). Costs of land

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7/ In theory, profits are zero as returns accrue to all factors of production in the form of economic rents (LaGrange multipliers). Maximization of profits here is interpreted as maximizing returns to household labor, fixed resources (i.e., land) and management. As such, the formulation makes no distinction between decisions of the household head and other family members on collective and private fields, respectively.

and labor are not incorporated directly in the objective function, but rather are accounted for implicitly by the shadow prices of resources, λ_i, associated with land and labor constraints in the model.

Producers have two sets of prices they consider when making production decisions. One corresponds to prices, P_k^m $(k = 1,\ldots,s)$, producers expect to receive in the private market when they sell their output. The other corresponds to prices in the government controlled official market. In the latter, grain is purchased by the government's national cereals marketing board (OFNACER) at set, uniform prices, P_k^*, across the country. Price P_k^* establishes a price floor which is effective as long as official prices exceed producers' expectations of private market prices and sufficient funds exist for the board to purchase commodities. Producers have complete flexibility to choose among markets, subject to whether the government can support price P_k^* through its commodity purchases.[8/]

The producers' objective function is maximized subject to constraints on producer behavior, resource levels, input flows and operations of factor markets. These constraints are described more fully below.

Supply and Demand for Human Labor

Total hours worked on crop enterprise X_j depends on type of crop, land, and production technology. Maize and groundnuts, for example,

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8/ An alternative is to enforce official prices for all market transactions by restricting operation of private markets. Historically, attempts to do this in Burkina Faso have been only marginally effective and limited to the larger urban markets where monitoring and enforcement of official prices are more cost effective.

are more labor intensive than millet. The higher labor requirements are due in part to cultural practices but also depend on type of soil. Soils of higher fertility require greater labor input due to greater weeding problems, heavier soils (which means greater energy requirements) and higher marginal physical product of labor. Attributes referring to type of crop and soil type are incorporated through the choice of activities contained in the set of manual tillage technologies, X_j^m, j=1,...,p.

Production technology also alters labor flows. Use of animal mechanization in tillage operations, especially weeding, can reduce human labor requirements per unit of land. Cultural practices associated with use of animal traction are represented by activities, X_j^d and X_j^o, j=1,...,p. Modern chemical technologies represented by X_j^f, j=1,...,pp may also alter labor requirements (e.g., use of fertilizer may increase weeding problems) though these are less significant than effects associated with animal mechanization.

For a given crop enterprise X_j, a timely flow of labor is required to achieve expected yields. If an operation such as weeding is poorly performed or delayed, yield reductions occur. Offsetting this, high shadow prices of labor associated with peak periods of labor demand encourage staggering crops and field operations to smooth labor flows. Producers balance these competing forces in scheduling cropping activities. The "optimum" labor schedule is implicit in labor estimates found in empirical studies and in turn of labor assumptions used in modelling frameworks (see Balcet and Candler (1981) and Crawford (1980) for Nigeria; Niang (1980) for Senegal and Mali;

Haswell (1953) and Jabara (1979) for Senegal; and Delgado (1978) and Jaeger (1984) for Burkina Faso). Hence, labor requirements reflect a priori assumptions regarding both total labor and timing of operations.

These assumptions may be important in two cases: when new technology alters the scheduling of crop operations (e.g., double cropping maize during the season); or when policy greatly alters returns of a technology (e.g., if the price of maize is substantially increased). The first problem is beyond the scope of analysis. The second is potentially important, especially for price swings outside the sample range of observation. Either of these can be addressed with additional activities in the model but at the additional cost of greater model size.

The derived demand for human labor can be written as:

$$(11) \quad \sum_{j=1}^{p} (A_{ij}^{m} X_j^{m} + A_{ij}^{md} X_j^{d} + A_{ij}^{mo} X_j^{o}) + \sum_{j=1}^{pp} A_{ij}^{mf} X_j^{f} \qquad \text{Seasonal Demand for Human Labor}$$

$$- MHR_i MW - FHR_i FW - CHR_i CW \leq 0$$

$$(i=1,\ldots,10 \text{ labor periods})$$

where:

A_{ij}^{m} = number of human hours required in the ith period to cultivate one hectare of the jth crop using strictly manual labor;

A_{ij}^{md} = number of human hours required in the ith period to cultivate one hectare of the jth crop with donkey cultivation;

A_{ij}^{mo} = number of human hours required in the ith period to cultivate one hectare of the jth crop with oxen mechanization;

A_{ij}^{mf} = number of human hours required in the ith period to cultivate one hectare of the jth crop using modern chemical technologies with manual or animal tillage cultivation;

MHR_i = number of hours a male adult worker (MW) can potentially work (labor intensity) in period i;

FHR_i = number of hours a female adult work (FW) can potentially work in period i;

CHR_i = number of hours a child worker (CW) can potentially work in period i.

The derived demand for family labor in period 'i' is derived from work requirements (A_{ij}^{m}, A_{ij}^{md}, A_{ij}^{mo}, and A_{ij}^{mf}) on manual tillage technologies, X_j^m, donkey mechanization technologies, X_j^d, oxen mechanization technologies, X_j^o, and modern chemical and irrigation technologies, X_j^f, respectively. Labor flows for traditional hand tillage technology are represented by A_{ij}^{m}. The labor reducing effects of animal traction are incorporated through A_{ij}^{md} and A_{ij}^{mo}, while possible labor augmenting effects associated with more land intensive technologies are incorporated through A_{ij}^{mf}.

Total labor ($\sum_{i=1}^{10} A_{ij}$) for crop enterprise X_j contains actual hours worked (as opposed to man-equivalents) by family members on planting through completion of weeding activities. No hiring of labor is allowed; harvesting and off-season labor activities are excluded.

Labor is disaggregated into i=1,...,10 periods to capture the seasonality of labor flows.

This formulation has two distinguishable characteristics. One, labor constraints delineate the seasonality of labor flows, but only for a 4 to 5 month period of the wet season. Studies by Crawford (1980) and Delgado (1978), by comparison, incorporate labor constraints for the entire calendar year.[9/] Second, constraints corresponding to the critical labor bottlenecks at first weeding are weekly in duration while slack periods vary from 2 to 3 weeks in length. Weekly periods are used to better capture the high shadow prices of labor which confront farmers at critical periods of labor demand. Shadow prices, λ_i, associated with these labor constraints, reflect the marginal value of an additional hour of work at various times of the agricultural season.

Equation (11) implies there is perfect substitution of labor among various members of the household. That is, one unit of time worked by a male adult (MHR) substitutes equally for one unit of time worked by a female adult or child (FHR or CHR). Many farm studies convert actual labor times to "man-equivalents" to adjust for perceived differences in productivity among age-sex groups by task. This procedure is avoided because weighting systems employed in practice are often arbitrarily chosen and lack empirical support. Also, differences in productivity, which may exist, tend to be discounted due

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9/ A narrower labor schedule was used because: it permitted smaller model size, enabling greater delineation of labor flows at critical periods; and, wet season labor requirements appeared to capture the relevant labor constraints to agricultural production.

to "division of labor."[10/] In this analysis, hours among age-sex groups are treated with equal efficiency, but female adults and children work fewer hours in the fields per day. This lower rate of work intensity is attributed to other farm and household activities performed by women and lesser endurance of children.

From equation (11) the total demand for human labor is represented by the expression, $MHR_i MW + FHR_i FW + CHR_i CW$, where the number of male (MW), female (FW) and child (CW) agricultural workers is constrained by each region's respective work force:

Supply of Agricultural Workforce

(12) $MW \leq b^w$

(12') $FW \leq b^f$

(12") $CW \leq b^c$

The terms b^w, b^f, and b^c represent the fixed supply of "active" workers by region. Shadow prices, λ_i, associated with b^w, b^f, and b^c in the LP solution, reflect the marginal value of each additional type of worker to agriculture in the region.

Labor markets in this formulation are rigid. Both labor intensity per worker and number of workers are exogenously set. Labor intensities (MHR, FHR, CHR) are assumed to remain invariant over the

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10/ Male adults may be more efficient than children at land preparation and weeding activities, but have no advantage on say bird scaring or guiding of draft animals. Hence, "divisions of labor" where workers perform the task in which they have a comparative advantage diminishes overall productivity differences.

course of the agricultural season. Moreover, no market is incorporated to permit buying or selling of labor services.

Production

Output of commodity 'k' by region is determined by the identity:

$$(13)\quad Q_k + Q_k^* - \sum_{j=1}^{p} (Y_{kj}^m X_j^m + Y_{kj}^d X_j^d + Y_{kj}^o X_j^o) - \sum_{j=1}^{pp} Y_{kj}^f X_j^f \leq 0$$

$$(k=1,\ldots,s \text{ commodities})$$

where:

Y_{kj}^m = yields per hectare of the kth commodity on the jth crop using manual technology, zero otherwise;

Y_{kj}^d = yields per hectare of the kth commodity on the jth crop using donkey technology, zero otherwise;

Y_{kj}^o = yields per hectare of the kth commodity on the jth crop using oxen technology, zero otherwise;

Y_{kj}^f = yields per hectare of the kth commodity on the jth crop with modern chemical inputs and/or irrigation, using either strictly manual or animal traction technology, zero otherwise.

Equation (13) makes explicit the relationship between output of a homogeneous commodity 'k' and type of technology used to produce it. Total physical output ($Q_k + Q_k^*$) is the sum (over $j=1,\ldots,p;1,\ldots,pp$) of what is produced with traditional hand tillage technology, $Y_{kj}^m X_j^m$,

animal mechanization technologies, $Y^d_{kj}X^d_j$ and $Y^o_{kj}X^o_j$, and modern chemical and irrigation technologies, $Y^f_{kj}X^f_j$. With this formulation, either an increase in yield, Y_{kj}, or an increase in cultivated area, X_j (superscripts denoting technology are dropped), ceteris paribus, result in increased total production of commodity 'k'.

Land

For a given type of technology (manual, donkey, oxen or chemical), yields of crop enterprise, X_j, vary directly with land quality. As land quality improves, so does soil fertility, soil structure and in turn water absorption capacity. Improved fertility and availability of water enable higher crop yields. (This is not always true as in the case of too much water on low-lying soils.) Not all crops possess the same yield response function to higher levels of inputs, however. As discussed in the description of farming systems, maize has higher yield response than sorghums or millets on the best quality soils under adequate water regimes. On poorer quality soils where supply of water is more constraining, cultivation of maize is risky. White sorghum yields better than millet under desirable soil and rainfall conditions, but requires higher quality land and more consistent rainfall. While millet is lower yielding, it has superior drought and disease resistance. It is the crop of last resort, planted on poor quality land with low water absorption capacity.

ICRISAT (1980) defines six soil types farmers distinguish in making their crop allocation decisions: a) soils adjacent to the

compound which are high in organic matter; b) lowland soils, periodically inundated; c) soils with higher loam or clay fractions located in the bush and those recently taken out of fallow; d) loamy-sand soils adjacent to the compound or village but low in organic matter; e) loamy-sand soils located at some distance in the bush but low in organic matter; and f) shallow, gravelly-sand soils, irrespective of location. With normal to good rainfall, farmers normally plant maize on soil type (a); red sorghum on soil types (b) and (c); millet and/or sorghums, often mixed with cowpeas on soil type (d); millet, often intercropped with cowpeas on soil type (e); and millet on soil type (f). With late arrival of rains, lowland soils and gravelly soils would normally be left unplanted. Plantings would consist almost exclusively of millet intercropped with cowpeas. Thus, land quality is an important determinant of cropping patterns.

For modelling purposes, land associated with traditional dryland agriculture is disaggregated into five soil types of varying degrees of productivity. Crop technologies are defined by land type. The derived demand for land type 'ℓ' is represented by the identity:

Demand for Land

$$(14) \quad \sum_{j=1}^{p} (t^{m}_{\ell j} X^{m}_{j} + t^{d}_{\ell j} X^{d}_{j}) + t^{o}_{\ell j} X^{o}_{j}) + \sum_{j=1}^{pp} t^{f}_{\ell j} X^{f}_{j} - T_{\ell} \leq 0$$

where:

ℓ = 1,...,5 types of land for traditional dryland agriculture and 6,...,9 types of land representing areas in land reclamation schemes and irrigated agriculture)

$t_{\ell j}$ = 1 if crop enterprise j is on land type 'ℓ', zero otherwise; and

T_ℓ = total derived demand for land type 'ℓ'.

The total derived demand for land, T_ℓ, is the sum of area cultivated in individual crop enterprises X_j, on land of homogeneous quality 'ℓ'. Land is assumed to be centrally managed, not differentiated by type of management as with communal versus private fields. As McMillan (1983) has shown, input-output relationships vary with type of management. But, gains of further differentiating land types by type of ownership are outweighed by higher costs of expanded model size.

Land qualities included in the model for traditional dryland agriculture are:

Swampy lowlands: marshy land suited for starchy tubers or rice production;

Compound land: land adjacent to the family's compound which receives regular and large deposits of night soil, household wastes, and animal manure;

Higher quality village and bush soils: soils corresponding to lower slopes of the topography, soils with high loam fractions and/or soils receiving significant deposits of animal manure or organic matter;

Lower quality village fields: loamy sand soils adjacent to the village, which receive only minor deposits of manure, hence are lower in organic matter;

Bush fields: lands furthest from the household which vary in fertility by region.

The land of highest quality are the "compound soils" and "higher quality village and bush soils" because of their higher organic matter content and superior water absorption capacity. These soils offer the greatest substitutability among crops, but tend to be planted in sorghum and maize due to their yield dominance. Lower quality village fields are normally low in fertility due to their permanent cultivation, removal of organic materials and low applications of manure. The quality of bush fields conceivably offers the greatest variability across regions. In areas of high population density and diminishing(ed) bush land fallow, these soils typically are exhausted and badly eroded. Where land fallow systems remain intact, soil fertility is likely superior to that of the lower quality village fields (Delgado, 1978, p. 25). Swampy lowlands are somewhat of an anomaly; even though they are highly productive, the intensive labor demands of crops suited to them may constrain full utilization.

Additional constraints need to be incorporated in the model for areas of land under AVV reclamation schemes and irrigation. These projects contribute to agricultural output, but are distinguished from traditional agriculture by parastatal involvement in their development and high investment costs to bring land into cultivation. Their areas are mainly constrained by institutional or financial forces, whereas land types in traditional agriculture are constrained largely by

physical factors. Four additional land types are included in the model to constrain area cultivated with these investments:

Improved lowlands: small scale irrigation based on partial water control, mostly on swampy bottomlands or below small earthen dams.

Single crop rice irrigation schemes: Large scale irrigation schemes bearing high investment costs, producing one crop of rice per year.

Double crop rice irrigation schemes: Large scale irrigation schemes bearing high investment costs, producing two crops of rice per year (Vallee du Kou and Plaine du Banzon in the Southwest).

AVV land reclamation: Areas of disease freed land settled by the AVV. Soils in these areas are richer and settlers follow improved farm management practices.[11/]

The supply of land is defined by the equation:

(15) $T_\ell - mnr_\ell MNR \leq b_\ell^t$ Supply of Land

$\ell = 1, \ldots, 9$ land types

11/ Due to poor information on distribution of AVV land across regions, it is assumed all cultivated area of the AVV falls in the Central region. From an aggregate perspective, this assumption is insignificant since less than 8,500 hectares of such land were cultivated in 1980 (Table 2.4).

where:

mnr_ℓ = the inverse of quantity of manure applied to either compound land, higher quality village and bush land or lower quality village land, respectively, zero otherwise;

MNR = additional manure provided by draft animals of animal mechanized teams, DK or OX; and.

b_ℓ^t = fixed endowment of land type 'ℓ'.

Equation (15) requires that total demand for land type 'ℓ' not exceed its supply, $mnr_\ell MNR + b_\ell^t$. The supply of land includes two components. The major component is endowment of land, b_ℓ^t, which is limited and scarce for higher quality land types but of unlimited supply for bush land. The second and minor component is the term, $mnr_\ell MNR$, which relates manure from draft animals to additional supply of higher quality land, 'ℓ'.

Since higher quality lands possess superior fertility, they are given priority in cultivation. Labor is allocated to these fields up to the limit of their availability, with the remainder spent on poorer quality bush land. Hence, while land supply limits the area of higher quality fields, total labor constrains the area of bush fields and total area cultivated (i.e., defined as $\sum_{i=1}^{L} T_\ell$). Higher quality fields then should possess positive shadow prices λ_i^t on endowments, b_ℓ^t, which increase with higher soil quality. These are the implicit prices on land which govern its allocation among competing enterprises. Bush

land possesses a shadow price of 0 because it is assumed to be available in unlimited supply.

The assumption of unlimited bush land is controversial. In areas of Burkina Faso where population densities are low and/or land fallow still practiced (i.e., in the east, west, and southwest), the assumption of abundant supply of land appears reasonable. For areas on the Central Plateau, however, where population densities are high and land fallow greatly reduced, it can be argued this assumption no longer holds. Two facts dispute this. One, data on cultivated area and total arable land in Table 2.2 imply arable land still remains unexploited. Next, farmers on the Plateau cite labor constraints at weeding (and next at planting) as the main limiting factors to expanded millet cultivation. It would be a minor task to impose constraints on endowments of bush land, if more conclusive evidence to the contrary is found.

The assumption of unlimited supply of bush land appears most consistent with empirical observation. It is important to recognize its implications, however. The fact that farmers expand onto bush land implies gains to extensification are higher than intensification of existing higher quality soils. This favors technologies which are mainly labor saving in nature like animal traction and weeding equipment. If bush land were constrained, however, economic incentives would shift in favor of more labor intensive, higher value crops like groundnuts and technologies like tied ridging and fertilization which increase productivity per unit of land. This issue should be kept in mind when addressing technology questions.

As for the term $mnr_{\ell}MNR$, applications of organic materials and manure are implicit in endowments of higher quality land. Compound land, for example, receives wastes from the household. Thus, its area should expand with larger family size, hence, larger rural population by region. Higher quality village and bush fields and lower quality village fields receive applications of animal manure collected from livestock paddocks or grazing of Fulani herds on village fields. Their area should expand with greater integration of crop-livestock systems. These applications of manure are already contained in the respective land endowments, b_{ℓ}^{t}. The additional benefits of manure from draft animals are incorporated through the coefficient, $mnr_{\ell}MNR$. Manure is treated as an input which expands the area of higher quality land.[12/] Since rates of manure application on compound land (cpd) are highest of any soil type, and those on lower quality (lq) fields the lowest, then $mnr_{\ell}^{cpd} < mnr_{\ell}^{hq} < mnr_{\ell}^{lq}$. The additional manure is allocated endogenously to expand those soil types where economic returns are highest.

12/ An alternative formulation would be to treat manure as a variable input like fertilizer which increases fertility of a given soil type. This method is more tedious in terms of additional activities which must be included to capture manure-crop production functions and interactions with other inputs.

Bush Land Fallow and Crop Rotations

The traditional means for maintaining overall fertility of outlying bush soils is through shifting cultivation.[13/] In this system, land is cultivated until it is exhausted. Then, it is abandoned and replaced by new fields cleared from the bush. The abandoned fields are reclaimed by the bush and restored in fertility over time. The newly opened fields, which are productive for several years following, decline in fertility with continued cultivation. At any point in time, there exists some continuum of higher to lower quality bush land whose overall level of productivity is defined by the length of land fallow and labor costs of land clearing.[14/] After fallow is broken, soils are commonly planted in sorghum for several years because of its superior yield response. As fertility declines with land use, sorghum is followed by groundnuts, cotton or millet. Hence, shifting cultivation affects both productivity and cropping patterns.

For modelling purposes, the above continuum is split into two discrete levels of soil fertility:

Land Fallow

$$(16) \quad \sum_{j=1}^{2} FPRD(X_j^m) - \sum_{j=3}^{p} (t_{\ell j}^m X_j^m + t_{\ell j}^d X_j^d + t_{\ell j}^o X_j^o) - \sum_{j=1}^{pp} t_{\ell j}^f X_j^f = 0$$

13/ This contrasts with the practices of manuring and crop rotations which are commonly employed to preserve fertility on fields nearest to the village.

14/ Conceivably, if land were abundant and labor costs for land clearing were zero, new land would be cleared and cultivated each year rather than farming cleared land over a period of time.

where:

($j = 2$ implies there is choice of 2 crop enterprises which may be grown on land just taken out of fallow; $j = 3,\ldots,p$ denotes possible crop enterprises which may be grown on bush soils after several years (length is determined by FPRD); and $j=1,\ldots,pp$ denotes activities for modern technologies on bush land)

FPRD = the ratio of lower to higher quality bush land resulting from land fallow for manual activities, X_j^m; 0 for animal traction activities, X_j^d and X_j^o.[15/]

Equation (16) is nearly equivalent to equation (14) for bush land, with the exception that now bush land is broken down into higher and lower quality soils. FPRD is the ratio of bush land having been cultivated from the third year onward to the area of relatively fertile soils, cultivated two years or less after breaking fallow. If FPRD = 2, then the area of land taken out of fallow is planted in sorghum or groundnuts ($j=1,2$) for two years followed by four years of other crops ($j=3,\ldots,p$ manual tillage activities or $j=1,\ldots,pp$ modern activities). Then land returns to fallow. To maintain a constant area of bush land, one-sixth of area must be retired to fallow each year, replaced by an equivalent area taken out of fallow. If FPRD=10, then two years of sorghum or groundnuts on relatively rich soils

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15/ By assumption, land following fallow can be cultivated only manually due to stumps in the field which impede animal traction. Only after several years of cultivation can animal traction be used.

soils is followed by 20 years of cropping before land is returned to fallow. Hence, as length of land fallow is reduced, represented by an increase in FPRD, the proportion of lower to higher quality soils increases and weighted average yields decline.[16/] This describes the situation on the Central Plateau where higher population densities are reducing the incidence of shifting cultivation. The effects, at least theoretically, are declining yields and decreasing significance of sorghum in the crop mix.[17/]

Animal Traction

There are three potential benefits to animal traction commonly cited in the literature (Sargent, et al., 1981). First, there are labor saving effects which reduce human labor requirements per hectare. Time worked by humans accompanying (performing complementary hand tillage cultivation) and driving the animal traction teams plus caring for animals are contained in A_{ij}^{md} for donkey and A_{ij}^{mo} for oxen. If animal traction decreases human labor requirements per unit of land, then

$$A_{ij}^{mo} \leq A_{ij}^{md} \leq A_{ij}^{m} \quad (\text{for } i=1,\ldots,10;\ j=1,\ldots,p)$$

16/ Base yields are assumed to be those obtained on continuously cultivated bush soils. In reality, yields would not fall so low under shifting cultivation before land is retired.

17/ Lack of good time series information on yields combined with falling rainfall over the past decade complicate efforts to empirically test this relationship. To the author's knowledge, this has never empirically been shown.

The amount of human labor time spent working with animal mechanization, A_{ij}^{md} and A_{ij}^{mo} on activities X_j^d and X_j^o, are less than human labor time spent working manually, A_{ij}^m on technology X_j^m. Oxen traction is assumed to have superior technical efficiency, though as will be shown in Chapter V, there is little empirical evidence to support this. When human labor requirements are reduced at peak periods of labor demand, area expansion occurs assuming there are no constraints on the area of bush land and no reductions in labor supply.

The second potential benefit is land intensification represented by higher yields, Y_{ij}^d and Y_{ij}^o, for donkey and oxen mechanization, respectively. Animal mechanization can potentially increase yields through deeper pre-plant plowing and incorporation of crop residues, more timely operations and supply of manure. Large yield increases have been achieved on the experiment station, but rarely have been sustained in practice.[18/] Still, moderate yield increases may theoretically be expected. In general,

$$Y_{ij}^o \geq Y_{ij}^d \geq Y_{ij}^m$$

18/ See Sargent, et al. (1981) for a review of 125 animal traction projects in francophone West Africa. They contrast labor saving and yield augmenting results achieved on the experiment station with poor rates of performance experienced in practice. Factors such as inadequate or inappropriate supply of equipment, lack of support services, poor training and management skills or constraints on use of equipment for plowing or weeding, typically diminish returns to the technology.

where yields under animal mechanization are assumed superior to manual cultivation, with productivity of oxen higher than donkey technology.

Third, the draft animals produce manure. Supply is determined by the identity,

(17) $MNR^{d}DK + MNR^{o}OX - MNR \leq 0$ Manure Supply from AT

where:

MNR^{d} = salvageable manure produced by a donkey,

MNR^{o} = salvageable manure produced by a team of oxen.

Equation (17) implies that total additional manure supply is derived from manure produced and recovered from traction animals. The benefits of manure come from equation (15) where greater production is obtained from expansion of higher quality land.

The demand for donkey and oxen traction services is represented by equation (18) and (19), respectively.

Demand for AT Services

(18) $$\sum_{j=1}^{p} A_{ij}^{d} X_{j}^{d} + \sum_{j=1}^{pp} A_{ij}^{df} X_{j}^{f} - DHR * DK \leq 0$$

(19) $$\sum_{j=1}^{p} A_{ij}^{o} X_{j}^{o} + \sum_{j=1}^{pp} A_{ij}^{of} X_{j}^{f} - OHR * OX \leq 0$$

where i = 1, ..., 10 labor periods

and

A^{d}_{ij} = number of hours required of the donkey team in the ith period to cultivate one hectare of the jth crop;

A^{o}_{ij} = number of hours required of the oxen team in the ith period to cultivate one hectare of the jth crop;

A^{df}_{ij} = number of hours required of the donkey team in the ith period to cultivate one hectare of the jth fertilized crop with donkey traction, zero otherwise;

A^{of}_{ij} = number of hours required of the oxen team in the ith period to cultivate one hectare of the jth fertilized crop with oxen traction, zero otherwise;

DHR_i = number of hours a donkey team, DK, can be worked in period 'i';

OHR_i = number of hours an oxen team, OX, can be worked in period 'i'.

The sum of time worked by donkey traction teams on strictly mechanized technologies, $A^{d}_{ij}X^{d}_{j}$, j=1,...p, plus time spent on mechanized cum fertilizer technologies, $A^{df}_{ij}X^{f}_{j}$, j=1,...,pp, represents the total derived demand for donkey traction services. Similarly, the sum of time worked by oxen teams on oxen mechanized technologies, $A^{o}_{ij}X^{o}_{j}$, j=1,...,p, and modern technologies $A^{of}_{ij}X^{f}_{j}$, j=1,...,pp, represents the derived demand for oxen services.

By assumption, donkey and oxen traction teams are fully and uniformly equipped. (For analyses comparing the performance of fully equipped versus partially equipped animal traction teams, see Jaeger, 1984 and Whitney, 1981). In practice, poor and highly variable rates

of performance are often observed due to poor equipment supply or use of inappropriate equipment for field cultivation. This could be handled by including additional activities for type of mechanization ("plowing only," "weeding only," "complete technical package") and constraints on resources and service flows for each. This was the approach Jaeger (1984) followed in his farm level analysis of animal traction performance. However, model size would have to be greatly enlarged to accommodate the higher levels of disaggregation.

From equations (18) and (19), the total derived demand for animal traction services are represented by the terms $DHR_i * DK$ and $OHR_i * OX$. The supply of traction teams by region is represented by equations:

(20) $DK \leq b^d$ <u>Supply of AT Teams</u>

(20') $OX \leq b^o$

where, b^d and b^o represent the fixed supply of "active" animal traction units, respectively, by region.

As with human labor above, both work intensity of animals in period 'i', DHR_i and OHR_i, and resource levels of animal mechanized teams, b^d and b^o, respectively, are assumed fixed. Work intensity is defined as the number of hours which "active" teams can work per period less time lost due to temporary illness, weakness, etc. The endowment of "active" mechanized teams is defined as the number of trained animal

traction units in the region less some percentage which are unemployed.

The dual prices, λ^d and λ^o, associated with right-hand-side endowments in equations (20) and (20'), reflect the marginal value of an additional donkey and oxen team to agricultural output in the region. Their values are determined by technical performance parameters assumed in the model and output and input prices (P_k, P_k^*, ψ^d, and ψ^o). Government policies which influence these parameters alter returns to the technology. In turn, shadow prices on inputs provide economic information to guide investment decisions.

Modern Chemical Technologies

Modern inputs such as fertilizer, pesticides, and Urea are not widely used in Burkina Faso. The inputs which are used tend to be consumed in cotton growing areas where input distribution systems are better developed. Several potential problems must be dealt with in incorporating chemical technologies in the modelling framework. The first involves what technologies to include in the model given the potentially large variety of agricultural chemicals, which may exist. The second involves the appropriate level of disaggregation of chemical technologies in view of the limited use of modern inputs in agriculture. Efforts which attempt to incorporate complete substitution among technologies for chemical inputs (across crops, land types and tillage practices), can greatly expand model size with little additional gain due to low current levels of input use. However, failure to include a "complete" technology mix can distort the crop

production response to changes in fertilizer policy, especially at high levels of modern input use in agriculture.

The first problem is of minor significance because of the limited array of agricultural chemicals which are distributed in the country. Over 85 percent of manufactured fertilizers by weight is a general purpose mixed cotton fertilizer, 14-25-14 (Appendix 1, Table A1.17). This is the principal fertilizer used on farms for cotton and cereal crop production (distributed through SOFITEX and the ORDs).[19/] Natural rock phosphates, which are mined locally are generally considered to be only marginally effective due to its limited solulability. The more common agricultural insecticides are Nuvacron, Endrine and Thioral for plant protection and seed treatment of cotton and cereals and Actellic and Gammagraine for post harvest grain protection.

With regard to the second problem, a subset of technologies need to be chosen which incorporate the more important substitution effects for chemical inputs. For this analysis, emphasis is placed on the derived demand for fertilizer because of its importance and the debate over appropriate levels of fertilizer price subsidies. Yield response to variable levels of fertilizer use are represented through production functions for principal sole crops and crop mixtures. The production functions, by assumption, exhibit diminishing returns to incremental levels of fertilizer use. Hence, they permit price

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19/ Minor quantities of Urea and groundnut fertilizer (super phosphates) are imported by the DSA. The sugar planation at Banfora, AVV and several vegetable growing cooperatives import small quantities of Urea, ammonium sulfate, ammonium phosphate, and potassium sulfate.

responsiveness in output and input levels based on marginal returns.

The derived demand for chemical technologies in the model are represented by the identities:

(21) $\sum_{j=1}^{pp} d_j^f X_j^f - FERT \leq 0$ <u>Demand for Fertilizer</u>

(22) $\sum_{j=1}^{pp} d_j^u X_j^f - UREA \leq 0$ <u>Demand for Urea</u>

(23) $\sum_{j=1}^{pp} d_j^p X_j^f - PEST \leq 0$ <u>Demand for Pesticide</u>

where:

d^f = application rate of cotton fertilizer per hectare of crop enterprise X_j^f, requiring fertilizer, zero otherwise;

d^u = application rate of Urea per hectare of crop enterprise X_j^f, requiring Urea, zero otherwise; and

d^p = application rate of Nuvacron per hectare of crop enterprise X_j^f, requiring pesticide, zero otherwise.

The total demand for modern chemical inputs is represented by the term FERT, for cotton complex fertilizer, UREA for Urea and PEST for Nuvacron pesticide. Demand for fertilizer is derived from fertilizer rate d_j^f on crop enterprise X_j^f, summed over pp possible modern chemical technologies. Demand for Urea and pesticides are derived in similar manner from the terms, $d_j^u X_j^f$ and $d_j^p X_j^f$, summed over j=1,...,pp activities. Costs of modern inputs are incorporated through the terms

ψ^f for fertilizer, ψ^u for Urea and ψ^p for pesticides in the objective function in equation (10).

Urea is assumed to be applied only on maize and scheme irrigated rice, while Nuvacron is applied strictly to cotton. Conceivably, the variety of manufactured fertilizers will increase over time with continued agronomic research. In this event, the current formulation (equations 21 to 22) will prove restrictive and the transition to working directly with nutrient levels will be necessary.

The supply of cotton complex fertilizer is represented by the equation:

(24) $FERT \leq b^f$ <u>Supply of Fertilizer</u>

where, b^f is the quantity distributed by parastatal organizations in each region. Quantities of Urea and Nuvacron are assumed to have unlimited supply because Urea is applied in fixed proportion with fertilizer while use of pesticides is limited by size of cotton area.

Solution of the model will give a dual price, λ^f, for the endowment of fertilizer (b^f) allocated to each region. This price reflects the marginal value product of an additional unit of fertilizer which will vary regionally with output prices P_k and P_k^*, fertilizer price ψ^f and the technical production function represented by input levels d_j^f and yields Y_j^f for activity X_j^f.

Fixing endowments of fertilizer in equation (24) has strong implications for policy analysis. If fertilizer use, FERT, is constrained by endowment, b^f, implying marginal returns exceed marginal

costs, then raising the price of fertilizer, ψ^f, may have no impact on fertlizer utilization. Yet, relaxing the fertilizer constraint would ignore factors--budget constraints, scarce foreign exchange, and capacity and institutional restrictions--which limit official market input distribution. A significantly greater supply of inputs by the private market is unlikely, given the weak participation of traders in modern input distribution at present and scarcity of foreign exchange to purchase fertilizer on international markets. Thus, the opportunity cost of holding fertilizer endowments at level b^f, in the official market, is explicit in the shadow price, λ^f. The potential demand for fertilizer and responsiveness of supply to changes in the fertilizer price may be examined by relaxing b^f.

Land in Cotton Zones

Producers in cotton zones of the west and southwest regions have better access to fertilizer due to the services of SOFITEX, the cotton marketing agency. Consequently, rates of fertilizer applied in practice are higher--100 to 150 kg./ha. of engrais coton to cotton (ORD des Hauts Bassins, 1980/81, p. 37)--than elsewhere in the region or country. If this phenomenon were unaccounted for in the modelling framework, fertilizer would be allocated over more area at lower rates of application, causing overestimation of crop production at a regional level. This stems from the assumption of free mobility of resources within the region, diminishing returns to the fertilizer production function, and limited fertilizer endowment relative to

potential fertilizer area. The area of fertilized land in cotton schemes is accounted for by the constraint:

$$(25) \quad \sum_{j=1}^{pp} X_j^f \leq \text{TOTAREA} * \text{LCTSCHM} * \text{LHQ} \qquad \underline{\text{Land in Cotton Schemes}}$$

That is, total area fertilized $\sum_{j=1}^{pp} X_j^f$ is constrained to be less than total area cultivated TOTAREA, (a proxy for $\sum_{\ell=1}^{L} T_\ell$), times the estimated percentage of total land in cotton schemes, LCTSCHM, times the percentage of higher quality land types LHQ, where fertilizers are normally applied. As the area in cotton zones LCTSCHM increases, rates of application fall due to diminishing returns to the production function. Conversely, as LCTSCHM falls, the area under fertilizer decreases (moving outward on the production function) and fertilizer per hectare increases.

Credit

The market for agricultural credit is influenced heavily by institutional forces linked with distribution of modern inputs. Outside cotton growing areas, short term credit for purchase of inputs is essentially unavailable.[20/] In cotton zones, credit from the ORDs

20/ Up to 1980, most agricultural credit for input purchases was provided through the ORDs or the Rural Development Fund with financing by the BND (Banque National de Developpement) and external donors. Throughout the late seventies, repayment by the ORDs was poor due to problems with financial management and failure to enforce eligibility standards. This lead to a reduction in credit for short term input purchases. By 1979/80, short-term credit was essentially unavailable outside cotton growing areas (The World Bank, 1980, p. 170.

is linked with distribution of inputs by SOFITEX with reimbursements made at the time of cotton collection. In this case, credit represents an additional cost to the purchase of inputs, rather than a constraint which limits their purchase.

The demand for credit is defined by the identity:

$$(26) \quad CDTMI\ (\psi^{u}UREA + \psi^{p}PEST + \psi^{f}FERT) - CDT \leq 0 \qquad \underline{\text{Demand for Credit}}$$

where:

CDTMI = the proportion of modern inputs which are purchased on credit.

If all modern inputs were purchased on credit, CDTMI would equal 1 and total demand for credit, CDT, would equal total cost of inputs. In this case, increasing the cost of credit (r) in the objective function in equation (10) would lead to higher credit payments for the purchase of modern chemical inputs through the term rCDT. If no modern chemical inputs are purchased with commercial credit (CDTMI = 0), demand for CDT would equal zero and an increase in 'r' would have no effect. For any level of CDTMI in between, increasing 'r' would increase the cost of modern inputs in aggregate by (1/CDTMI)(CDT)(r).

In theory, the proportion of inputs purchased with credit, CDTMI, is inversely related to 'r' (as 'r' increases, CDTMI falls). However, it is assumed to remain constant in this analysis to maintain computational ease. The purpose of equation (26) then is to estimate the budget share of credit (for chemical inputs) out of aggregate income of the crop sector. It also permits responsiveness in supply to

changes in the cost of borrowing (r) from the government. Costs of medium term credit for animal traction are accommodated for in the annualized costs, ψ^d and ψ^o, in equation (10).

Constraints on Official Sales

One area that remains unclear, due to lack of information, is what flexibility farmers have to allocate modern inputs among alternative crops. More specifically, can producers purchase inputs from SOFITEX and allocate them entirely to cereals if returns there are highest? Can producers, borrowing capital to purchase inputs, repay their loans with cereals sold at private market prices (the only relevant price for cotton is the official price); or, must output or some fraction of output be sold back to para-statal institutions (i.e., cereals to OFNACER or cotton to SOFITEX) at controlled prices? If either of these structural relationships are true and private market prices exceed official market prices, then an additional implicit cost is imposed on the purchase of inputs.[21/]

To make explicit this possibility,

21/ No evidence could be located by the author which either supports or refutes these contentions. In a two market economy, where fertilizer is subsidized by the government in one market (and cotton exports provide revenues to support government operating expenses), but commodity prices are higher in the private market, restrictions on input distribution would be expected.

Restrictions on Input Purchases

$$(27) \quad \sum_{i=1}^{s} P_k^* Q_k^* + \text{OFFAT}\ (\psi^{d*}\ \text{DK} + \psi^{o*}\text{OX}) + \text{OFFMI}\ (\psi^{u}\text{UREA} + \psi^{f}\text{FERT} + \psi^{p}\text{PEST}\ ) \leq 0$$

where:

ψ^{d*}DK = annual debt payments for donkey traction teams, DK, equivalent to annualized costs of animals, equipment plus interest payments;

ψ^{o*}OX = annual debt payments for oxen traction teams, OX, equivalent to annualized costs of animals, equipment plus interest payments;

OFFAT = proportion of annual debt payments for animal traction teams requiring repayment with sales on the official market;

OFFMI = proportion of modern input purchase requiring repayment with sales on the official market.

This relationship says that debt repayment of some proportion OFFAT, of animal traction units plus some proportion OFFMI of modern input purchases must be paid for by commodities marketed through official government channels. If OFFAT and OFFMI equals zero, then producers have complete flexibility to sell where market prices are highest. If OFFAT and OFFMI equals 1 then producers must sell to the government at official prices an amount equivalent to total debt payments for animal traction and modern inputs.

Output Constraints

Restrictions on the minimum or maximum level of production of commodity 'k' are often used in LP to adjust for incorrect specification of producers' utility, the production possibilities set or some factor which is scarce to the production process. These bounds on production are written as:

(28) $Q_k + Q_k^* \geq G_k$ for minimum constraints

and

(28') $Q_k + Q_k^* \leq G_k$ for maximum constraints

$(k = 1, \ldots, s)$

where

G_k = minimum or maximum levels of the kth commodity, zero otherwise.

In this analysis, a minimum constraint is placed on maize production to ensure the family has sufficient food for the "hungry" season. Similarly, total cereals production is constrained to meet annual caloric needs of rural producers. Bounds are also placed on production of minor crops (fonio, bambara nuts and starchy tubers), to maintain their balance in total crop mix, and on red sorghum, to reflect its derived demand from beer consumption and livestock feeding.

Placing bounds on production activities allows emphasis to be directed to the most important crops while minimizing the extent of crop substitution in the model. Bounds, however, have important

implications. In the case of maize, the possibility of using higher marketed surplus as a strategy to buy food during the "soudure", reducing the need for maize cultivation, is precluded. In the case of red sorghum, upper bounds prohibit greater production for sale, if higher demand were generated. These phenomena lay outside the range of efficient possibilities at present. However, they may become profitable strategies with changing price relatives and structure of agriculture. Thus, one should bear quantity restrictions in mind when interpreting the cross-commodity supply response in model simulations.

Finally, there are the usual non-negativity conditions, Q_k, $X_j \geq 0$ for all 'k' and 'j'.

Conclusions

This chapter presented the formulation of a theoretical model of aggregate supply response. First, there was an overview of farming systems in Burkina Faso describing the structure of traditional agriculture. This description led to a discussion of structural requirements of the model plus two special problems--lack of explicit prices for land and labor--which require special attention in the analysis. The formal model was then specified. It outlined the specification of producers' objective function, the derived demand and supply of inputs and technical requirements of the production possibility set. The estimation procedures used to empirically implement the model for each of five producing regions are covered in the next chapter.

CHAPTER V

EMPIRICAL APPLICATION OF THE THEORETICAL SUPPLY MODEL

This chapter describes the application of the theoretical supply model, developed in Chapter IV, to estimation of empirical models of supply in each of the five producing regions. Specifically, it describes production activities defining manual, animal mechanization and modern agricultural technologies, and data and assumptions concerning input demands, yields, resource endowments and input costs. Data underlying the specification of regional demand, trade, output prices, and retail margins are covered in Chapter VI.

The quantity of data contained in the five regional supply models is large. To reduce confusion over the amount of information presented, only data for one model (e.g., central region) are included in this chapter. Data and empirical assumptions for the remaining supply models are in noted appendices. Since all models have the same underlying theoretical structure, the description of data and the process of empirical model development for the central region are equally relevant for other regions as well.

Production Activities

The complete set of production activities representing alternative tillage technologies in the central region supply model are outlined in Table 5.1. Production activities for remaining supply regions are in Appendix 2, Table A2.1. The set of manual technologies, X_j^m, contains a maximum of 30 crop activities spread among 5 land types. These activities include sole crops and crop mixtures (intercrops), which define cultural practices of 12 principal crops: white and red sorghum, millet, maize, paddy, fonio, groundnuts, bambara nuts, soybeans, cowpeas, cotton and starchy tubers (not all crops are grown in all regions). The same set of crop enterprises are contained in X_j^d and X_j^o, permitting choice of cultivation with animal traction. In total, there are around 90 crop activities which define manual, donkey and oxen technologies in each of the regional models.

Crop mixtures are incorporated in the modelling framework to accommodate the pervasive influence of intercropping in the farming system. Data on prevalent crop mixtures have been reported in Kabore, et al. (1983, pp. 30-32), Singh, et al. (1983, p. 21), Ford (1982), Lassiter (1981 and 1982) and McIntire (1982, pp. 40-41). The findings of Kabore, et al. and Singh, et al., are summarized in Table 5.2. One set of estimates calculates the percentage of mixtures based on number of fields, the other by area planted. Thus, results are not directly comparable across studies. Nevertheless, data in the table uniformly show a high occurrence of intercropping of cereals. For millets and sorghum, 39 to 83 percent of fields and 44 to 95 percent of area

Table 5.1. Crop Activities and Yield Levels Associated with Manual Traction Technologies, Central Region Supply Model.[1/]

Type of Land T_ℓ	No.	Crop Mixture X_j^m, X_j^d, X_j^o	Yield-Manual Technologies (kg./ha.) Y_j^m
Swampy lowlands	1	Paddy	975
Compound land; Other highly manured soils	2	Maize	925
	3	Red Sorghum	830
	4	White Sorghum	770
	5	R.Sorg.(.75)/W.Sorg.(.25)	641-198
High quality village and bush fields	6	Maize	550
	7	Red Sorghum	640
	8	R.Sorg./Cowpeas	640-65
	9	White Sorghum	600
	10	W.Sorg./Cowpeas	600-65
	11	R.Sorg.(.80)/Maize (.20)	527-113
Lower quality village fields	12	Red Sorghum	430
	13	R.Sorg./Cowpeas	430-50
	14	White Sorghum	450
	15	W.Sorg./Cowpeas	450-50
	16	Millet/Cowpeas	420-50
	17	W.Sorg.(.75)/R.Sorg.(.25)/Cowpeas	348-111-50
	18	W.Sorg.(.75)/Millet(.25)/Cowpeas	348-108-50
	19	Cotton	480
	20	Bambara Nuts	360
	21	Groundnuts	520
Bush fields	22	Cult.Fallow-Sorg./Cowpeas	475-55
	23	Cult.Fallow-Millet/Cowpeas	450-55
	24	W.Sorg./Cowpeas	310-35
	25	Millet	340
	26	Early Millet/Cowpeas	340-35
	27	Late Millet/Cowpeas	310-25
	28	Millet(.75)/W.Sorg.(.25)/Cowpeas	263-80-35
	29	Cotton	310
	30	Groundnuts	480

Table 5.1. (continued)

Source: Information on crop mixtures were adapted from R. Ford, "Subsistence Farming Systems in Semi-Arid Northern Yatenga," 1982, (North); P. D. Kabore, Y. Lebene, and P. J. Matlon, "Modeles de Culture dans Trois Zones Agro-Climatiques de Haute Volta," Mars 1983, pp. 30-32 (North, Central, West); R. Singh, E. Kehrberg, and W. H. M. Morris, Small Farm Production Systems in Upper Volta: Descriptive and Production Function Analysis, 1983, p. 21 (North, Central); G. Lassiter, "Cropping Enterprises in Eastern Upper Volta," 1981, pp. 27-40 (East); G. Lassiter, "A Polyperiod Linear Programming Analysis of Draft Animal Adoption in Eastern Upper Volta," 1982, p. 1 (East); and J. McIntire, "Sondages de Reconnaissance au Nord et a L'Ouest de la Haute Volta," 1982, p. 17 (West and Southwest).

Table 5.2. Incidence of Intercropping and Common Crop Mixtures Reported in Selected Farm Management Studies, Burkina Faso.

Principle Crop	Mono-culture	Cereals Associations	Cowpeas	Other
	----Percent of Fields Planted in Mixtures----			
Millet	27(2)	4(44)	62(51)	7(3)
Red Sorghum	39(9)	-	39(83)	22(8)
White Sorghum	35(100)	18(-)	47(-)	-
Maize	20(15)	12(-)	-	68(85)
Groundnuts	98(76)	-	-	2(24)

Source: Data are from Singh, et al. (1983, p. 21) for the village of Nedogo and Digre (figures for Digre are in parentheses).

	-----Percent of Area Planted in Mixtures------			
Millet	53(19)	-	44(81)	3(0)
Red Sorghum	80(100)	2(-)	-	18(-)
White Sorghum	25(3)	3(-)	70(95)	2(2)
Maize	68(7)	20(41)	-	12(52)

Source: Data are from Kabore, et al. (1983, p. 31) for a sample of hand tillage farms in the villages of Kolbila and Ouonon (figures for Ouonon are in parentheses).

planted were intercropped with cowpeas. Some intercropping with other cereals also exists.[1/] For maize, which is normally planted in garden type plots surrounding the compound, intercropping with vegetables is more common. Groundnuts are normally grown in sole stands.

The number of different crop combinations which exist in the farming system is potentially large. Norman, et al. (1979, p. 57) identified 230 different crop mixtures in their village studies in northern Nigeria. However, 53 percent of total area was accounted for by six crop enterprises, implying many mixtures are of minor importance.

Incorporating minor crop mixtures into the analysis poses two problems. First, the literature on intercropping is scarce, especially for minor crop mixtures, making input-output relationships difficult to estimate. Second, minor crops can assume dominance in mathematical programming models (Balcet and Candler, 1981) due to measurement error in data, poorly constrained models or inappropriate specification of producer utility. For purposes of this study, only predominant crop enterprises were included in the analysis. These were sole crops, millet-cowpea and sorghum-cowpea intercrops, and predominant cereal "associations".

Several characteristics concerning the set of crop activities in Tables 5.1 and A2.1 are noteworthy. First, they reflect a priori assumptions which restrict crop enterprises to soil types where they

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1/ A frequently mentioned crop mixture is roselle cultivated as a border crop around cereal fields. These mixtures could equally be considered separate crops grown in close proximity.

have a comparative advantage. For example, rice and starchy tubers are restricted to lowland soils. Maize and sorghum technologies dominate high quality soils while millet, fonio and cash crops concentrate on lower quality soils. They also reflect geographic and climatic variations. As one moves from the Central Plateau to more fertile areas to the east or west, greater substitution possibilities are allowed among sorghum technologies. In the more arid north, millet technologies begin to dominate those of sorghums on some of the better soils. The inverse is true in the more humid southwest where maize and sorghums begin to substitute for millet on the worst soils.

Yields-Manual Technologies

Yields of manual tillage technologies, Y_j^m (Tables 5.1 and A2.1) are differentiated by soil type, crop, type of mixture and geographical location. Further variation is introduced through yields associated with animal traction technologies, Y_j^d and Y_j^o, and modern agricultural technologies, Y_j^f. This section discusses derivation of Y_j^m. The derivation of Y_j^d, Y_j^o and Y_j^f are explained later in respective technology sections.

The most difficult aspect of estimating yields is achieving high levels of disaggregation in the model from scarce and highly aggregated farm management data. A sample of yield data, representative of what are available in the farm management literature, is given in Table 5.3 and Appendix 1, Table A1.20. Several points are noteworthy. First, farm level data on maize, rice and red sorghum are relatively scarce compared to millet or white sorghum. Yield data for minor

Table 5.3. Yield Levels Observed with Mainly Traditional Technology, Selected Farm Studies, Burkina Faso. 1/

Region	Reference a/		Millet	White Sorg.	Red Sorg.	Maize	Rice	Peanuts	Cotton	Reference
			(kg./ha.)							
North	Kaya	Pure stands	323	296	417	463				McMillan, 1983
	1979/(23)	Two crops	384	377	317	124				
North	Kaya, 1982, (63*-65*)		380	509 c/						SAFGRAD-FSU, 1983 b/
North	Kaya, 1983, (25)		218	406		268				SAFGRAD-FSU, 1984 d/
Central	Ouagadougou, 1981, (10)		494	194		598		223		Swanson, 1981 b/
Central	Ouagadougou, 1982 (64*-257*)		342	410 c/				461		SAFGRAD-FSU, 1983 b/
Central	Ouagadougou, 1980, (44)		250	402	684	676		273		ICRISAT, 1980 b/
Central	Tenkodogo	Compound	584			650		346	400	Delgado, 1978b
	1978, (41)	Bush	273					820		
		Lowland					561			
East	Fada N'Gourma, 1982, (55*-197*)		346 e/	361				497		SAFGRAD-FSU, 1983 b/
East	12 Zones, 1978, (355)			421/116 g/		588	982	287	145	Lassiter, 1982
West	Solenzo, 1983, (30)		1692	1402		615				SAFGRAD-FSU, 1984 f/
Southwest	3 Villages, 1978, (9)		948	1510		1563		1605		Dumont, 1979
			840	613		1382	966	698		
			633	405		1143	1173	597	898	

1/ Figures are average yields per hectare of samples of mainly hand tillage households employing traditional management techniques.

a/ Cities are the major urban center nearest to site of data collection. Years denote the date in which the survey was conducted. The figures in parentheses represent number of households in the sample unless accompanied by an "*" which implies number of fields.

b/ Some households including animal traction teams are included in the sample.

c/ The figure is for red and white sorghum.

d/ These are farmer managed trials ranging from .04 to .12 hectares in size. The results correspond to the control treatment in these trials, 1 replication per farm, representing yields under traditional management practices.

e/ This is a sorghum/millet mixture comprised of around 75-90 percent millet with the rest sorghum.

f/ Yields were obtained from researcher managed trials on farmers' fields. Yields are those of local varieties grown under traditional management practices.

g/ Sorghum and millet are grown in association. The first figure is for sorghum, the second for millet.

crops such as bambara nuts, traditional cotton, sesame and fonio are virtually nonexistant. Next, data are generally sample averages aggregated across field types, crop mixtures and varying levels of traditional and modern input use. Consequently, yield estimates in farm management studies typically possess large variances. Overall, yield data are sketchy reflecting the lack of emphasis historically on farm level research. Yield data from experiment station research are relatively abundant, but not indicative of on-farm conditions.

An alternative source is area, production and yield data published in official government accounts. While these data serve useful benchmarks for setting yield levels in the model, they contain gross aggregation and measurement error.[2/] Moreover, they (Tables 2.3 and A1.5) appear to over-estimate yields reported by on-farm research (Table 5.3), particularly for millet, sorghum and groundnuts in the north, central and east regions. Reasons for this are unclear, but poor quality data, statistical bias of macro studies toward collecting yield data on more accessible, higher quality fields and specificity (unrepresentativeness) of farm level research are possible factors.

Crop yields in the model were estimated from the above data sources and subjective judgement. The procedure used is outlined below:

[2/] These data are perceived to be very unreliable by international donors and Burkina officials alike, based on observations made while working in the Ministry of Rural Development from May 1983 to January 1984.

1) Yield inferences were made from observations that crops tend to be land quality specific (SAFGRAD-FSU, 1982; ICRISAT, 1980). Millet yields reflect average productivity of lower quality soils, sorghums of higher quality soils and maize of compound soils. Hence, "base" yields of millet on bush land (340 kg./ha. in Table 5.1), white sorghum (450 kg./ha.) on lower quality village fields; red sorghum (640 kg./ha.) on higher quality village fields and maize (925 kg./ha.) on compound soils should closely correlate with yields observed in practice (as in Table 5.3).

2) The relationship between "base" yields across crops and soil types were inferred from comparative yield coefficients like those presented in Table 5.4. For the north and central regions where millet is the staple cereal, white sorghum yields are shown to be .92 to 1.86 times those of millet. Similarly, the relationship between millet and other crops are shown to be .98 to 2.74 for red sorghum, 1.01 to 3.26 for maize, 2.05 to 4.47 for paddy, 1.07 to 3.00 for groundnuts and 1.47 to 2.64 for cotton. "Base" yields in Table 5.1--white sorghum (1.32), red sorghum (1.88), maize (2.72), rice (2.86) and groundnuts (1.41)--were set to fall within these ranges to maintain consistent estimates of land productivity across soil types. For the east, west and southwest regions, yield relationships were estimated using sorghum as the norm.

Table 5.4. Synthesis of Comparative Yield Levels Among Crops, Selected Studies, Burkina Faso.

Region - Survey Area	Millet	White Sorghum	Red Sorghum	Maize	Paddy	Ground-nuts	Cotton	Source
	(Yields/ha.)	----------Ratio of Crop Yields to Millet----------						
North-Kaya	(260)	1.05	.98	1.75				McMillan (1983)
-Kaya	(323)	.92	1.29	1.43				McMillan (1983)
-Kaya	(380)	1.34				1.43		SAFGRAD-FSU (1982)
-Kaya	(218)	1.86		1.23				SAFGRAD-FSU (1983)
-Djibo		1.00		1.01	4.47	2.32	2.64	Jaeger (1984)
Central								
-Ouagadougou	(350)	1.47	1.20	3.26		1.43		Jaeger (1984)
-5 villages	(412)	1.29		3.21		1.07		Singh, et al. (1984)
-Ouagadougou	(250)	1.61	2.74	2.70		1.09		ICRISAT (1980)
-Tenkodogo	(273)[a/]			2.38	2.05	3.00[a/]	1.47	Delgado (1978)
East								
-Fada	(329)[b/]	.52		4.34		.78		Jaeger (1983, p. 14)
-12 regions	(537)			1.09	1.83	.53	0.27	Lassiter (1982,p.27)
West & Southwest								
-Solenzo	(1692)	.83		.36				SAFGRAD-FSU (1984)
-Banfora	(840)	.73		1.64	1.15	.83	1.42	Dumont (1979)
-Banfora	(633)	.64		1.81	1.85	.94		Dumont (1979)

a/ Yields of crops stated as being specifically grown on bush fields.

b/ Millet, sorghum association.

3) The level of "base" yields set in (2) above implies productivity per unit of land increases with higher quality soils.[3/] However, as shown in the next section, labor requirements increase as well. Thus, yield levels must also exhibit rising returns per unit of labor if estimated land prices (in the LP solution) are to rise with higher quality land resources.

4) The choice of crops on a given soil type depends on expected net returns and in turn on yields. For millet to dominate sorghum on lower quality soils implies net returns of millet are superior. Hence, for bush soils in Table 5.1, millet yields (340 kg./ha.) are assumed to be superior to that of sorghum (310 kg./ha.). Millet yields are not required to be superior to groundnuts, however, because the two crops possess different labor schedules and have different labor costs and returns.

The choice of crop yields based on expected returns is an important assumption. It assumes away other factors such as risk which may influence cropping patterns. Millet for example could possess lower yields but with less risk still be rationally chosen over sorghum given sufficiently high risk averse behavior of producers. Risk is not incorporated in the

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3/ In areas where bush fallow systems remain intact, the fertility of bush fields may exceed that of lower quality village fields. Thus, average returns to labor spent on field work may be superior. However, bush fields are further from the household requiring more time spent traveling to and fro. Hence, returns to labor overall are hypothesized to be less. The fact that village fields continue to be planted, even though fertility (through land fallow) of bush fields is higher, lends support to this argument.

analysis and lack of data preclude comparison of yields of millet and sorghum on similar soil types. Implicitly, the effect of other factors are accounted for by adjustments in expected yields.

5) Intercrops in the model are assumed to have higher crop yields than sole crops. In northern Nigeria, Norman, et al. (1979, pp. 62-63) found mixed cropping to increase returns by 35 percent over sole stands and provide better distribution of seasonal labor.[4/] However, data could not be located to document the magnitude of yield effects in Burkina agriculture. To avoid over-estimating returns, yields of cereals grown in association were increased 3 percent (over yields of crops grown individually). Cowpeas intercropped with cereals are assumed to have no effect on cereal yields because of the low planting densities culturally practiced. The low levels of cowpea yields are supported by Singh, et al. (1983), ICRISAT (1980), Swanson (1981) and Lassiter (1981).[5/]

Another product of cereals cultivation is straw. Straw is a scarce commodity valued as fodder and raw material for granary and

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4/ They found seasonal labor requirements to be 10 percent higher during the peak farming period, but the average value per hectare of crop mixtures was 35 percent higher than the value of sole crops. Average returns per labor from crop mixtures was 28 percent higher than sole stands.

5/ Singh, et al. (1983, p. 28, 34) report cowpea yields in association with sorghum and millet of 5 to 37 kg./ha., ICRISAT (1980, I10b), 9 to 14 kg./ha., Swanson (1981), 13 to 24 kg./ha. and Lassiter (1981, p. 27) 11 to 125 kg./ha.

building construction and artisan industry. Millet and sorghum straw are particularly useful for construction purposes. To capture this benefit from millet, sorghum and maize production, straw yields of 1.4 to 4.0 tons per hectare (Table 5.5), depending on soil type, technology and region, were incorporated in the analysis. Yields are estimated to increase with better quality soils, applications of fertilizer and regionally from north to central to east to west and southwest with better rainfall and soil fertility.

Labor Demand

This section deals with derivation of labor coefficients, A^m_{ij}, for demand of human labor on crop technologies, X^m_j. Following sections describe how these labor coefficients are altered with adoption of labor saving technologies, X^d_j and X^o_j, and land saving technologies, X^f_j. These labor effects are incorporated in A^d_{ij}, A^o_{ij} and A^f_{ij}, respectively.

To derive A^m_{ij}, $i = 1,\ldots,10$, information is required on total labor, $\sum_{i=1}^{10} A^m_{ij}$, of crop enterprise, X^m_j, and a labor schedule showing the proportion of total labor time worked in period 'i'. This procedure is used because it is most compatible with labor data reported in the literature. The derivation of total labor is discussed first followed by the schedule of labor activities.

Table 5.5. Quantity of Straw (Millet, Sorghum and Maize) Produced per Hectare Assumed in the Representative Farm Models.

	North	Central	East	West and Southwest
Traditional Management:				
Compound Soils	1400	1800	2200	2500
Village Soils	900	1300	1500	1800
Bush Soils	700	900	1000	1200
Modern Technologies:				
Compound Soils:				
50 kg./ha. Cotton Fert.	1700	2000	2600	3000
100 kg./ha. Cotton Fert.	2000	2600	3000	3500
150 kg./ha. Cotton Fert.	2300	3000	3400	4000
Village Soils				
50 kg./ha. Cotton Fert.	1200	1600	1800	2200
100 kg./ha. Cotton Fert.	1500	1900	2100	2600
150 kg./ha. Cotton Fert.	1800	2200	2400	3000

Source: The figures in this table are a synthesis of straw yields achieved on various on-farm trials by IRAT, "Rapport de Synthese, 1982," pp. 127, 136, 149, 156, and 179.

Total Seasonal Labor

Despite its importance, empirical estimates of labor in the literature are limited. The data contained in Table 5.6, showing total hours worked by crop by mainly hand tillage households, are representative of what are available. Studies reporting labor times by type of activity do exist (e.g., Singh, et al., 1984, p. 57; McIntire, 1981, pp. 9-14; and Lassiter, 1981, p. 23) but are less common than estimates of total hours worked. Several observations concerning the data in Table 5.6 merit attention. One, the data are sample averages aggregated across soil types, crop mixtures, technologies and households. With the exception of labor time comparisons between animal traction and non-animal traction households, little has been done to stratify labor flows by agronomic or socioeconomic factors. Moreover, the coverage of labor times across crops is incomplete and labor estimates vary widely among studies. Time worked on millet, for example, ranges from 274 to 586 total hours per hectare while for maize time varies from 383 to 1233 total hours.

There are several methodological differences which contribute to inter-study variability. Several studies (SAFGRAD-FSU, 1983; McMillan, 1983; and Lassiter, 1981) use productivity weights to convert labor times of men, women, and children into male adult equivalents. Labor studies also vary in degree of coverage. ICRISAT (1980), McMillan (1983) and Ford (1982), for example, include all activities of the agricultural season while others like SAFGRAD-FSU (1982) limit the scope to planting through weeding.

Table 5.6. Estimates of Total Labor on Mainly Hand Tillage Technologies, Selected Farm Studies, Burkina Faso. a/

Region	Details b/	Millet	White Sorghum	Red Sorghum	Maize	Rice	Groundnuts	Cotton	Reference
		----------Hours/Hectare/Season----------							
North	Kaya, 1979, (23) wh	467	594	711	437	396			McMillan, 1983,
		(444)	(566)	(786)	(433)	(447)			p. 398
North	Kaya, 1982 (63* to 65*) w	300	380				266		SAFGRAD-FSU, 1983,
		(339)	(429)				(295)		p. 27
Central	Ouagadougou, 1981 (10) h	553	525		1233				Swanson, 1982
		(395)	(463)		(1084)				
Central	Ouagadougou, 1982 (64* w	310	471				414		SAFGRAD-FSU, 1983,
	to 257* fields)	(406)	(636)				(546)		p.27
Central	Ouagadougou, 1980 (44) h	586	1065	951	695		1020		ICRISAT, 1980,
		(500)	(941)	(836)	(624)		(715)		pp. I10a, I10b
East	Fada N'Gourma, 1982, w	274	250				311		SAFGRAD-FSU, 1983,
	(55* to 197*)	(337)	(298)				(429)		p. 27
East	12 zones, 1978, wh		576 c/		960	1121	649	633	Lassiter, 1981,
	(355)		(616)		(1046)	(1199)	(707)	(677)	p. 23

a/ Figures without parentheses are average total hours worked. A "w" means labor times are man-equivalents. An "h" implies total hours include harvest labor. Figures in parentheses are estimates of actual hours worked from planting through completion of weeding. Two adjustments were made to original labor data to derive these estimates: (1) other activities--harvesting, manuring, land clearing--were deducted; and (2) man-equivalent hours were reconverted to estimates of actual hours worked. For a more complete review of labor studies performed in Burkina Faso and details on derivation of adjusted total labor coefficients, see M. Roth, "Working Data for Development of Farm Planning Models in Burkina Faso," (forthcoming).

b/ City is the urban center nearest to the survey site. Year denotes the date of the survey. Figures in parentheses are number of farms in the sample unless accompanied by an "*" which stands for fields.

c/ Comprises sorghum/millet and millet/sorghum mixtures.

The second set of labor estimates in Table 5.6 standardizes labor times to adjust for these differences (figures in parentheses are "adjusted total" hours). This is done by reconverting man-equivalent hours, where found, into actual hours worked and deducting labor on outside activities. This exercise was performed on all labor times used in the analysis to place labor estimates on common grounds for comparison.[6/]

Estimates of total labor, $\sum_{i=1}^{10} A^{m}_{ij\ell}$, for crop enterprise 'j' on land type 'ℓ' and hand technology 'm' for the central region supply model are shown in Table 5.7. Total labor estimates assumed for other regional models are in Appendix 2, Table A2.2. These data were inferred from the set of adjusted total labor coefficients in Table 5.6 and comparative labor coefficients defining relative time requirements among crops.

The latter were taken from Table 5.8 which compares estimates of "adjusted total" labor among crops and selected studies. Time worked on millet, which is more common on bush and lower quality village fields, is the lowest of any crop. It represents around .55 to .85 of total hours worked on sorghum and .35 to .70 of total hours worked on maize. "Total adjusted" hours worked on sorghum, which is generally planted on higher quality soils, are 1.15 to 1.8 times those of millet. For maize, which is typically planted on highly fertile soils

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6/ A synthesis of on-farm studies of labor allocation on Burkina farms along with procedures for deriving adjusted total labor coefficients are included in M. Roth, (1986, forthcoming).

Table 5.7. Labor Demands Per Hectare for Principal Crop Mixtures, Traditional Technologies, Central Region Supply Model.

No.	Crop Mixture	Bush Fields l=1	Lower Quality Village Fields l=2	Higher Qual. Village & Bush Fields l=3	Low Lying Areas & Compound Soils l=4,5
		(Total Hours/Hectare. $\sum_{i=1}^{10} A^{m}_{ij}$)[a]			
1	Paddy-Trad. Management				1200
2	Maize			675	750
3	Red Sorghum		467	551	685
4	R. Sorghum/Cowpeas		520	615	
5	R. Sorghum/W. Sorghum				685
6	White Sorghum		467	551	685
7	W. Sorghum/Cowpeas	445	520	615	
8	R. Sorghum/Maize			-	
9	W. Sorghum/R. Sorghum/Cowpeas		520		
10	W. Sorghum/Millet/Cowpeas		520		
11	Cult. Fallow-W. Sorghum	400			
12	Cult. Fallow-Millet	400			
13	Millet	392			
14	Early Planted Millet/Cowpeas	445	520		
15	Late Planted Millet/Cowpeas	420	500		
16	Millet/W. Sorghum/Cowpeas				
17	Cotton	500	550		
18	Peanuts	550	600		
19	Bambara Nuts		650		

a/ Total labor includes unweighted time worked by family members on land preparation through second weeding activities. It excludes time spent manuring and clearing of fields in the off-season and harvesting.

Source: This information was adapted from various agro-economic studies of labor flows on cropping operations in Burkina Faso. See Table 5.6 for elaboration.

Table 5.8. Synthesis of Comparative Labor Times Among Crops, Selected Studies, Burkina Faso.

Region - Survey site	Millet	White Sorg.	Red Sorg.	Maize	Paddy	Ground-nuts	Reference
	(Total Adjusted Hours/Ha.)	---Ratio of Adjusted Hours to Millet[a/]----					
North:							
- Damesma	(277)	1.61	1.36	3.40	9.57	1.26	McMillan, 1983, p. 397
- Ouahigouya	(506)	1.38					Ford, 1982
- Kaya	(339)	1.27				.87	SAFGRAD-FSU, 1983, p. 27
- Kaya	(473)	1.11		2.03	2.81	1.41	Unpublished data, SAFGRAD-FSU, 1982
Central:							
- Ouagadougou	(395)	1.17		2.74			Swanson, 1982
- Ouagadougou	(406)	1.57				1.34	SAFGRAD-FSU, 1983, p. 27
- 5 Villages	491	1.20		1.43		1.08	Singh, et al., 1984, p. 57
- Ouagadougou	(324)	1.81	1.54	2.08		2.31	Unpublished data, SAFGRAD-FSU, 1982
- Ouagadougou	500	1.88	1.67	1.25		1.43	ICRISAT, 1980, pp.I10a,I10b
East:							
- Fada N'Gourma	(337)	.88				1.27	SAFGRAD-FSU, 1983, p. 27
- Fada N'Gourma	(369)	1.49	1.09	1.95	4.02	1.98	Unpublished data, SAFGRAD-FSU, 1982
- 12 Zones		(61F)[b/]		1.70	1.95	1.15	Lassiter, 1981, pp. 27-40

a/ These figures are based on adjusted total labor coefficients computed from labor times reported in respective farm studies. Refer to Table 5.6 for elaboration.

b/ Includes sorghum/millet and millet/sorghum mixtures, of which the first crop in the mixture predominates.

surrounding the compound, "total adjusted" hours exceed those of millet by a factor of 1.4 to 2.75. Total labor coefficients were estimated based on these relative weights to maintain consistency in labor requirements among crops and soil types.

Two assumptions are implicit in the estimates of total hours worked. First, labor times increase with higher quality soils. This is attributed to more strenuous work to cultivate heavier soils, greater weed problems associated with higher soil fertility and higher marginal physical product of labor, ceteris paribus, with time worked on lower quality soils. Second, labor times increased in sequential order from north to central to east to west to southwest regions in accordance with climatic and geographical differences which affect precipitation and soil fertility (e.g., compare labor coefficients for the central region in Table 5.7 with those assumed for other regions in Appendix 2, Table A2.2).

The first assumption is supported by data in Table 5.8. The second assumption is based on theory and is not testable given the empirical evidence available. While labor times have been estimated for the north, central and east regions, high inter-study variation and extreme local specificity of estimates make cross-region comparisons difficult. The lack of labor budgets for the west and southwest regions preclude comparisons entirely. Based on subjective judgement and estimates of labor in the literature, total hours worked per hectare in the Central region is assumed to be roughly 15 percent higher than in the north. Total labor is around 30 percent higher in the east and west regions and 33 percent higher in the southwest.

These percentages represent approximate measures, since labor times across regions exhibit differences because of crop and soil type.

With regard to intercropping, crops cultivated in mixtures are assigned higher labor requirements than sole crops. For cereals intercropped with other cereals, labor times are increased 5 percent in all periods.[7/] Different assumptions were used for cereal-cowpea mixtures. Labor estimates in the literature already reflect higher labor requirements for cowpeas due to the pervasiveness of this mixture in cropping patterns. Hence, with data from ICRISAT (1983, p. G.45), labor times for sole cropped cereals were estimated by decreasing planting time of mixtures by 6 hours, and first and second weedings by 15 and 9 percent, respectively.[8/]

Seasonality of Labor

Labor calendars which break down total seasonal labor into weekly, fortnightly, or monthly labor flows are not abundant in the

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7/ This is less than the labor increase observed by Norman (footnote 4) but consistent with yield assumptions used for cereals mixtures in the model.

8/ The density of cowpeas in millet and sorghum mixtures is generally low, varying between 1000 to 5000 plants per hectare. An ICRISAT study (1983, p. G-45) found that decreasing the cowpea density from an average of 8000 to 3500 plants per hectare reduced labor requirements at planting (of cowpeas only) from around 22 to 14 hours and decreased weeding labor (of the cereal-cowpea mixture) by 39 percent at first weeding and 26 percent at second weeding. Model assumptions are based on 1750 plants per hectare cowpea density and linear extrapolations of labor reductions observed by ICRISAT.

literature. The most common labor calendars are line graphs which depict whether or not activities were performed in period 'i'. Examples can be found in Singh (1981, pp. 62-64) and Ford (1982, p. 506). These are of limited use for linear programming because they imply work is performed with equal intensity in all periods (in which an activity was performed). Others have partitioned labor by periods of the agricultural season. SAFGRAD-FSU (1982, p. 29) provides a weekly schedule; Delgado (1978, p. 19), a fortnightly schedule; and Lassiter (1981, p. 23), a monthly calendar of labor flows. These make explicit the seasonality of agriculture and labor tradeoffs at critical periods.

The labor calendar in Table 5.9, for the central region, shows the percent of total labor time worked (from planting through second weeding) by period of the agricultural season. Observations on the nature of labor activities are contained in Table 5.10. Labor calendars for the remaining regions are given in Appendix 2, Table A2.3. These schedules were derived from unpublished labor data collected by SAFGRAD-FSU in the north, central, and east regions of the country plus adaptations of labor calendars mentioned above. Activities such as land clearing and manuring are done prior to the onset of period 1 while harvesting and threshing commence after termination of period 10.

Period (1) is five weeks in duration to cover planting, starting with the first arrival of rains. Periods (8) to (10), covering three weeks apiece, are less critical periods of the agricultural season. Periods (2) through (7) are weekly in duration. A shorter interval

Table 5.9. Agricultural Labor Calendar of Field Crop Operations, Central Region Supply Model.

Constraint	Time Period	Red Sorghum a/	White Sorghum b/	Millet c/	Maize	Pea-nuts	Bambara nuts	Cotton	Traditional Rice
		(Percent of Total Seasonal Labor Per Hectare)							
1	May 3- June 6	20.0	18.4	18.4	-	6.6	-	-	10.2
2	June 7-13	9.2	3.4	3.8	-	7.1	-	-	16.9
3	June 14-20	7.1	10.3	5.5	17.0	8.7	16.6	-	17.4
4	June 21-27	8.8	6.7	5.7	32.7	11.7	37.1	5.6	8.2
5	June 28-July 4	4.3	11.5	8.3	8.2	23.5	9.6	5.6	6.4
6	July 5-11	3.5	1.1	12.0	6.4	-	2.0	8.2	5.4
7	July 12-18	3.4	0.8	11.4	1.4	2.0	2.6	8.2	10.1
8	July 19-Aug. 1	16.1	8.8	7.5	27.5	10.9	-	18.2	9.3
9	Aug. 2-22	18.6	30.9	17.5	5.1	25.9	13.7	30.6	17.7
10	Aug. 23-Sept. 12	9.0	8.1	10.1	1.7	3.6	18.4	23.6	4.4

a/ The calendar for red sorghum is used to schedule labor activities for all millet and sorghum mixtures on higher quality village and bush fields.

b/ The calendar for white sorghum is used for all millet and sorghum mixtures on lower quality village fields.

c/ The calendar for millet is used to schedule labor activities for all millet and sorghum mixtures on bush fields.

Source: The agricultural labor calendar for all crops except cotton was summarized from labor data collected by SAFGRAD-FSU for the village of Nedogo, near Ouagadougou, 1982. Data for cotton were taken from Delgado (1978b, p. 19). For further details concerning the implementation of the calendar in practice, refer to accompanying footnotes in Appendix 2, Table A2.3.

Table 5.10. Observations on the Scheduling of Labor Activities, Central Region Supply Model.

Constraint	Time Period	Observations
1	May 3-June 6	Planting of red sorghum, white sorghum and millet begin with the onset of rains, intensifying toward the period's end. Soil preparation and planting of rice and peanuts begin.
2	June 7-13	First weeding commences on red and white sorghum fields. Soil preparation and planting of rice and peanuts continue.
3	June 14-20	First weeding of millet begins while weeding of red and white sorghum continues. Land preparation and planting of peanuts and rice proceed while first weeding of early rice begins.
4	June 21-27	First weeding progresses on red sorghum, white sorghum, millet and rice fields. Later fields of peanuts are prepared and planted. Land preparation and planting of maize start.
5	June 28-July 4	Weeding of red and white sorghum and millet gain intensity. The last of the peanuts and maize are planted.
6	July 5-11	Work proceeds on first weeding of red sorghum, white sorghum, millet, and rice. First weeding of maize begins.
7	July 12-18	First weeding continues on red sorghum, white sorghum, millet, maize and rice fields.
8	July 19-August 1	Work continues on first weeding of later planted cereal fields. Second weeding starts on red and white sorghum and rice. Plots of peanuts and maize receive their first major weedings.
9	Aug. 2-22	First weeding of later planted cereals comes to an end. Second weeding commences on all major cereals fields. First weeding of peanut and maize plots continue.
10	Aug. 23-Sept. 12	The second and final weedings of all cereals are completed. The first weeding of maize and peanuts is finished.

Note: These observations correspond to the preceding labor calendar estimated by SAFGRAD-FSU for the village of Nedogo, 1982.

was used to capture the extreme peaks of seasonal labor flows and high shadow costs of labor associated with them. The period from late June (4) to mid July (7) is the most critical according to farmers (Appendix 3, Table A3.1). During this period, first weeding of millets and sorghums and planting of maize, groundnuts and bambara nuts are performed.

Labor coefficients for manual technologies in the model (e.g., A^m_{ij}, i=1,...,10; j=1,...,30) were derived by multiplying percentages in the agricultural calendar (Table 5.9) times total seasonal labor requirements (Table 5.7). Since both total labor and yields increase with higher quality soils, returns per unit of labor must also rise if land values are to increase with better quality land. Yields can rise relatively more than total labor yet net returns may fall due to high shadow costs of labor at critical periods. Only labor requirements for binding labor constraints in the model are relevant for calculating crop returns (since labor in non-constraining periods have shadow prices of zero). The estimation procedure for A^m_{ij}, then, enables a first approximation at seasonal labor requirements. In practice, some minor adjustments to A^m_{ij} may be necessary at critical periods to bring shadow prices of land resources into proper alignment (more will be said on this problem in Chapter VIII).

Animal Traction Technology

Animal mechanization of crop tillage offers three potential benefits. Potential is emphasized because performance in practice has typically fallen short of results obtained in experiment station

research in West Africa.[9/] First, mechanized tillage may reduce human labor requirements per task per unit of area, thereby reducing labor demands at peak periods. This determines the technology's labor saving effects which, ceteris paribus, with abundant land resources, enable land extensification. Next, use of animal traction to perform deep plowing or facilitate more timely operations, increases crop yields. Also, manure from draught animals when applied to the soil augments soil fertility. These latter two benefits increase productivity of existing land resources, constituting the technology's land intensifying effects.

The types of operation for which animal traction is used depends on the power source. Donkey mechanization is most suited to weeding and field cultivation. It is less suited for deep plowing because the animals lack sufficient strength for the task. Two soil preparation activities that are performed with donkey traction are line tracing and scarification (3-5 cm. deep). These operations loosen the surface crust and facilitate line planting and subsequent weeding with animal traction equipment. Oxen are stronger than donkeys and better suited for deep plowing. However, low availability of feedstuffs during the long dry season before plowing often weakens the animals, thus limiting their performance.

The operation of animal traction in practice also varies according to crop, cultural practice, geography, and equipment availability. In its village studies on the Central Plateau, ICRISAT (1980, p. 19)

9/ A comprehensive review of animal traction performance in 125 related projects in francophone West Africa is found in Sargent, et al., 1981.

observed farmers seldom plow prior to onset of rains because soils are too hard. After the rains when the soil is loosened, farmers prefer planting immediately rather than incurring planting delays.[10/] Hence, weeding activities are more frequently mechanized. Singh, et al., (1983, p. 33) report similar findings in the central region but found land preparation more likely to be mechanized in the north (Appendix 4, Table A4.1). In the east, pre-plant plowing is more predominant (Jaeger, 1983, p. 7; Barrett, et al., 1982, p. 47).[11/] This has been attributed not to the unavailability of plows and ridgers in the region, but to inadequate supply of weeding equipment (Barrett, et al., 1982, p. 46). For minor crops like maize, cotton, groundnuts, and bambara nuts, mechanized land preparation is more common. These crops are planted following completion of planting of major cereal fields when soils are looser and weed problems have emerged (land preparation seconds as a weeding activity).

Thus, generalizations on performance of animal traction in practice are difficult to make. On-farm studies have shown performance to vary with the learning curve governing managerial skills of

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10/ Farmers start planting immediately with onset of rains to take full advantage of seasonal rainfall. Fields can be planted for only 2 to 3 days after rains before surface crusting begins. Plowing of fields thus slows the rate of planting. This strategy suggests that losses of foregone production from late planting are greater than the higher potential yield response to plowing, ceteris paribus, with donkeys. Limited oxen traction in ICRISAT's village sample precludes comparisons with oxen traction.

11/ In their eastern region study, Barrett, et al. (1982, p. 50) report that 59 and 85 percent of area cultivated by donkey and oxen households, respectively, were plowed using animal traction. Only 14 and 10 percent percent of area cultivated, in the same sample, were weeded using donkey and oxen traction, respectively.

adopters (Jaeger, 1983, p. 23; Barrett, et al., 1982, p. 45), availability of appropriate equipment, health of animals, and technical support for acquisition, maintenance and operation of equipment (Barrett, et al., 1982). Constraints on any of the above reduce technical performance and economic returns. These factors must be taken into consideration when interpreting and comparing efficiency parameters in experiment station research and on-farm studies.

Human Labor Saving Effects

Labor bottlenecks at first weeding, followed by plowing, are the most critical labor constraints (Appendix 4, Table A4.2). Use of animal traction with appropriate equipment can reduce peak period labor demands by increasing productivity of human labor (decreasing time spent per unit of area). In on-station research trials by IRAT in Mali (in Sargent, et al., 1981, p. 25), use of fully equipped oxen teams on sorghum/millet and peanuts reduced human labor requirements by 50 to 68 percent at weeding and 17 to 24 percent at land preparation (Appendix 4, Table A4.3).

A synthesis of selected on-farm studies of labor utilization with donkey mechanization is given in Table 5.11. A similar synthesis for oxen mechanization was not possible due to lack of empirical research. Results of Table 5.11 show labor savings at weeding of 11 to 40 percent for millet and sorghum and 5 to 51 percent for maize and groundnuts. For land preparation activities, results on millet and sorghum are minor and mixed, while labor savings of 18 to 57 percent

Table 5.11. On-Farm Comparison of Labor Between Samples of Hand Tillage and Donkey Households, Selected Farm Management Studies, Burkina Faso.

Region/Details[b/]	Activity	Millet	White Sorghum	Red Sorghum	Maize	Peanuts	Reference
		----------Hours/Hectare (Percentage Labor Savings)[a/]----------					
Central, North, 5 Villages, 1980	Land prep.	24 (8)	27 (26)		218(-18)	136(-57)	Singh, et al., 1984, p. 57
	Planting	68(-26)	89 (-44)		88(11)	83 (6)	
	First weeding	237(-26)	285 (-30)		259(- 6)	307(- 5)	
	Second weeding	162(-40)	187 (-34)		140(67)	4	
	Total	491(-29)	583 (-31)		705 (7)	530(-17)	
Central, Ougadougou, 1980	Land prep.	22(-18)	6 (183)	21(319)	175	272(-42)	McIntire, 1981, pp. 9-14
	Planting	79	145	98	134	145	
	First weeding	298(-31)	558 (-31)	339(105)	201	353(-14)	
	Second weeding	167(-11)	313 (-35)	267 (78)	71	186(-51)	
	Third weeding				74		
	Harvest	86	125	115	71	309	
	Total (less harvest)	457(-19)	749 (-27)	1397 (93)	956(46)	700(-27)	
East, 12 zones, 1981[w]	Seeding		55 (-15)[c/]		139(-33)[c/]	62(20)[c/]	Lassiter, 1981, p. 23.
	Tillage		471 (-20)		763(-48)	549(-45)	
	Other		50		58	38	
	Harvest		155 (- 4)		187(-48)	428 (5)	
	Total (less harvest)		566 (-20)		960(-49)	649(-37)	

a/ A "w" implies labor estimates are man-equivalent hours. Figures in parentheses are the percentage decrease (a "+" implies an increase) in hours worked by donkey households compared with hand tillage households.

b/ City is the urban center nearest to the survey site. Year denotes the date of the survey.

c/ Lassiter emphasizes that "all zone" averages should not be used to compare "hoe" versus animal traction samples. This is because the "hoe" sample contains a broader regional coverage than does the animal traction sub-sample. Unfortunately, no data were located which compared labor times by activity for "hoe" versus animal traction sub-samples in common zones.

are reported for maize and groundruts. Labor savings overall are less than those obtained from experiment station research.

The demand for human labor associated with donkey and oxen activities are estimated by:

$$(5.1) \quad A_{ij}^{md} = (1+S_{ij}^{d})A_{ij}^{m}$$

$$(5.2) \quad A_{ij}^{mo} = (1+S_{ij}^{o})A_{ij}^{m}$$

where:

S_{ij}^{d} and S_{ij}^{o} = percentage reductions in human labor for period 'i' and activity 'j' from using donkey and oxen traction, respectively.

That is, human labor on donkey and oxen technologies, A_{ij}^{md} and A_{ij}^{mo}, are estimated from human labor requirements, A_{ij}^{m}, on manual tillage activities and labor savings, S_{ij}^{d} and S_{ij}^{o}, obtained with animal mechanization.

The coefficients in Tables 5.12 and 5.13 represent labor savings, S_{ij}^{d} and S_{ij}^{o}, incorporated in regional supply models. The results are conservative compared to experiment station research but are similar to performance observed in practice. Due to lack of information, labor savings from oxen traction, S_{ij}^{o}, are extrapolated from S_{ij}^{d} for donkey mechanization.

Several assumptions are implicit in the data. First, activities of land scarification for donkeys and plowing for oxen in period 1 are assumed to increase human labor, hence S_{ij}^{d} and S_{ij}^{o} are zero for nearly

Table 5.12. Labor Saving Effects Associated with Donkey Traction Technology, Regional Supply Models.

	Swampy Lowland		Compound Soils		Higher Quality Village & Bush		Lower Quality Village and Bush Fields					
Period	Rice	Starchy Tubers[d/]	Maize	Sorghums	Maize	Sorghums & Millets[b/]	Sorghums & Millets[b/]	Fonio[d/]	Cotton	Soy-beans[c/]	Ground-nuts	Bambara nuts
	(Percentage Reduction of Labor, S_{ij}^{d})[a/]											
1	-25	-	-	-	-	-	-	-	-	-	-	-
2	-25	-	-	-20	-	-29	-31	-	-	-	-	-
3	-25	-	-20	-20	-40	-29	-31	-	-	-	-	-48
4	-15	-	-20	-20	-40	-29	-31	-	-45	-	-45	-48
5	-15	-	-15	-15	-30	-29	-31	-	-45	-45	-45	-32
6	-15	-	-15	-15	-30	-24	-26	-	-30	-45	-30	-32
7	-	-	-10	-10	-20	-24	-26	-	-30	-30	-30	-11
8	-	-	-10	-10	-20	-19	-21	-	-25	-30	-10	-11
9	-	-	-10	-10	-20	-19	-21	-	-25	-25	-10	-11
10	-	-	-10	-10	-20	-19	-21	-	-25	-25	-10	-11

a/ These coefficients were used for the central region supply model. Coefficients for other regions are of the same magnitude but their scheduling may vary slightly due to different timing of crop operations.

b/ Millet and sorghum mixtures include sole crops and mixtures with cowpeas, maize, and other cereals.

c/ Data on soybeans apply strictly to the eastern region.

d/ Animal traction, by assumption, is not used on starchy tubers and fonio because of lack of data to assess performance and their minor significance in the crop mix (particularly of fonio).

Table 5.13. Labor Saving Effects Associated with Oxen Traction Technology, Regional Supply Models.

	Swampy Lowland		Compound Soils		Higher Quality Village & Bush		Lower Quality Village and Bush Fields					
Period	Rice	Starchy Tubers[d/]	Maize	Sorghums	Maize	Sorghums & Millets[b/]	Sorghums & Millets[b/]	Fonio[d/]	Cotton	Soy-beans[c/]	Ground-nuts	Bambara nuts
	(Percentage Reduction of Labor, S^o_{ij})											
1	-30	-	-	-	-	-	-	-	-	-	-	-
2	-30	-	-	-25	-	-39	-41	-	-	-	-	-
3	-30	-	-25	-25	-48	-39	-41	-	-	-	-	-57
4	-20	-	-25	-25	-48	-39	-41	-	-55	-	-55	-57
5	-20	-	-20	-20	-40	-39	-41	-	-55	-55	-55	-37
6	-20	-	-20	-20	-40	-32	-34	-	-35	-55	-35	-37
7	-	-	-15	-15	-25	-32	-34	-	-35	-35	-35	-17
8	-	-	-15	-15	-25	-25	-27	-	-30	-35	-15	-17
9	-	-	-15	-15	-25	-25	-27	-	-30	-30	-15	-17
10	-	-	-15	-15	-25	-25	-27	-	-30	-30	-15	-17

a/ These coefficients were used for the central region supply model. Coefficients for other regions are of the same magnitude but their scheduling may vary slightly due to different timing of crop operations.

b/ Millet and sorghum mixtures include sole crops and mixtures with cowpeas, maize, and other cereals.

c/ Data on soybeans apply strictly to the eastern region.

d/ Animal traction, by assumption, is not used on starchy tubers and fonio because of lack of data to assess performance and their minor significance in the crop mix (particularly of fonio).

all 'i' and 'j'.[12/] Next, efficiency declines on higher quality land types due to heavier soils and greater weeding problems. Also, performance declines as the season progresses as plants grow taller and managing equipment becomes more difficult. Third, animal traction is performed with equal efficiency nationwide such that S^d_{ij} and S^o_{ij} remain constant across regions. This condition stems from the assumption that teams are fully equipped and possess equal technical support in all zones.[13/] Finally, animal traction is not used on fields just brought out of fallow, because stump problems impede use of equipment.

Animal Traction Labor

Incorporating labor demands, A^d_{ij} and A^o_{ij}, for donkey and oxen teams in the model are necessary because, unlike mechanization with tractors, animals have limited endurance. What are required are estimates of labor requirements in period 'i' by the animal traction team, exclusive of human labor. These data are not easily or directly obtained from the literature. They must be estimated indirectly from information on animal traction performance (Appendix 3) and labor savings, S^d_{ij} and S^o_{ij}, associated with animal mechanization.

The labor coefficients are estimated by equations:

12/ For i=1, human hours A^m_{ij} is increased 13 hours for scarification with a donkey and 45 hours for plowing with oxen for all relevant j activities.

13/ Animal traction probably receives greater support in the cotton zones of the west and southwest. Hence, returns there are likely underestimated compared to those of other regions.

$$(5.3.)\quad A^{d}_{ij} = \frac{A^{m}_{ij} - (1+S^{d}_{ij})\, A^{m}_{ij}}{\phi^{d}_{ij}} = \frac{A^{m}_{ij} - A^{md}_{ij}}{\phi^{d}_{ij}}$$

$$(5.4.)\quad A^{o}_{ij} = \frac{A^{m}_{ij} - (1+S^{o}_{ij})\, A^{m}_{ij}}{\phi^{o}_{ij}} = \frac{A^{m}_{ij} - A^{mo}_{ij}}{\phi^{o}_{ij}}$$

where, ϕ^{d}_{ij} and ϕ^{o}_{ij} are technical efficiency parameters relating hours worked by animal traction teams to labor savings associated with animal mechanization in period 'i' on activity 'j'. That is, one hour worked by a donkey or oxen team displaces ϕ^{d}_{ij} and ϕ^{o}_{ij} hours, respectively, of human labor in period 'i' on manual technology 'j'. Hence, given estimates of labor savings (the numerator in equations 5.3 and 5.4) and efficiency parameters ϕ^{d}_{ij} and ϕ^{o}_{ij}, one can work backward to derive time worked by traction teams, A^{d}_{ij} and A^{o}_{ij}.

Estimates of labor savings, S^{d}_{ij} and S^{o}_{ij}, were given in Tables 5.12 and 5.13. What is needed are estimates of ϕ^{d}_{ij} and ϕ^{o}_{ij}. These are derived in Appendix 3, for weeding activities, from information on technical performance of animal traction and assumptions on human labor requirements. From the estimation procedure, parameters are estimated as $\phi^{d}_{ij} = 2.5$ and $\phi^{o}_{ij} = 3.6$. These imply that one hour of work with a donkey team displaces 2.5 hours of human labor and for an oxen team, 3.6 hours of human labor. These coefficients are assumed to remain constant for all crops, regions and tillage activities. Use of the same coefficients for maize and groundnuts as major cereals perhaps overestimates labor requirements on land preparation of minor crops, but insufficient information hinders further disaggregation of

ϕ^d_{ij} and ϕ^o_{ij}. For land preparation activities (i=1), land scarification with a donkey is estimated to take A^d_{ij} = 6.5 hours and plowing with oxen, A^o_{ij} = 30 hours per hectare.

Yields

Land intensifying effects of animal traction technologies are incorporated through Y^d_j for donkey and Y^o_j, j = 1,...,n, for oxen. Research performed on the experiment station have shown that dramatic yield improvements are possible. Charreau and Nicou (1971, p. 935) found deep plowing increased yields of groundnuts by 19 percent, cereals by 20 to 30 percent, cotton by 27 percent and rice by more than 50 percent on experiments conducted by IRAT in Senegal (Sargent, et al., 1981, p. 14). In the northern region of Burkina Faso, IRAT (1982, p. 150) obtained yield increases of 56 to 63 percent on millet with deep plowing. In further experiments, in the central region, (IRAT, 1982, p. 163), plowing with oxen (weeding with donkey) produced yield gains of 41(19) percent for sorghum, 32(16) percent for millet, and 49(42) percent for cowpeas.

The literature on yield performance of animal traction under on-farm conditions is limited. Information for oxen are nearly non-existant. Hence, inferences are based mainly on results for donkey mechanization. Table 5.14 compares average yields between samples of animal traction owners and non-owners taken from selected on-farm studies. Figures without parentheses are average yields from a sample of mainly hand tillage households. Figures in parentheses are the percentage yield increase (a "-" implies a decrease) of yields in

Table 5.14. On-Farm Yield Comparisons Between Samples of Hand Tillage and Donkey Households, Selected Farm Management Studies, Burkina Faso. 1/

Reference a/	Millet	White Sorghum	Red Sorghum	Maize	Peanuts	Bambara Nuts	Rice	
	(kg./ha.)							
Central, Ouagadougou, 1982, (24 to 36)	350(-4)	515(-33)	421(37)	1140(-15)	502(-13)			Jaeger, 1984
Central, Ouagadougou, 1983, (25)	346 (2)	430 (3)		836 b/				SAFGRAD-FSU, 1984 d/f/
North, Central, 5 Villages, 1980, (60)	412(-1)	533(-21) c/		1324(-42)	441 (10)	331		Singh, et al., 1984
Central, Ouagadougou, 1980	201(-2)	291(47)	380(29)	567(-51)	287(-34)	133(-43)		McIntire, 1981
East, Fada N'Gourma, 1982, (11)	329 e/ (22)	171(150)		1429(14)	256(103)			Jaeger, 1983
East, Fada N'Gourma, 1983, (25)		363 (33)		1270(-7)				SAFGRAD-FSU, 1984 f/
East, 12 Zones, 1978		377 (1)		349(68)	366(-19)		554(-46)	Barrett, et al., 1982

1/ These studies stratify yields by animal traction and non-animal traction households. Figures without parentheses are average yields from a sample of strictly hand tillage households. Figures in parentheses are the percent yield increase (a "-" implies decrease) of yields in donkey traction over hand tillage households.

a/ Cities are the major urban center nearest to the site of data collection. Years denote when the data survey was conducted. The figures in parentheses represent number of households in the sample unless accompanied by an "*" which implies number of fields. b/ Some households including animal traction teams are included in the sample. c/ Figure is for red and white sorghum combined. d/ These are farmer managed trials ranging from .04 to .12 hectares in size. The results correspond to the control treatment in these trials, 1 replication per farm, representing yields under traditional management practices. e/ This is a sorghum/millet mixture comprised of around 75-90 percent millet with the rest sorghum. f/ Yields were obtained from researcher managed trials on farmers' fields. Yields are those of local varieties grown under traditional management practices.

donkey traction households vis-a-vis hand tillage households. Large yield increases are reported in some instances, but negative yield effects are common as well. Where large yield gains are reported, it is difficult to separate yield effects from other influences.[14/] Animal traction adopters, for instance, are often better managers with better resource endowments who employ higher levels of other inputs in the production process.

The yield assumptions for animal traction technologies are shown in Table 5.15 for the central region and in Appendix 1, Table A2.1 for other regions. Yields are estimated by equations:

$$(5.5) \quad Y_j^d = (1 + r^d)\, Y_j^m$$

$$(5.6) \quad Y_j^o = (1 + r^o)\, Y_j^m$$

where:

r^d and r^o are percentage yield increases over respective manual tillage technologies, Y_j^m.

The yield effects, r^d, for donkey and, r^o, for oxen are conservative compared with experiment station results. They also reflect several important assumptions. One, the yield response to animal mechanization increases on higher quality soils, reflecting positive

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14/ A more appropriate comparison would be yields of fields tilled with animal mechanization with those that are not within the same sample of adopters.

Table 5.15. Crop Activities and Yield Levels Associated with Animal Traction Technologies, Central Region Supply Model.[1]

Type of Land	Crop Mixture	Percentage Increase Over Manual Technologies	
		Donkey Tillage	Oxen Tillage
T_ℓ	X_j^m, X_j^d, X_j^o	r^d	r^o
		-----(percent)-----	
Swampy lowlands	Paddy	8	16
Compound Land; Other Highly Manured Soils	Maize	8	16
	Red Sorghum	6	12
	White Sorghum	6	12
	R.Sorg.(.75)/W.Sorg.(.25)	6-6	12-12
High Quality Village & Bush Fields	Maize	7	14
	Red Sorghum	5	10
	R.Sorg./Cowpeas	5-7	10-14
	White Sorghum	5	10
	W.Sorg./Cowpeas	5-7	10-14
	R.Sorg.(.80)/Maize(.20)	5-7	10-14
Lower Quality Village Fields	Red Sorghum	5	10
	R.Sorg./Cowpeas	5-7	10-14
	White Sorghum	5	10
	W.Sorg./Cowpeas	5-7	10-14
	Millet/Cowpeas	5-7	10-14
	W.Sorg.(.75)/R.Sorg.(.25)/ Cowpeas	5-5-7	10-10-14
	W.Sorg.(.75)/Millet(.25)/ Cowpeas	5-5-7	10-10-14
	Cotton	5	10
	Bambara Nuts	7	14
	Peanuts	7	14
Bush Fields	Cult.Fallow-Sorg./Cowpeas	-	-
	Cult.Fallow-Millet/Cowpeas	-	-
	W.Sorg./Cowpeas	3-5	6-10
	Millet	3	6
	Early Millet/Cowpeas	3-5	6-10
	Late Millet/Cowpeas	3-5	6-10
	Millet(.75)/W.Sorg.(.25)/ Cowpeas	3-3-5	6-6-10
	Cotton	3	6
	Peanuts	5	10

Table 5.15. (continued)

1/ Source: Information on crop mixtures were adapted from R. Ford, "Subsistence Farming Systems in Semi-Arid Northern Yatenga," 1982, (North); P. D. Kabore, Y. Lebene and P. J. Matlon, "Modeles de Cultures dans Trois Zones Agro-Climatiques de Haute Volta," Mars 1983, pp. 30-32 (North, Central, West); R. Singh, E. Kehrberg, and W. H. M. Morris, Small Farm Production Systems in Upper Volta: Descriptive and Production Function Analysis, 1983, p. 21 (North, Central); G. Lassiter, "Cropping Enterprises in Eastern Upper Volta," 1981, pp. 27-40 (East); G. Lassiter, "A Polyperiod Linear Programming Analysis of Draft Animal Adoption in Eastern Upper Volta," 1982, p. 1 (East); and J. McIntire, "Sondages de Reconnaisance au Nord et a L'Ouest de la Haute Volta," 1982, p. 17 (West and Southwest).

interactions between fertility, moisture, and tillage. Higher yields for oxen result from preplant plowing and deeper tillage at weeding compared with donkey tillage, which is used primarily for weeding.

Manure

Animals of traction teams are a source of manure, MNR, which can be used to augment soil fertility. Estimates of manure production from one 400 kg. ox have been estimated by Nourrisat (1965) for Senegal at 7.5 to 10.0 tons per year. In the U.S., cattle (horses) produce around 8.6 (5.9) tons of solid manure and 3.3 (1.3) tons of liquid manure (Martin and Leonard, 1967, p. 139). Due to lower food intake of animals in West Africa, manure production is less. Here, a donkey is assumed to produce 3.8 tons and an ox, 7.0 tons (14.0 tons for a pair of oxen) per year. Not all manure is recoverable, however. Assuming that 20 percent is recovered, based on best judgement, manure supply with a donkey, MNR^d, and pair of oxen, MNR^o, is increased 0.8 and 2.8 tons, respectively.[15/]

The amount of manure applied in practice varies with type of crop and land type. In on-farm research by Bonkian (Appendix 4, Table

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15/ These results compare favorably with Bonkian's (1980) results which show total manure use of hand tillage and animal traction (mainly donkey) households as 631 and 1442 kg., respectively. The difference (811 kg.) reflects variances in family size, livestock and animal traction ownership among samples. Still, it provides a rough benchmark for gauging estimates of additional manure supply due to ownership of traction animals. In contrast, Delgado (1978) assumed 1 ton of recoverable manure per animal while the Republique Francaise, (1975, p. 117) predicts 2.4 metric tons per year.

A4.4) and McMillan (1983, p. 394), maize was planted on compound soils where rates of manure application were highest. Land where sorghums are normally cultivated receive less manure while, millet and groundnuts on outlying bush fields receive the least.

As explained in Chapter IV, manure is assumed to augment endowments of higher quality land. That is, areas of compound land, and higher and lower quality village soils can be expanded through sufficient applications of manure to bush land. To do so, the assumption is made that compound land requires 16 tons, higher quality village fields 9 tons, and lower quality village fields 6.5 tons of manure per hectare. These estimates are based on ob erved application rates of animal manure and assumptions of soil fertility on respective soils.[16/] Thus, an additional ton of manure increases the area of compound land by mnr^c = 0.6 hectare, higher quality village and bush soils by mnr^{hq} = .11 hectare, and lower quality village soils by mnr^{lq} = .15 hectare.

Modern Technologies

Three types of modern technologies are incorporated in the regional supply models. First, there are chemical technologies

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16/ When only those fields receiving manure in Bonkian's sample are considered, application rates are 319 kg. for millet, 700 kg. for peanuts, 887 kg. for red sorghum, 1100 kg. for white sorghum, and 5317 kg. per hectare of maize (figures are for hand tillage sample computed by the author). Bonkian's survey includes only partial estimate of manure supply. Total manure in Bonkian's study includes manure from household livestock and residues. It excludes human night soil and night paddocking of animals. Hence, these figures under-estimate actual manure application.

defining fertilizer production functions for principle crop mixtures plus the application of pesticides on cotton. Next, there are activities for small and large scale irrigation, reflecting improved water management practices. Also, activities are included for crop agriculture on land reclaimed by the Volta Valley Authority (AVV).

Fertilizer

Fertilization possesses characteristics of both a land intensifying and labor augmenting technology. The former increases productivity of land resources through higher yields, Y_j^f. The latter stem from higher labor requirements for fertilizer application, harvesting (due to greater production) and greater weeding problems accompanying fertilizer use. Only land intensification effects are incorporated in the analysis. Labor augmenting effects were excluded (with exception of labor for fertilizer application) because harvest labor lay outside the coverage of total labor in the model. Also, lack of empirical data on increased weeding requirements, make adjustments to A_{ij}^f difficult.[17/]

Theoretically, the yield response, Y_j^f, of crop enterprise, X_j^f, to chemical fertilizers can be written as:

$$(5.7) \quad Y_j^f = Y_j^f\,(FERT_{ki},\ W_i,\ t_g,\ T_\ell,\ a)$$

17/ For labor on fertilizer application, A_{ij}^f is increased by 5 hours for 50 kg./ha. of fertilizer, 8 hours for 100 kg./ha. and 10 hours for 150 kg./ha. By assumption, fertilizer is applied in slack period, i=3, corresponding to beginnning of first weeding of major cereals.

where, yields are defined as a function of quantity of fertilizer (FERT) of type 'k' applied in period 'i', quantity of water (W), available for plant growth in period 'i', type of tillage system (t_g), land type (T_ℓ), and the variable 'a' encompassing other factors. The latter, for example, includes climate, managerial ability of the farmer, labor availability, crop variety and soil conservation. As explained by the World Bank (1981) in their review of fertilizer research in Burkina Faso, the interactions among these factors are complex, making yield generalizations difficult.

To empirically estimate the model, (FERT) is defined as kilograms of cotton complex fertilizer, engrais coton (14-23-14) applied per hectare. For maize and irrigated rice, an additional dosage of Urea is applied, equivalent to one-half the dosage of cotton fertilizer.

The set of crop activities defining the fertilizer production functions for technologies, X_j^f, in the central region supply model are shown in Table 5.16. Fertilizer activities for remaining supply regions are shown in Appendix 2, Table A2.4. Production functions are included for only those crop mixtures expected to dominate economic substitution for a given soil type. They are also defined for both cereals and cash crops to permit economic evaluation of food versus export oriented pricing policy.

Production functions are defined over three discrete levels of fertilizer application, d^f: 50, 100, and 150 kilograms per hectare. The lower extreme is consistent with low application rates observed in farm management studies. The higher levels are representative of application rates used in experimental research. By assumption, the

Table 5.16. (Continued)

Land Type	Crop:Fertilizer-Tillage[c]		Kg.[b] Cereals per kg. $N + P_2O_5$	Yield Y_i^f	Absolute Increase Over Base Yields, y^f
	W.Sorg./	50-Hand	4.5	534	84-11
	Cowpeas:	100-Hand	4.3	610	160-20
	Millet:	50-Hand	4.0	494	74-11
		100-Hand	3.8	560	140-20
Bush Fields	Millet:	50-Hand	2.5	387	47-5
		100-Hand	2.4	430	90-10
AVV Land Reclamation Scheme	Maize:	75-Oxen	6.4	795	-
		150-Oxen	6.0	950	-
	W.Sorg./	75-Oxen	5.8	730-81	-
	Cowpeas:	150-Oxen	5.5	875-95	-
	Cotton:	75-Oxen	7.4	865	-
		150-Oxen	7.0	1050	-
Improved Lowlands	Rice:	50-Hand	11.6	1190	-
		100-Hand	11.2	1390	-
		150-Hand	10.8	1575	-
Scheme Irrigation	Rice:	100-Hand[d]	16.0	2760	-
		150-Hand	15.5	3195	-
		200-Hand	15.0	3600	-

a/ Yield response figures for fertilizer activities were derived from on-farm fertilizer trials. A synthesis of farm level fertilizer research is reported in Appendix 1, Table A1.20 and World Bank (1981, p.78). Yield information for rice irrigation was taken from official government statistics (Appendix 1, Table A1.21). The yield response functions to the fertilizer input are assumed to possess diminishing returns.

b/ These response rates show yields of cereal per kg. of N plus P_2O_5 applied per hectare for sake of comparison with World Bank (1981, p.78) and IFDC (1977, pp.20-24) reporting methods.

c/ Yield responses were based on the application of a mixed N.P.K. fertilizer (14-23-14) adapted for cotton. It also contains small quantities of sulphur and baracine. The label 'Maize: 50-Hand' implies 50 kg. of cotton fertilizer are applied per hectare of maize cultivated manually.

d/ Irrigated rice under scheme management receives an application of Urea (46-0-0) in addition to the cotton mixed fertilizer. It is applied at half the rate of the cotton fertilizer. Yield response figures calculated per kg. of N plus P_2O_5 are adjusted for the additional nitrogen applied.

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production function possesses diminishing returns to fertilizer use, as illustrated in Figure 5.1.

Line segment OA corresponds to yields under traditional technology. Segment DE refers to the absolute yield increase with use of 150 kg. of cotton fertilizer per hectare. If average returns were constant, line AD would represent the production function. However, average returns here are increased by 4-5 percent at rates of 100 kg./hectare (point C) and 8-10 percent at 50 kg./hectare (point B), depending on the region. This slope is moderate, but allows adjustment in fertilizer intensity with changing price relatives ψ^f/P_k.

Production functions were estimated from yield response data obtained from on-farm trials (Appendix 1, Table A1.20) and from syntheses of yield response studies by the World Bank (1981, p. 78) and IFDC (1977). Yields for fertilizer technologies are estimated by equation:

$$(5.8) \quad Y_j^f = Y_j^m + y_j^f$$

where y_j^f is the absolute yield increase associated with the rate of fertilizer application, d^f. Fertilizer response rates in Tables 5.16 and A2.4 are also expressed in returns per kilogram of N plus P_2O_5. This permits comparison with fertilizer response rates estimated by the World Bank and the IFDC. In general, yield response estimates are moderate but suppressed by other limiting factors, principally water availability. New technologies combining fertilizer with water conservation and mechanized tillage have produced dramatic yield

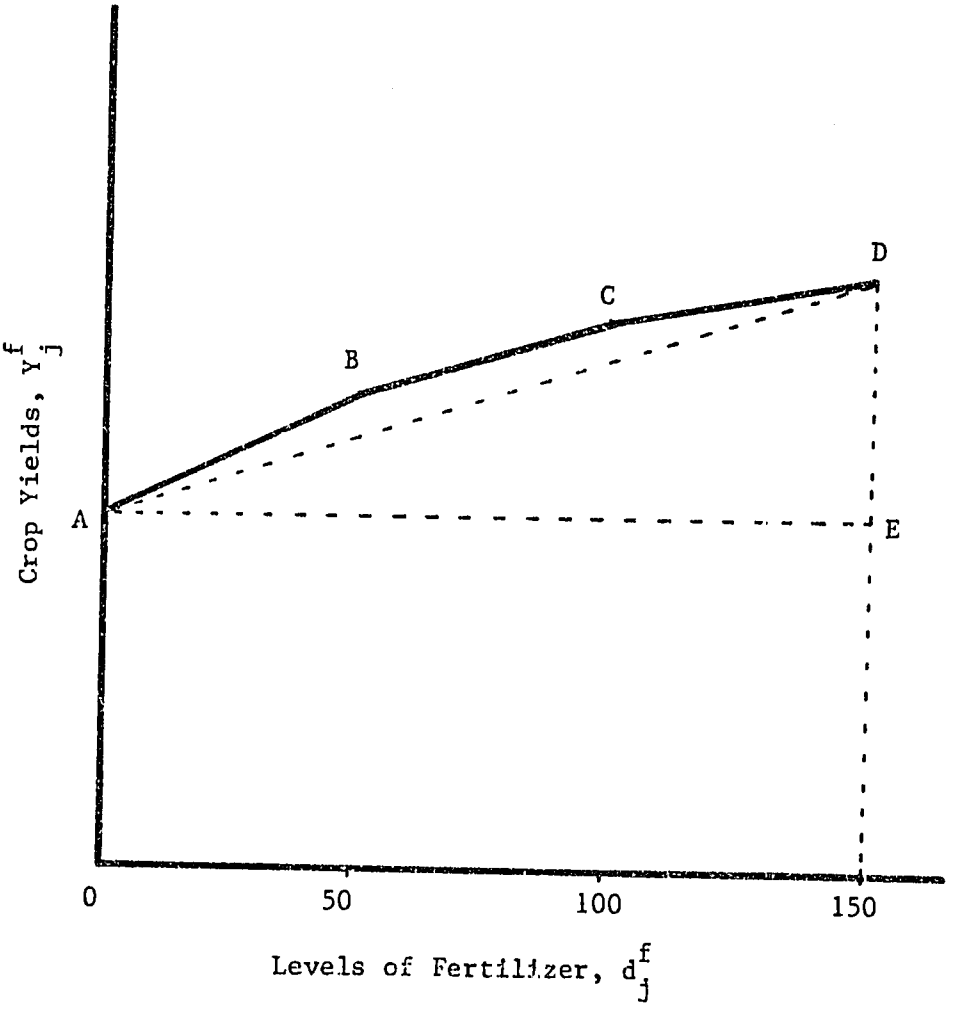

Figure 5.1. Production Function of Fertilizer.

improvements (SAFGRAD-FSU, 1982, 1983, 1984). But, research either remains in the experimental phase or use in practice is highly localized. Thus, technologies dealing with improved availability of water (other than irrigation) through water conservation are excluded from the analysis.

Returning to equation 5.7, fertilizer response in the analysis varies with several additional factors. First, yield coefficients, Y_j^f, decline with lower quality soils, represented by variations in land type, T_ℓ. Data from on-farm research in Appendix 1, Table A1.20 lend some support for this hypothesis. However, the assumption is mainly based on agronomic theory which relates higher yields with better soils and improved water absorption capacity.[18/] Yield coefficients, Y_j^f, also increase from North to Central to East to West to Southwest regions in accordance with geographical and climatic variation. The higher yields are attributed to superior soils and/or higher precipitation in respective regions. Third, yield interactions between mechanized tillage, t_g, and fertilizer are assumed to be neutral. Positive though moderate interactions may be expected with deep plowing but these effects are excluded to keep estimates conservative.

While the production function for manual crop technologies is defined for three discrete levels of fertilizer application (e.g., 50,

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18/ An exception is compound land where lower yield response is assumed. These are based on on-farm data in Appendix 1, Table A1.20, though reasons underlying the phenomena are unclear. One possible factor is higher organic matter which may tie-up nutrients in the short run.

100, and 150 kg./ha.), the production function for animal traction technologies includes only one possible application rate--100 kg./ha. This procedure was used to reduce the number of fertilizer activities included in the model. For low endowments of animal traction resources, b^d and b^o, the fertilizer-output response function is relatively continuous due to varying input levels in the traditional (hand tillage) sector. For scenarios examining the impacts of large endowments of animal traction resources, the output response to fertilizer is more discontinuous. The effect is moderate, however, due to slight diminishing returns assumed in the production function; average returns to fertilizer have small variance across application rates.

Irrigation

Irrigation systems in practice vary widely depending on source of water, degree of water control, type of water delivery and level of investment. The World Bank (1981, p. 60), for example, summarizes types of irrigation systems which have been implemented in Burkina Faso. These range from simple bottomland irrigation based on bunding, which provide limited water control with small levels of investment, to large pumping and gravity-fed schemes associated with dams, which incur substantial investment costs.

For sake of simplicity, but without much loss of detail, two types of irrigation investment are permitted in the model. One is bottomland irrigation, supplying imperfect water control, with paddy yields of 1.5 to 1.6 mt./hectare and investment costs of .075 million

FCFA/hectare. The second is irrigation below dams, with high levels of water control, yields of single crop paddy of 3.0 to 4.3 mt./hectare, and investment costs of 1.25 million FCFA/hectare. In the southwest region only, a third set of activities are included for double cropped paddy in the Vallee du Kou and Plaine du Banzon. Here, yields of more than 7.0 mt./hectare for two crops combined are possible. Together, these encompass the most prevalent types of irrigation found in the country.

Yield levels Y_j^f, for irrigation activities in Tables 5.16 and A2.4 are three-year averages computed from published government statistics (Appendix 1, Table A1.21). Multiple activities per type of irrigation define yield response functions to varying levels of fertilizer use. Varying levels of water control and operational costs are not directly incorporated in the analysis although they are implicit in comparisons of the three irrigation systems within a region. Annual costs of irrigation, ψ^i, contain annualized costs of investment plus fixed operation and maintenance charges (Table 5.17).

Pesticides

By assumption, pesticides, specifically Nuvacron, are applied to cotton at rates of $d^p = 3.5$ liters/hectare for protection against insects. This rate is less than the 11.6 to 13.4 liters of Nuvacron applied by farmers in newly reclaimed areas of the AVV (Murphy, 1980, p. 47) but slightly exceed rates observed by McMillan (1983, p. 391) and Hauts Bassins ORD (1980 annual report) in actual on-farm use. The

Table 5.17. Input Costs Based on 1980 Financial Prices, Regional Supply Models, Burkina Faso.

	North	Central	East	West	Southwest
Seed Costs,[a/] $\psi_j^s = sd_k * P_k$					
Planting Density, sd_k (kg./ha.)					
White Sorghum	13	13	13	13	13
Red Sorghum	13	13	13	13	13
Millet	13	13	13	13	13
Maize	29	29	22	29	29
Paddy	55	55	59	55	55
Peanuts	28	28	22	28	28
Cotton	10	10	10	10	10
Bambara Nuts	28	28	22	28	28
Soybeans	-	-	71	-	-
Fonio	8	8	-	8	8
Starchy Tubers	-	-	-	-	950
Land Clearing[b/] ('000 FCFA/ha.):	2.25	2.25	2.25	2.25	2.25
Modern Inputs[c/] ('000 FCFA/ha.):					
Donkey team, Ψ^d (per unit)	24.0	24.0	24.0	24.0	24.0
Oxen team, Ψ^o (per unit)	35.0	35.0	35.0	35.0	35.0
Urea, Ψ^u (per ton)	79.0	79.0	79.0	60.0	60.0
Cotton fertilizer, Ψ^f (per ton)	45.0	45.0	45.0	40.0	40.0
Pesticide, Ψ^p (per kilo-liter) plus sprayer rental (per year)	360.0	360.0	360.0	340.0	340.0
Credit, r (percent)	.5	.5	.5	.5	.5
	8	8	8	8	8
Water Control[d/] ('000 FCFA/ha.)					
Simple Bottomland Irrigation	23.0	23.0	23.0	23.0	23.0
Perimeter Irrigation	217.0	217.0	217.0	217.0	217.0
AVV Land Reclamation[e/] ('000 FCFA/ha.)	-	65.9	-	-	-

Table 5.17. (Continued).

a/ Seed costs Ψ_j^s on activity j equals planting density of crop 'k' times 1.5 its output price, P_k; 0 otherwise. The coefficient 1.5, representing the ratio of planting to harvest prices, was estimated from selected seasonal price series. Data on planting densities were adapted from Lassiter (1981, pp. 27-41) for the eastern region, and from ICRISAT (1980, p. I10b) elsewhere.

b/ Charges for land clearing to bring land out of fallow were adapted from McIntire (1982, pp. 43-51).

c/ Annualized costs of animal traction are computed in Appendix 5. Prices of modern inputs are financial prices collected by the World Bank (1981, p. 209) in 1980. Murphy (1980) reports the rental price of a Nuvacron sprayer as 730 FCFA plus at least 460 FCFA for batteries per year covering four sprayings.

d/ Simple bottomland irrigation provides imperfect water control with limited bunding. The annual cost of 23,000 FCFA/ha. was computed by World Bank (1981, pp. 60-61) based on 75,000 FCFA initial investment, 8 percent interest, 4 year life span and no maintenance or pumping charges. No maintenance is charged because these are allowed to fall into disuse after four years (about 50 percent of the bottomlands developed by the Rural Development Fund remain in use according to World Bank, 1981, p. 210). Investment costs for pumping and gravity fed schemes run between 1 to 2 million FCFA. Assuming 1.25 m. FCFA/ha. for development of irrigation below dams (exclusive of dam cost), 10 year lifetime and 8 percent interest the annualized cost of investment is 186,000 FCFA. With operation and maintenance costs at 2.5 percent of investment, total annual costs are 217,000 FCFA/ha.

e/ Annualized costs of land resettlement are computed in Appendix 5, Table A5.2.

cost of pesticide ψ^P (Table 5.17) includes its financial price plus the cost of sprayer rental.

Land Reclamation

Large tracts of land primarily along river valleys of Burkina Faso have historically remained unsettled due to onchoceriasis. Spraying programs, implemented by the World Health Organization in 1973 have gradually brought disease in these areas under control. With success of the spraying programs, large areas of new land have become available. The Volta Valley Authority (AVV) has charge over settlement and economic development of nearly 30,000 km^2 of these areas. While potential area is large, development of area cultivated in 1979-1981 averaged around 8,200 hectares.

A principal objective of the AVV is to organize controlled resettlement of these valleys with volunteer families from high density regions. The program's potential benefits are several-fold. One, reclaimed land is of higher fertility than exhausted soils of the Central Plateau. This combined with improved management practices extended in AVV settlements permit higher yields. Second, public investment in physical and social infrastructure in settlement zones may stimulate private settlement in the longer run that otherwise would not occur, or occur at a slower settlement rate, due to market imperfections. The former benefits are incorporated in yields Y_j^f for AVV activities (Table 5.16), based on yield data in Appendix 1, Table A1.22. The latter are difficult to quantify, hence are excluded, even though its long term impact is potentially greater.

Costs per hectare of bringing one hectare of AVV land into cultivation ψ^{AVV}, are estimated in Appendix 5, Table A5.2 and summarized in Table 5.17. These are based on annualized costs to the AVV of resettling one family in reclaimed areas in 1978, exclusive of spraying and additional administrative costs.

Input Prices

Input costs associated with production activities are outlined in Table 5.17. Seed costs ψ_j^s, are estimated from data on seed requirements and planting period prices. Land clearing charges, to bring fallowed land back into cultivation, were adapted from McIntire (1982, pp. 43-51). Costs of Urea (ψ^u), cotton fertilizer (ψ^f), and pesticides (ψ^p), are financial prices charged to farmers by the ORDs, in 1980. Costs of animal traction, ψ^d and ψ^o, and irrigation ψ^i, include annualized costs of fixed investment and maintenance and operation charges (refer to Appendix 5 for their derivation).

Resource Endowments

Resource endowments for human, donkey, and oxen labor, higher quality land and fertilizer are given in Table 5.18.

Supply of Human Labor

The supply of human labor is derived from the number of male adults (MW), female adults (FW), and children (CW) employed as active workers in agriculture, their respective work intensities per day, MHR_i, FHR_i, and CHR_i and the number of potential workable days DYS_i,

Table 5.18. Resource Endowments Estimated for Regional Supply Models, Burkina Faso.

		North	Central	East	West	Southwest
Human Labor: $DYS_i (MHR_i * MW + FHR_i * FW + CHR_i * CW)$						
Days:	DYS_i (i=1)	15.0	15.0	15.0	15.0	15.0
	(i=2,...7)	6.0	6.0	6.0	6.0	7.7[a/]
	(i=8)	12.0	12.0	12.0	12.0	15.4
	(i=9....10)	18.0	18.0	18.0	18.0	23.1
Hours/Day:	MHR_i	7.3	7.2	7.5	7.5	7.7
	FHR_i	5.1	5.0	5.2	5.2	5.3
	CHR_i (i=1...10)	3.4	3.4	3.5	3.5	3.5
Active Ag. Population:	$MW \leq b^m$	368,804	474,269	98,225	148,015	192,861
	$FW \leq b^f$	361,698	471,414	91,811	149,615	198,914
	$CW \leq b^c$	13,712	20,373	5,069	5,727	8,412
Donkey Labor: $DYS_i (DHR_i * DK)$						
Days (less time loss):	$DYS_i - dys_i^d$ (i=1)	10-.05	10-.05	10-.05	10-.05	10-.05
	(i=2...7)	6-.02	6-.02	6-.02	6-.02	6-.02
	(i=8)	12-.04	12-.04	12-.04	12-.04	12-.04
	(i=9...10)	18-.06	18-.06	18-.06	18-.06	18-.06
Hours/Day: DHR_i		6.7	6.7	6.7	6.7	6.7
Donkey Teams: $DK \leq b^d$		9,935	16,260	2,070	2,990	715

Table 5.18. (Continued).

		North	Central	East	West	Southwest
Oxen Labor: $DYS_i (OHR_i * OX)$						
Days (less time lost): $DYS_i - dys_i^o$	(i=1)	10-.05	10-.05	10-.05	10-.05	10-.05
	(i=2...7)	6-.6	6-.6	6-.6	6-.6	6-.6
	(i=8)	12-1.2	12-1.2	12-1.2	12-1.2	12-1.2
	(i=9...10)	18-1.8	18-1.8	18-1.8	18-1.8	18-1.8
Hours/Day OHR_i (i=1...10)		6.7	6.7	6.7	6.7	6.7
Oxen Teams $OX \leq b^o$		7,755	3,290	865	8,625	5,620
Fertilizer: $FERT \leq b^f$ (m.t. engrais coton)		1,530	1,360	145	3,565	5,815
Land ($T_l \leq b_l$)						
Swampy Lowlands		2,308	12,648	2,450	4,137	15,137
Compound Land		39,451	56,946	9,848	15,581	20,017
HQ Village & Bush Fields		83,665	118,052	21,674	38,614	60,547
LQ Village Fields		106,745	151,781	31,098	52,404	82,170
Bush Fields		-	-	-	-	-
Improved Lowlands		245	1,088	262	450	2,500
Single Crop Rice Irrigation		278	358	133	-	383
Double Crop Rice Irrigation		-	-	-	-	1,228
AVV Reclaimed Land		-	8,207	-	-	-

a/ Periods in the Southwest region supply model are longer in duration compared with other regions.

in period 'i'. The most recent and comprehensive data on size and demographics of the male workforce, b^m, are available in the 1975 population census (Appendix 1, Tables A1.15 and A1.16). These provide the basis for estimates of male agricultural work force in Table 5.18.

The census, however, grossly underestimates size of female work force, b^f. It contains data only for primary occupation, which for women respondents was menageres, or domestic work. This runs counter to empirical observation which show women providing a substantial if not major portion of labor in agriculture. Here, female adult and children "actives" are estimated from data on size and age distribution of males in agriculture and regional female population (refer to Appendix 1, Table A1.15 for the derivation). An annual growth rate of 1.72 percent was used to raise 1975 work force figures to 1980 totals.[19/]

Estimates of MHR_i, FHR_i, and CHR_i, for family workers, and DHR_i and OHR_i, for traction animals, were summarized from the empirical literature on work intensity in Appendix 3. Since labor intensities remain constant for all 'i' periods, slack labor with shadow prices of zero will result in off periods of labor demand.[20/] Variances in MHR_i, FHR_i, and CHR_i across regions reflect adjustments to bring model

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19/ It is unrealistic to assume that populations grew equally among all regions when strong interregional migration was taking place. However, poor data precludes more disaggregated estimates of population growth. The figure 1.72 was the average rate of population growth estimated by INSD (1979, p. 26) over the period 1960-1975.

20/ An alternative procedure would be to estimate labor intensity from the labor-leisure difference curve for all periods 'i' of labor demand. Not only is data limiting for this, the methodology risks overestimation of shadow prices of labor in off-periods.

estimates of total production into alignment with regional production figures estimated by the government.

Supply of Land

The total supply of land resources, $\sum_{1}^{L} T_{\ell}$, is unconstrained due to the assumption that bush land is unlimited. Areas of higher quality land are constrained, reflecting scarce supply. In the literature, several studies (Kabore', et al., 1983; Jaeger, 1984; and Delgado, 1978) distinguish between compound, village, and bush soils as proxies of soil quality. These distinctions are generally based on geographical proximity to the household, not to soil types farmers use in crop allocation decisions (the two, however, are correlated). A more appropriate breakdown is ICRISAT's (1980) stratum of soil types and crops typically allocated to each. But, empirical estimates of land area by soil type are unavailable.

An indirect procedure was used to estimate the area of land resources in the model. Endowments are estimated from data on cropping patterns and inferences on the specificity of crops to certain soil types. Paddy is primarily grown on swampy areas; maize is cultivated on highly manured areas surrounding the family compound; sorghums are planted on the more fertile village soils with red sorghum cultivated on the most fertile of these; millet, as the crop of last resort, is normally planted on the poorest soils.

The estimation procedure involves two steps. First, information on cropping patterns were assimilated from data reported in on-farm studies. A sample of such data for the central region are reported in

Table 5.19.[21/] Aggregate statistics published in national accounts appear to underestimate the area of millet. Thus, modal averages from the synthesis of on-farm studies were used to estimate crop area. Second, an assessment is necessary of the extent of cross-over of a crop onto more than one soil type. Sorghum, for instance, may be grown on soils of various qualities. This step is difficult, requiring subjective judgement. Land endowments were estimated in the following manner:

1) Swamp land equals the area of paddy observed in cropping patterns. Based on data in Table 2.4, this area ranges from .005 percent of total crop area in the north to .035 percent in the southwest (excluding irrigated rice).

2) Compound land, next to the family's living quarters, varies with the amount of waste produced by the family which in turn depends on family size. Land area is calculated from estimates of rural population (Table 5.20) and a ratio of 0.25 to 0.30 ha./rural inhabitant, depending on the region. Land per resident ratios were adapted from Jaeger (1984). The area of compound land, resulting from this calculation, amounts to roughly 5 percent of total crop area (from Table 2.4). This area is sufficient to grow maize, normally 2 to 3

21/ For a complete synthesis of data on cropping patterns for the five supply regions, refer to M. Roth, "Working Data for Development of Farm Planning Models, Burkina Faso," (1986, forthcoming).

Table 5.19. Cropping Patterns, Selected Studies, Central Region, Burkina Faso.

Nearest Urban Center:	Ouagadougou[a]	Ouagadougou[b]	Yako[c]	Ouagadougou[d]	Yako[e]
Survey Village:	Nedogo	5 Villages	Kolbila Ouonon	Nakomtenga Nabitenga	Arbolle
		(Percent of Total Area Cultivated)			
Sorghum (undefined)		19.8			
White Sorghum	17.8		53.0	7.6	30.9
Red Sorghum	10.0		4.0	10.7	1.9
Millet	63.6	66.4	27.0	73.4	46.0
Millet/Sorghum	0.1				
Maize	2.4	2.8	2.0	1.9	8.6
Paddy	0.3				
Groundnuts	4.9	7.6	9.0	5.2	2.2
Bambara Nuts	0.7	1.3	2.0	1.2	
Cotton	-		1.0		5.3
Fonio					
Soybeans	-				
Cowpeas	-				
Sesame					
Tubers			1.0		4.7
Okra		0.2			
Other	0.2	1.8	1.0		0.3
Total Hectares Cultivated	6.63	5.05	5.01	2.95	3.65

Source: (a) SAFGRAD-FSU, "1982 Annual Report," p. 16; (b) Singh, et al., Small Farm Production Systems in Upper Volta, Descriptive and Production Function Analysis, 1984; (c) Kabore, Lebene and Matlon, Modeles de Culture dans Trois Zones Agro-Climatiques de Haute Volta, 1983; (d) McIntire, Two Aspects of Farming in Central Upper Volta: Animal Traction and Intercropping, 1981, p. 4; and (e) Dumont, "Enquetes Socio-Economiques Concernant le Problem des Tubercules en Haute Volta," 1979.

percent of total crop area on the Central Plateau, then red sorghum or white sorghum if the hungry season constraint for maize is binding.

3) Higher quality village and bush fields roughly equal the area of red sorghum in the crop mix. Red sorghum is grown on soils higher in fertility than those of white sorghum, due to its superior yield response (Cohen, 1982). Data for the central region are best suited for estimating this area, because red sorghum is prevalent, hence soil regimes are better defined. In the east, cultivation of red sorghum is constrained by religious belief (beer, from red sorghum, is forbidden by Islamic law). In the west and southwest, soil quality regimes are less clearly defined, since maize begins to substitute for sorghum on these soils. As shown in Table 5.19, the area of red sorghum varies from 2 to 11 percent of total area, depending on the study. Since production of red sorghum is constrained by its derived demand for beer and livestock feed, the area of higher quality land is probably greater. For the model, the area of higher quality land was estimated at .115 to .145 percent of total cultivated area (in Table 2.4). This area is sufficient to account for the area of red sorghum (until output constraints are met) then maize or white sorghum. Variations in regional percentages reflect adjustments to bring indivdiual supply models into equilibrium with aggregate production data in the 'base' case.

4) Lower quality village fields are estimated from the area of white sorghum in the central region. In the north, land area is less clearly defined, since millet substitutes for sorghums on these soils. Millet/sorghum "associations" substitute for white sorghum in the east while maize or cotton may substitute for white sorghum in the west and southwest. Estimates of white sorghum in the cropping pattern (Table 5.19) range from 8 to 53 percent of total area. Since white sorghum may be cultivated on compound land, higher quality village soils and bush land (on land recently taken out of fallow), the area of lower quality village soils would lie closer to the lower end of this range. For the model, land area was estimated at .165 and .190 percent of total area. The sum of the two village soils combined, (3) and (4), roughly equal the total area of sorghum observed in cropping patterns (i.e., 28 percent modal average in Table 5.19).

5) Bush fields occupy the largest fraction of land area. As argued in Chapter IV, it is not constrained by fixed endowments. Rather, its area is constrained by the supply of labor at critical time periods (e.g., first weeding of major cereals). Its cultivated area may diminish or expand with labor reallocations among crop enterprises, adoption of animal traction or changes in labor supply.

Areas of land in modern irrigated agriculture and AVV reclaimed areas were taken from actual hectares cultivated in 1980 (Table 2.4 and Appendix 1, Table A2.1, respectively).

Supply of Modern Inputs

Endowments of donkey teams, b^d, and oxen teams b^o, are based on 1978/79 stocks data (Appendix 1, Table A1.18), a 90 percent rate of utilization and a growth rate of 15 percent from 1978 to 1980. The available supply of fertilizer is taken from 1979-81 data on average utilization of engrais coton (Appendix 1, Table A1.17).

Other Variables and Restrictions

Table 5.20 contains estimates of remaining variables in the model. These include FPRD, representing the incidence of shifting cultivation in regional farming systems; the proportion of chemical inputs, CDTMI, purchased on credit; proportion of chemical inputs, OFFMI, and animal traction units, OFFAT, paid for with revenues from sales on the official market; annual debt payments ψ^{d*} and ψ^{o*} for animal traction teams purchased on credit; and the area of land lying within the bounds of cotton schemes, TOTAREA * LCTSCHM.

Minimum and maximum bounds, G_k, on production activity 'k' are represented by the equation

$$(5.9) \quad G_k = CONS_k * RURPOP_h$$

Table 5.20. Estimates of Other Variables, Regional Supply Models, Burkina Faso.

		North	Central	East	West	Southwest
Incidence of Fallow:	FPRD[a/]	50	50	7	7	7
Proportion of Chemical Inputs Purchased on Credit:	CDTMI	.75	.75	.75	.75	.75
Forced Input Purchases with Official Sales:	OFFMI	.75	.75	.75	.75	.75
	OFFAT	.35	.40	.25	.40	.40
	ψ^{d*} ('000 FCFA)[b/]	18.5	18.5	18.5	18.5	18.5
	ψ^{o*} ('000 FCFA)[b/]	43.2	43.2	43.2	43.2	43.2
Area in Cotton Schemes:	LCTSCHM[c/]				.40	.24
	TOTAREA ('000 ha.)				275.8	432.5
	LHQ				.19	.19
Bounds (maximum; a "-" implies minimum):						
Rural Population	RURPOP ('000)	1591	2051	429	679	872
Maize/Capita		-4.6	-7.7		-17.5	
Red Sorghum/Capita		-1.5	37.0	10.0		-30.0
Starchy Tubers/Capita						30.0

a/ A 50 implies low quality bush land is 50 times the area of fertile soils resulting from fallow. Thus, shifting cultivation is nearly non-existant. A 7 implies two years of fertile land after breaking of fallow are followed by 14 years of permanent cultivation before land is returned to fallow.

b/ Loan payments on animal traction teams, ψ^{d*} and ψ^{o*} are based on a four year loan period, interest rate of 8 percent, costs of draft animals and equipment in Appendix 5 and 10 percent down payment. These terms are consistent with credit offered by CNCA.

c/ Percent of land in cotton schemes is extrapolated from estimates of total hectares of cotton by region (Table 2.4) and percentage cotton in the crop mix of cotton producing farms (IRCT, 1981/82, and Schar, 1983).

where RURPOP is rural population in region 'h' in 1980 (from Appendix 1.14 and a growth rate of 1.72 percent) and $CONS_k$ is minimum or maximum consumption of commodity 'k' per rural inhabitant. A minimum consumption constraint on maize is imposed to ensure there is sufficient grain for the hungry season. Production of red sorghum is constrained to meet estimated regional demands for beer making and livestock feed. Production of starchy tubers is constrained in the southwest by regional consumption requirements. Data in Table 5.20 show maximum bounds on production (minimum if negative) for regions where constraints are binding.

Conclusion

This chapter drew on the empirical farm management literature and official data in Burkina Faso to empirically estimate the theoretical supply model developed in Chapter IV. Data underlying empirical development of the five regional supply sub-models (for the north, central, east, west, and southwest regions) were described along with an analysis of data strengths and weaknesses. This completes the description of the supply side of the market equilibrium model. Attention now turns to the construction of an aggregate commodity balance sheet in Chapter VI which provides the basis for estimating demand in Chapter VII. The validation of supply sub-models is left for Chapter VIII, where base model results are presented.

CHAPTER VI

COMMODITY BALANCE SHEET AND MARKET PRICES

This chapter deals with commodity supply, utilization, trade and prices in the agricultural sector of Burkina Faso. Sparse data on trade and consumption are combined with government production figures to estimate a commodity balance sheet for the country. The balance sheet serves two purposes. It ensures that proper accounting relationships between supply, utilization, and trade are met. It also generates a consistent set of utilization estimates for estimating demand in Chapter VII. This procedure is necessary because data on utilization are not available in official statistical accounts. Also, consistent data are essential for benchmarking model parameters and for ensuring accurate model performance.

Following that, price information from various secondary sources are pooled to estimate base period prices by commodity and region. Commodity prices include those in private and official markets. Inter-regional price differentials are calculated to estimate marketing margins. These in turn are applied as restrictions to ensure that price estimates in the private market are consistent across regions.

Quantities demanded and prices provide data for estimating private market demand in Chapter VII. Marketing margins are used in price linkage equations in the sector model.

Aggregate Commodity Balance Sheet

Commodity balance sheets equate production plus imports of a commodity in a region with consumption less exports (net of stock adjustments and losses). Official estimates of regional production and international trade are routinely reported in statistical bulletins published by the Ministeries of Planning and Rural Development. However, no official estimates of trade or consumption at the regional (ORD) level are available. In order to estimate regional demand, unofficial estimates of trade flows (compiled by USAID) are integrated with official estimates of production in a commodity balance sheet. Stocks are assumed to remain constant. Consumption then is obtained as a residual.

Supply

The data in Table 6.1 show the net supply of tradable commodities (fonio is not traded) at the national level and gross production by region. 'Net total supply' equals 'total production' of the country plus 'official' and 'clandestine' imports less losses. Total production figures are averages (1979-81) computed from official statistics. Losses are assumed to represent 5.5 percent of domestically produced cereals and groundnuts for seed requirements and harvest losses, 8 percent of domestically produced cereals, groundnuts and imports for marketing and storage losses, a 0.65 conversion of paddy into milled

Table 6.1. Commodity Balance Sheet, Supply of Tradable Commodities (Excluding Fonio), Burkina Faso, 1979-81 Average.

('000 tons)

		North[a]	Central[a]	East[a]	West[a]	South-west[a]	Total Production[a]	Official Imports[e]	Clandestine Imports	Less Losses[f]	Net Total Supply
Sorghum	off.est.	97.21	213.24	50.06	106.11	152.68	619.30				
	rev.est.	52.99	197.74	50.06	106.11	152.68	559.58	15.37	8.85	77.48	506.32
Millet	off.est.	106.87	150.28	31.32	51.35	50.59	390.41				
	rev.est.	151.09	165.78	31.32	51.35	50.59	450.13	-	3.45	61.04	392.54
Maize		7.31	15.72	6.33	12.14	69.03	110.53	16.43	2.70	16.45	113.21
Rice (Paddy)		(3.70)	(14.69)	(3.40)[b]	(4.74)	(22.00)	(48.53)	23.60		23.13	49.00
Fonio		0.15	-	-	0.87	4.03	5.05	-	-	0.68	4.37
Wheat Flour (Grain)		-	-	-	-	-		(28.75)		10.23	18.52
Groundnuts[d]		19.41	21.46	5.49	6.20	26.62	79.20	-	-	10.69	47.96
Cotton:	Crude Fiber	1.85	6.02[c]	0.24	28.39	31.59	68.09	-	-	19.07	
	Ginned Cotton										25.19
	Seed										23.83
Cereal Prod.	Gross	130	184	206	253	332	191				
per Capita:	Net	112	157	176	217	280	163				176

Table 6.1. (Continued).

a/ Total production figures are 1979-81 averages (missing values excluded) taken from Ministere du Developpement Rural, Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81, 1981/82. For millet and sorghum, 'off. est.' refers to these official production figures. The second, 'rev. est.', are revised estimates of the author. b/ From AGROPROGRESS (1982, p. 96) due to incomplete data in official statistics. c/ Includes 2.6 thousand tons of cotton from the AVV. d/ Bambara nuts may also be included because official statistics are titled 'Arachides'. e/ Figures are 1979-81 averages taken from FAO data in Appendix 1, Table A1.8 except for maize where 1977-79 estimates by INSD in Appendix 1, Table A1.9 are used (FAO data exclude maize flour equivalents). f/ Losses are estimated at 5.5 percent for harvest loss and seed requirements of domestically produced commodities, 8.0 percent marketing and storage losses for domestically produced commodities and imported cereals, a 0.65 conversion of paddy into milled rice, a 0.70 conversion of wheat into flour, a 0.70 shelling rate for groundnuts and conversion of seed cotton into ginned cotton and seed at rates of 0.37 and 0.35, respectively. Cotton losses are included in conversion rates.

rice, and a 0.70 milling and shelling rate for wheat and groundnuts, respectively. Conversion rates of raw cotton into ginned cotton and seed are 0.37 and 0.35, respectively.[1/] Supply then represents grain and flour equivalents of sorghums, millet and maize, milled rice, wheat flour, and ginned cotton and seed (less seed requirements, harvest and post-harvest losses).

'Official imports' include trade reported for the private and public sectors in official accounts. Food aid comprises the largest portion of public imports (Appendix 1, Table A1.9). 'Clandestine' imports are incorporated in the balance sheet to account for the sizeable illicit trade across the country's borders which purportedly takes place. There are no estimates (objective or subjective) of the magnitude of clandestine trade across the country's borders. Thus, a figure of 15,000 tons is assumed, the mix determined by the production mixture of commodities in the west and southwest regions (areas adjacent to Mali, Ivory Coast and Ghana where clandestine imports normally originate). Between time of importation and time of final consumption, 8 percent of total imports are assumed lost in the marketing process.

Two sets of production estimates are shown for millet and sorghum. The first set are official production figures, taken from government sources. The second are revised estimates of the author.

1/ Percentage losses, milling and conversion rates assumed in this analysis are summarized from the World Bank (1981) and unofficial government estimates.

Independent estimates of crop mix (area harvested) in farm level studies consistently show a higher proportion of millet and less sorghum in the north and central regions than is implied by official sources.[2/] It is the author's opinion after reviewing both data sources and considering the poor data collection techniques employed by the government in making crop production estimates, that government sources exaggerate the extent of sorghum production. In developing supply models for these regions, on-farm estimates of millet and sorghum were used as "benchmarks" for area harvested. The revised estimates of millet and sorghum in Table 6.1 are adapted from model simulations with the combined total production of millet and sorghum, from official sources, maintained.

With the revised estimates, Burkina Faso's supply of cereals in 1979-81 averaged 1,084.0 thousand tons, including 506.3 thousand tons of sorghum, 392.5 of millet, 113.2 of maize, 49.0 of milled rice, 4.4 of fonio and 18.5 thousand tons of wheat flour. No distinction is made between white and red sorghum in official production statistics. Also, 'groundnuts' are ambiguously defined in official accounts and may include crops such as bambara nuts. Taking this joint interpretation as given, groundnuts (plus bambara nuts) averaged about 48.0 thousand tons after shelling and losses. Total cotton production amounted to 68.1 thousand tons or 25.2 thousand tons of ginned fiber and 23.8 of cotton seed after processing.

2/ See M. Roth, (1986 forthcoming) for a synthesis of these on-farm estimates of area cultivated.

Net cereal production per capita in Table 6.1 ranges from 112 kg./capita in the north to 280 kg./capita in the southwest, averaging 163 kg./capita for the nation overall. With imports included, the total supply of cereals, net of losses, is 176 kg./capita.

Trade

Given the estimates of total supply in Table 6.1, levels of consumption or inter-regional trade could be derived, provided data were available for one or the other. However, no 'official' estimates of either exist in the literature. USAID (1984) provides perhaps the best source of data on trade flows of coarse grains, wheat and rice. No data are available for groundnuts. The USAID data are shown in Table 6.2 (1980/81 and 1981/82 averages). Estimates have been lowered to account for lower import levels of wheat, rice and coarse grains corresponding to the 1979-81 period. Their estimates of the distribution of official wheat imports came from conversations with the donor community, ministry officials and OFNACER. The distribution of official rice imports were provided by OFNACER, CRS and PAM. Estimates of private inter-regional trade in rice were inferred from interviews with the Chamber of Commerce, merchants and the transport union. Inter-regional trade in coarse grains was computed from estimates of production, per capita demand and population by region.

Imports labeled 'official' in Table 6.2 are import levels reported by public sources in Appendix 1, Tables A1.8 and 1.9. They include food aid and public and private transactions. The term 'Inter-Regional Trade' shows the net movement of cereals originating within the country. It includes trade by private merchants and the

Table 6.2. Domestic and International Trade in Coarse Grains, Wheat and Rice, Burkina Faso.

		Coarse Grains				Wheat		Rice	
		Clandestine Imports[ac/]	Off. Imports Inc. Food Aid[bc/]	Inter-Reg. Trade[cd/]	Clandestine Exports (Niger)	Off. Imports Inc. Food Aid[b/]	Off. Imports Inc. Food Aid[b/]	Inter.-Reg. Trade[c/]
		tons						
North	Centre Nord	3,000	5,300	14,875		1,830	1,595	500
	Yatenga	3,250	7,420	28,525		1,665	1,755	2,870
	Sahel	2,500	3,180	4,185		925	640	1,050
Central	Centre	1,750	4,240	8,500		11,090	10,205	1,145
	Centre Ouest	1,250	3,180	14,725		2,320	2,550	1,845
	Centre Est	1,250	1,590	3,600		1,100	795	-850
East	Est	1,500	2,120	-	-5,000	1,100	795	-650
West	Volta Noire		2,120	-19,250		1,805	795	-645
South-west	Bauts/Bassins/ Comoe		1,590	-50,110		5,790	4,145	-5,425
	Bougouriba	500	1,060	-5,050		1,105	325	60
		15,000	31,800	-	5,000	28,750	23,600	-

a/ Data are subjective estimates of coarse grains at final destinations after entering the country through illicit market channels.

b/ Official imports of grain including that of food aid (1979-1981 average) computed from Appendix 1, Tables A1.8 and A1.9.

c/ Regional trade flows (clandestine and official) are adapted from USAID/Upper Volta, 'Regional Cereal Balance Sheets' for 1980 and 1981.

d/ Includes trade in both private and official sectors.

government's cereals marketing board, OFNACER. 'Clandestine' trade refers to grain which illegally flows across the country's borders.

The trade flows reported in Table 6.2 are intuitively plausible. In the north, the most serious deficit region, around 72.2 thousand tons of coarse grains, 2.6 thousand tons of wheat and 8.5 thousand tons of rice are imported. The next most serious deficit area, the central region, receives net imports of coarse grains totalling 40.1 thousand tons, 14.5 thousand tons of wheat and 15.7 thousand tons of rice. A large fraction of net imports in the central region goes to the urban market in Ouagadougou, though USAID does not provide a breakdown of rural-urban markets.

Trade in domestic coarse grains originates mainly in the west (net exports of 19.3 thousand tons) and southwest regions (net exports of 55.2 thousand tons) where productivity is highest. The east region is a small net exporter overall, due mainly to the illicit outflow of grain over the border with Niger. No data are available on clandestine trade in cereals. Imports of grain were set at 15,000 tons (from Mali, Ivory Coast and Ghana) and exports at 5,000 tons (to Niger) based on 'sizeable' trade flows which reportedly take place.[3/] (To gain perspective on the significance of these figures, 20,000 tons of grain traded through clandestine channels is equivalent to 1000 trucks

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3/ There was no consensus among "experts" in the country on the extent of clandestine trade, whether even large or small. No one contacted would hazard a guess of the magnitude of trade that might take place. Information on the location of trading routes and direction of trade came from personal conversations with Traori Bonniventure, Agricultural Office, USAID, and Tim Mooney, OFNACER during 1984.

with 20 ton capacity crossing the border annually, a figure which seems plausible.)

The largest importers of wheat and rice are the Centre and Hauts Bassins ORDs which contain the two main urban centers, Ouagadougou and Bobo-Dioulasso, respectively. The Centre ORD receives net imports of 11.1 thousand tons of wheat (39 percent of total) and 10.2 thousand tons of rice (43 percent), excluding rice imported through private inter-regional trade. Likewise, the Hauts Bassins/Comoe' ORD receives imports of 5.8 thousand tons of wheat (20 percent) and 4.1 thousand tons of rice (17.6 percent). However, the region is a net exporter of rice overall, since it is the major supplier of domestically grown rice in the country.

Overall, 74.4 thousand tons of domestically produced coarse grains and 7.6 thousand tons of domestically produced rice move between ORDs. Combined, these represent around 7.1 percent of total cereals production (computed from Table 6.1). This figure is lower than the 15 percent used by the government to estimate grain marketed, but it ignores trade within regions. (Presumably, considerable trade exists between households and local markets within a region that is not accounted for in grain movements between ORDs.) If clandestine and official imports of coarse grains, wheat and rice (amounting to 104.2 thousand tons) are included, inter-regional grain shipments represent over 16.0 percent of gross production and 14.8 percent of gross cereals supply.

Official Market Demand

Up to this point, no distinction has been made between 'official' and 'private' markets when discussing commodity flows. The data in Tables 6.3 and 6.4 pertain to marketing activities in the government controlled official market. Table 6.3 reports average food aid imports received in 1979-81 and "estimated" levels of cereals bought by OFNACER, groundnuts by the CSPPA and cotton by SOFITEX from domestic producers.

Levels of food aid imports in Table 6.3 are adapted from estimates reported by USAID (1984) for 1980. Around 30,000 tons of coarse grains, 5,500 tons of rice and 3,500 tons of wheat were received by the government. While data in Tables 6.2 and 6.3 are not directly comparable (Table 6.2 contains three-year averages of cereal imports; estimates of food aid in Table 6.3 are for 1980 alone), food aid represented roughly all of total imports in coarse grains, 23 percent of total rice imports and 12 percent of total wheat imports. The remainder were handled through the private market. The commodity composition of food aid was inferred from the mix of total coarse grain imports in Appendix 1, Table 1.9 given the assumption that millet imports are zero.[4/]

Along with receipt of food aid, the government through OFNACER acquired 14,100 tons (1979-81 average) of cereals from domestic

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4/ Imports of millet and sorghum are not separately given in official statistics. The assumption of zero imports is based on observations that little millet is traded internationally (Roth and Abbott, 1983).

Table 6.3. Commodity Procurements and Food Aid Imports, Supply of Official Market Commodities, 1979 to 1981. a/

	North	Central	East	West	Southwest	Total[b/] Cereal Purchases	Total[d/] Aid Imports	Total
	(tons)							
White Sorghum	650	2300	2080	3300	1370	9700	15,370	25,070
Millet	500			400		900		900
Maize					1200	1200	16,430	17,630
Paddy (Rice)[e/]					2310	2310	(5,500)	(7,000)
Wheat Flour							2,450	2,450
Groundnuts (Shelled)[c/]					757			757
Cotton: Crude Fiber[c/]	896	4905	95	28,400	31,567			65,863
Ginned Fiber								24,369
Seed								23,052

a/ Marketing of cereals is handled by OFNACER, groundnuts by CSPPA and cotton by SOFITEX. b/ Total cereal purchases of 13,300 tons (1979-1980 average) is taken from Ministere du Developpement Rural, Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81, 1981/82, p. 114. The mix of cereals is adapted from cereal percentages obtained by OFNACER in 1978. (From World Bank, "Upper Volta, Agricultural Issues Study," p. 230). The regional distribution of cereals purchases is adapted from Office National des Cerealos, "Plan de la Campagne National de Commercialisation Cerealiere, 1982-1983," p. 2. c/ Figures for cotton and groundnuts are taken from Ministere du Developpement Rural, Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81, and 1981/82, pp. 115-116 for cotton and pp. 142-143 for groundnuts. d/ Data on food aid imports are from USAID (1984) for 1980. e/ Figures in parentheses are for milled rice.

Table 6.4. Market Rationing of Food Aid and Domestically Purchased Cereals, Official Market. a/

	North	Central	East	West	Southwest	Ouagadougou	Bobo-Dioulasso	Export Markets	Total
	(tons)								
White Sorghum	11,500	5,870	1,000	1,000	100	4,500	1,100		25,070
Millet	900								900
Maize	8,300	3,930	1,000	1,000	200	2,000	1,200		17,630
Rice	1,375	800	200	200	200	2,825	1,400		7,000
Wheat	195	330	70	105	105	980	665		2,450
Groundnuts (unshelled)								1,081	
(shelled)								757	757
Cotton: Crude Fiber								65,863 b/	
Ginned Fiber								24,369	24,369
Seed								23,052	23,052

a/ Rationing rules governing distribution of food aid and domestic purchases are adapted from USAID (1984) and subjective judgement. b/ Data on ginned cotton exports do not equate with actual export figures in Table 6.5 because of data reporting errors, inaccurate conversion rates and no allowance for inventory adjustment.

producers. The composition of cereal procurements is not provided in official accounts, but based on recent buying campaigns (Office National des Cereals, 1982) and OFNACER operations in 1978 (World Bank, 1981, p. 230), the breakdown was estimated as 9,700 tons of white sorghum, 900 tons of millet, 1200 tons of maize and 2,300 (1,500) tons of paddy (rice). Over 70 percent of cereals were obtained in the east, west and southwest regions where private market prices are lower compared, with the fix-rate producer prices offered by the government. Grain procurement targets set annually by the government are normally around 30,000 to 40,000 tons, however, suggesting official 'producer' prices are still low compared with prices in grain surplus regions.

In total, OFNACER held supplies of 13.3 thousand tons of domestically procured cereals (including milled rice) plus 39.8 thousand tons of food aid. Excluding food imports, OFNACER's market share was around 16.2 percent of trade in domestically produced cereals (82.0 thousand tons of coarse grains and rice), consistent with the range of 10 to 20 percent commonly used by the government. With clandestine and official imports of cereals included (104.2 thousand tons), OFNACER's market share is around 28 percent. OFNACER's market share increases because most imported cereals are distributed through the official market.

Data for cotton are actual purchases of crude fiber by SOFITEX over the period 1979-1981. SOFITEX purchased around 65.9 thousand tons of seed cotton, nearly all of the nation's total production (68.1 thousand tons). No data are available on CSPPA operations for groundnuts, so actual exports of 757 tons (shelled) are assumed.

Table 6.4 contains "estimates" of commodity sales in the official market by point of destination. These data represent quotas for rationing the supply of commodities procured through official market operations. Since stocks are assumed to remain constant, total supplies in Table 6.3 and rations in Table 6.4 sum to zero (marketing losses of 8 percent are not yet deducted in Table 6.4 to simplify accounting). For political reasons, data on official cereals distribution is suppressed by the government. Consequently, estimates are based on fractionary evidence compiled from various sources, particularly from USAID (1984), and subjective judgement.

The market rationing scheme in Table 6.4 is biased toward the north and central regions and Ouagadougou. The 'north' receives 22.3 thousand tons of cereals and wheat flour, representing 42 percent of total volume on the official market. The central region and Ouagadougou receives 10.9 and 10.3 thousand tons, representing 21 and 19 percent of OFNACER sales volume, respectively. The regional bias implied by these figures can be a source of contention. This proved to be the case in 1984 when the ORD of Volta Noire, which historically is a major supplier of OFNACER grain, experienced a severe drought and sought return of grain it had supplied to OFNACER in the past.[5/]

5/ This was possibly due to the ORD's confusion over government involvement in both grain marketing and cereal bank programs.

Regarding cotton, SOFITEX would have been able to export 24.4 thousand tons of ginned cotton in 1979-81, based on the simple conversion rate of 0.37 (ginned to seed cotton ratio). Actual exports were 23.8 thousand tons, reflecting the monopoly powers held by SOFITEX in the cotton market.

Utilization

Three further problems need to be addressed to estimate levels of commodity demand on a regional basis. The first involves determining levels of trade of individual commodities from estimates of trade in coarse grains. The second entails estimating levels of consumption of rural versus urban populations within the Centre and Hauts Bassins/Comoe ORDs. The third is concerned with estimating demand for groundnuts and cotton, for which estimates of trade and consumption are unavailable.

To handle the first problem, concerned with trade of individual coarse grains, trade flows in Table 6.2 are broken down based on the production mix of the west and southwest regions where trade originates. This composition is 59 percent sorghum, 23 percent millet and 18 percent maize. Likewise, official imports of coarse grains by region are broken down by the mix of cereals reported by INSD (Appendix 1, Table A1.9). This mix was 48 percent sorghum and 52 percent maize. These fractions are applied uniformly in all regions.

Concerning the second question of commodity demand in urban areas, additional information is needed on the composition and levels of rural versus urban diets. Appendix 6 contains a synthesis of selected food budget studies performed in Burkina Faso and studies

comparing rural and urban diets in Mali and Senegal. In Table A6.1 of Appendix 6, food budgets of consumers in Ouagadougou and Bobo-Dioulasso are contrasted with those of consumers in surrounding rural areas. Urban consumers are shown to consume 1.5 to 2 times more fruits and vegetables, 3 to 5 times more oils, 4 to 8 times more tubers and 5 to 6 times more meat. Consequently, urban consumers tend to consume less cereals than their rural counterparts (Tables A6.1, A6.6 and A6.7). Further, cereals in diets of urban consumers contain higher fractions of wheat and rice and less sorghum and millet than those of rural households.

Table 6.5 contains levels of regional cereals demand estimated by the author. Estimates are based on production figures in Table 6.1, trade flows in Table 6.2, previous assumptions made on the composition of trade flows of coarse grains and the synthesis of food budget surveys in Appendix 6. Estimates are also presented on a per capita basis to permit comparison across regions.

The mainly rural populations of the north, central, east, west and southwest regions are estimated to consume 0 to 4 kg./capita fonio, 2 to 4 kg./capita wheat, 4 to 8 kg./capita rice and 10 to 15 kg./ capita maize (excluding the southwest region where maize is more prominent in rural diets). Consumption of sorghum plus millet range from 138 kg./capita in the north to 175 kg./capita in the west, though the fraction of sorghum increases and millet declines as one moves towards the south, west or east. Demand by urban populations contains higher fractions of wheat (24 to 26 kg./capita) and rice (34 to 36 kg./capita), substituting mainly for millet (11 to 13 kg./capita) and sorghum (69 to 70 kg./capita).

Table 6.5. Commodity Balance Sheet, Demand for Tradable Commodities, Burkina Faso, 1979-1981 Average.

	North	Central	East	West	South-west	Ouaga-dougou	Bobo-Dioulasso	Exports to Niger	Exports through Abidjan	Total Utilization
	('000 tons)									
Sorghum	85.96	180.27	42.26	80.81	92.28	13.16	8.63	2.95	-	506.32
Millet	143.78	147.76	26.40	39.80	29.83	2.44	1.38	1.15	-	392.54
Maize	23.14	21.20	5.91	8.79	46.05	2.22	5.00	0.9	-	113.21
Rice	10.27	16.04	2.00	2.75	6.83	6.82	4.28	-	-	49.00
Fonio	0.13	-	-	0.75	3.49	-	-	-	-	4.37
Wheat Flour	3.34	5.66	.71	1.17	2.14	3.20	2.30	-	-	18.52
Groundnuts	11.06	14.34	3.41	5.81	7.55	2.63	2.39	-	0.77	47.96
Cotton: Fiber						0.82	0.55	-	23.82	25.19
Seed										
Population	1652	2141	443	692	899	188	125			
Sorghum/capita	51	84	101	117	103	70	69			
Millet/capita	87	69	62	58	33	13	11			
Maize/capita	14	10	15	13	51	12	40			
Rice/capita	6	7	5	4	8	36	34			
Fonio/capita	-	-	-	1	4	-	-			
Wheat (grain equivalents/ capita)	3	4	2	2	3	24	26			
Total	161	174	185	185	202	155	180			

a/ Population figures are taken from 1975 population estimates (Appendx 1, Table A1.14) and a growth rate of 1.72 percent in 1980.

b/ Exports of groundnuts and cotton are three year averages taken from Appendix 1, Table A1.10. Shelled groundnuts are converted to unshelled form at a rate of 0.70.

Per capita consumption of cereals varies from 161 kg./capita in the north to 202 kg./capita in the southwest, showing large differences in prosperity among regions. Urban consumers in Ouagadougou and Bobo-Dioulasso are estimated to consume around 20 kg./capita less cereals on average than rural households in their respective central and southwest regions.

Whether these estimates accurately reflect levels of food demand in Burkina Faso is difficult to verify. The only base for comparison are food budget surveys in Appendix 6. These lack comprehensive coverage across regions, are very specific to locale and differ widely in methodologies (i.e., survey time frames vary from one week to one year). The data in Table 6.6 are annual equivalents of consumption estimates in Appendix 6. While estimates vary widely among studies--from 100 to 308 kg./capita in the north, 135 to 200 kg./capita in the central, 90 to 194 kg./capita in the east and 163 to 196 kg./capita in the southwest--they appear broadly consistent with demand estimates found in this study.

Concerning the third problem--consumption and trade of groundnuts and cotton--several assumptions are made. First, consumption of groundnuts (shelled) and groundnut oil equivalents are assumed to rise with income. Hence, demand was estimated at 7 kg./capita in the north and central regions and 8 kg./capita in the east, west, and southwest. Consumption in Ouagadougou and Bobo-Dioulasso are estimated at 14 and 19 kg./capita, respectively, due to higher demand for oils in urban areas (Appendix 6, Table A6.1). Nearly all cotton fiber is exported, but the remainder is assumed to be consumed by cottage industries in Ouagadougou and Bobo-Dioulasso in proportion with resident population.

Table 6.6. Estimates of Total Cereals in Consumer Diets, Selected Studies, Burkina Faso.

Reference		North	Central	East	West	Southwest	Ouagadougou (Urban)	Bobo-Dioulasso (Urban)
		(kg./capita/year)						
Republique de Haute-Volta, 1963-64[a/]			162			163	138	177
Republique de Haute-Volta, 1978:[b/]	Noaka	100						
	Guilla	160						
	Goungla	157						
ICRISAT,[c/] 1982	Oure	308						
	Kolbila	281						
	Koho	256						
SAFGRAD/FSU,[d/] 1983-84	I	150	163	194	255			
	II		135					
Republique de Haute-Volta, 1978-79:[e/]	Diapaga			159				
	Fada			146				
	Diabo			90				
Dumont,[f/] 1978-79			200			268		
ORANA,[g/] 1953-54						296		

a/ From Appendix 6, Table A6.1. b/ Summarized from Appendix 6, Table A6.3. c/ Data were collected in July and August, when food shortages occur. Estimates for Oure is an average of two ethnic groups. From ICRISAT, 1982 Annual Report, p. G90. d/ Consumption surveys were conducted from December 1983 to November 1984 in 30 households each in the villages of Bangasse near Kaya in the North; Nedogo (I) near Ouagadougou and Poedogo (II) near Manga in the Central region; Diapangou near Fada in the east and Dissankuy near Solenzo in the west. From SAFGRAD/FSU, 1984 Annual Report, p. 99. e/ Consumption surveys were conducted in 12 villages in the zones of Diapaga, Fada and Diabo from December 1978 to November 1979. A total of 42 households with 330 consumers were surveyed. From RHV/MDR, Rapport Annuel, 1980-81, p. 77. f/ From Appendix 6, Table A6.4. g/ From Appendix 6, Table A6.5.

Commodity Prices

Accurate price data are essential for benchmarking the model. Consumers base their purchase decisions on prices; producers base their planting decisions on expected prices, which in turn depend on historical prices; the direction and quantity of inter-regional trade depends on inter-regional price differentials. For accurate model performance, a consistent price series across commodities and regions is crucial.

Price analysis in Burkina Faso, as in many LDCs, is severely hampered by lack of reliable price statistics. Little price information are available for prices actually received by producers or paid by consumers for the bulk of commodities traded in the marketplace. Berg (in CRED, 1977) in his comprehensive study of cereals marketing in Burkina Faso, outlines four main sources of price data, not all of which are published:

(1) Government fixed or announced official prices for cereals, groundnuts, cotton, sesame and sheanuts;

(2) Price quotations for a wide number of goods in Ouagadougou markets by the Service de Statistiques (or INSD) of the government;

(3) Price data collected by the Banque Centrale des Etats de l'Afrique de l'Ouest (BCEAO) in Ouagadougou markets, independent of the government; and

(4) Price information collected by the ORDs in rural markets. In principle, the ORDs collect prices (for millet, sorghum, maize, paddy, rice, groundnuts and cowpeas) for periodic (weekly) markets in the country (Berg in CRED, 1977). In

practice, staffing problems and lack of funds usually limit data collection, compilation and publication efforts.

A fifth category may be added to cover occasional price observations provided by various agencies in research reports.

In this section, data from sources (1), (2) and (5) are assimilated to construct the matrix of base period prices for the model. Price measurements collected by the BCEAO in (3) are not readily available for public use. Berg has observed that considerable data have been collected by the ORDs in (4), but these are not tabulated or made available in published form.

With reference to INSD prices in (1), Table 6.7 shows average annual prices for select commodities in the Ouagadougou market. The set is comprehensive in coverage, representing the sole time series of prices known to the author. Up through 1979, prices were routinely reported for a wide variety of goods. Thereafter, publication ceased.

Prices are shown to have risen sharply during the 1970s. Between 1968 and 1979, the World Bank (1981b, p. 26) estimates that prices (INSD series) of millet and sorghum rose on average 19.0 percent annually, maize 20.5 percent, rice 9.5 percent and bread 7.2 percent. By 1979, prices of millet and sorghum reached 136 FCFA/kg. and maize, 183 FCFA/kg.

The levels and trend of these prices appear spurious. First, while prices of millet, sorghum and maize more than doubled between the 1973-76 and 1977-79 periods, cereals supply increased around 7 kg./capita (Appendix 1, Table A1.6). Also, GDP over the same period rose at an average annual rate of 8.5 percent while prices of consumer goods rose 7.3 percent. These relatively low growth rates discount the

Table 6.7. Average Annual Prices [a/] of Selected Food Commodities, Ouagadougou Market, 1973 to 1979.[b/]

Commodity	Form	1973	1974	1975	1976	1977	1978	1979	1980
		(Francs FCFA per kg.)							
Millet & Sorghum[c/]	Grain	60	68	45	57	124	124	136	
	Flour	73	70	62	69	105	119	129	
Maize	Grain	69	65	44	57	118	168	183	
	Flour	75	73	76	83	101	113	111	
Rice	Local Red	73	93	121	144	174	165	165	
	Local White	71	65	101	151	174	177	175	
Wheat	Bread[d/]	100	120	125	125	125	125	145	
Manioc	Root	45	53	71	45	80	39	60	
	Flour	90	145	117	229	361	265	-	
Groundnuts	Unshelled	83	60	67	76	110	127	146	
	Shelled	69	92	285	158	190	219	263	
	Oil (liter)	125	158	250	250	310	300	328	
Price Indices (Base 1958)									
Food						353.8	367.7	361.1	463.7
General						271.0	353.7	330.0	370.3

a/ Prices are simple averages of monthly price observations. b/ Based on purchases of very small quantities. c/ Simple average of prices for millet and white sorghum. d/ Official price.

Source: Ouagadougou prices are from Ministere du Plan et de la Cooperation/INSD, Bulletin Mensuel D'Information Statistique et Economique, 1976 and 1979, pp. 28, 29 and World Bank, "Upper Volta, Agricultural Issues Study," 1981, p. 205. Price indices are from BCEAO, Upper Volta, Statistiques et Monetaires, 1983, p. 18.

role of inflation as the cause. Further, price levels are not supported by independent measurements of Ouagadougou prices.

To demonstrate the latter point, Appendix 7 contains a synthesis of agricultural commodity prices reported by various research agencies (corresponding to (5) above). Prices of millet and sorghum in Ouagadougou markets were reported by World Bank and Smith as 70 to 83 FCFA/kg. in 1980 (Tables A7.1 and A7.5), 107 FCFA/kg. by OFNACER in 1981 (Table A7.2), and 75 to 93 FCFA/kg. by OFNACER and Bukowski in 1982 (Tables A7.3 and A7.4). Thus, price quotations of INSD appear high.

Given the dubious quality of INSD estimates, other data sources are required to estimate base period prices. The synthesis of commodity prices, in Appendix 7, provides price data for the cities of Ouagadougou and Bobo-Dioulasso and rural areas. Methodologies across studies incorporate different sizes of markets (urban versus rural village versus rural bush market) at different locations for different years and time of year for different units of measure (i.e., tine versus sack). Thus, prices reported in Appendix 7 can be difficult to interpret. Nevertheless, the data ultimately proved very useful for setting regional prices and relative prices among commodities.

To estimate base-period prices for the analysis, the following procedure was used.

1) Prices of major cereals in the central, east and southwest regions and cities of Ouagadougou and Bobo-Dioulasso were adapted from data collected by the World Bank in March 1980 (Table A7.1). Slight modifications were made to remain

consistent with inter-regional marketing margins (computed in (2) below).

2) Data reported for rural markets in Appendix 7 were compared with a central urban market wherever possible to enable computation of inter-regional price differentials (as in Tables A7.1, A7.2, A7.3, A7.4, A7.5, and A7.6). These were combined with data collected by Bukowski (1986) to estimate marketing margins between regions. With these margins, price levels in the north and west regions were subsequently estimated based on a priori assumptions concerning direction of trade flows.

3) Relative prices among commodities are inferred from Tables A7.1 through A7.8, except wheat, for which data are unavailable. This aspect was particularly difficult since the range of relative prices is wide. For example, the relative price of white sorghum to cowpeas in the central region is reported as 58/65 FCFA in Table A7.1 and 60/105 FCFA in Table A7.5. To resolve these differences, median values and subjective judgement were used.[6/]

Commodity prices and marketing margins estimated with the above procedure are reported in Tables 6.8 and 6.9. As expected, prices are highest in the north, where grain shortages are most acute, and lowest

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6/ Exercising this procedure requires considerable judgment and a priori expectations of direction of trade flows between regions and of price levels in absence of trade. The procedure is effective and is the only approach available, given the severe data limitations which exist.

Table 6.8. Estimates of Private Market Prices for Traded and Non-Traded Commodities, 1980.

Commodity	North	Central	East	West	South-west	Ouaga	Bobo	Frontier: Niger[d/]	Frontier: Mali	Abidjan[e/]
	(FCFA per kg.)									
Traded:										
White Sorghum	83	58	46	54	44	72	61	61	44	50
Red Sorghum	76	53	42	50	40	66	55	57	40	-
Millet	85	59	47	55	45	72	62	62	45	-
Maize	82	56	43	53	43	69	59	58	43	54
Rice (Paddy)[a/]	99	83	76	81	75	-	-	-	-	-
(Milled)	153	128	117	125	115	142	132	-	-	-
Wheat Flour[b/]	143	137	158	128	139	132	122	-	-	54
Groundnuts (unshelled)[c/]	109	92	69	84	68	-	-	-	-	-
(shelled)	156	131	99	120	97	138	121	-	-	94
Cotton (Ginned Fiber)[f/]	-	-	-	-	-	223	234	-	-	283
Non-Traded:										
Fonio	72	50	-	47	40					
Bambara Nuts	106	72	59	66	58					
Cowpeas	147	102	78	86	70					
Soybeans	-	-	72	-	-					
Starchy Tubers	-	-	-	-	40					
Straw	4	3.5	3.5	3	2.5					

a/ Based on 0.65 conversion of paddy to milled rice. b/ Estimated from Table 6.9 based on 0.70 milling conversion and world price of wheat. c/ Based on a 0.70 shelling conversion. d/ Prices are subjectively set 15 FCFA/kg. higher than prices in the Eastern region to cover transportation costs. e/ Figures are FOB prices in Abidjan for exported commodities and CAF Abidjan for imported commodities adapted from Appendix 8. f/ Figures are for ginned cotton fiber, computed from Appendix 8.

Source: Figures are estimated from Appendix 7 and 8.

Table 6.9. Market Margins Assumed Between Regional Markets in the Analysis.[1/]

(FCFA/Kg.)

	North	Central	East	West	South-west	Ouaga	Bobo	Frontier: Mali	Frontier: Niger	Abidjan
	(Cereals and 'Other' Good)									
North		-	40	29	-	12	-	-	-	-
Central	-		18	20	-	13	16	-	-	-
East (Groundnuts	60	32		-	-	26	-	-	15	-
West and	44	30	-		12	18	7	10	-	-
Southwest Coton)	-	-	-	18		-	16	-	-	-
Ouagadougou	18	20	39	27	-		11	-	-	-
Bobo-Dioulasso	-	24	-	11	24	(17)11		-	-	26-31[2/]
Frontier: Mali	-	-	-	15	-	-	-		-	-
Frontier: Niger	-	-	23	-	-	-	-	-		-
Abidjan	-	-	-	-	-	-	26(49)[2/]	-	-	

1/ Note, the presence of cost coefficients indicates that possibilities for trade between respective regions have been included in the model. A '-' implies no direct trade is possible though intermediate markets may occur. Maket margins are the same to and from respective regions; the matrix of market margins is thus symmetric.

2/ Margins vary by type of commodity (Appendix 8). Costs for sorghums, millet and maize from Abidjan to ex-depot Bobo are 26 FCFA/kg. (7.0 for transport and handling in Abidjan, 5.5 for importer commission, 11.9 for rail transport and 1.8 for handling in Bobo). For wheat and rice, costs are 31 FCFA/kg. (7.0 for transport and handling in Abidjan, 10.4 for importer commission, 11.9 for rail transport and 1.8 for handling in Bobo). For peanuts, the cost from Bobo to Abidjan is 26 FCFA/kg. including 1.8 for handling in Bobo, 8.4 for rail transport to Abidjan, 8.5 for exporter commission and 7 for transport and handling in Abidjan (freight not included). Figures in parentheses are margins for cotton, calculated in Appendix 8.

in the southwest, where agriculture is highly productive. Prices are also low in the east due to the high producivity of agriculture (compared with the north and central regions) and high marketing costs (due to poor infrastructure) between it and bordering regions.

Within rural regions, prices are the amount producers receive and consumers pay (FCFA/kg.) for agricultural commodities on the private market. Marketing margins are assumed to be zero. Realistically, a margin should drive a wedge between farm-gate and consumer prices within a region. But, eliminating margins simplifies the analysis without loss of model behavior. Marketing losses of 8 percent are charged to maintain consistency in the food balance equation.

Price differentials between regions are large. Margins of 15 to 30 FCFA/kg. are not uncommon between regions, reflecting the high transactions cost of marketing goods in the country (Bukowski, 1986). Price linkages between the Bobo-Dioulasso market and FOB prices at Abidjan (26 to 31 FCFA) are taken from Appendix 8. Margins for groundnuts appear larger than for cereals (by an order of magnitude of 1.5) though it remains unclear why this should be so. One possible explanation is that groundnut trade requires special licenses or fees, although this could not be verified.

Table 6.10 contains a time series of official 'producer' and 'consumer' prices offered by the government in its marketing operations. These price series correspond to data source (2) mentioned earlier. Producer prices are regularly published by the government, but consumer prices are rarely published. The consumer prices in Table 6.10 were taken from secondary sources (not first hand from government sources) because of this problem.

Table 6.10. Producer and Consumer Prices in Official Markets, Burkina Faso, 1977 to 1981.

	Producer Prices					Consumer Prices				
	1977	1978	1979	1980	1981	1977	1978	1979	1980	1981
	(FCFA/kg.)									
Cereals:										
W. Sorghum	32	40	40	45	50	45	57	57	69	80
R. Sorghum		30	32	37	42		47	47	61	75
Millet	32	40	40	45	50	45	57	57	69	80
Maize	32	40	40	45	50	45	57	57	69	80
Paddy (1st Choice)	63	63	63	63	68					
Paddy (2nd Choice)	-	-	-	-	66					
Rice						115	125	125	125	
Wheat (Bread)						125	125	145		
Oilseeds:										
Cowpeas	27	45	45							
Groundnuts (unshelled)	30	37	37	56	88					
(shelled)	44	54	54	82	131					
Other:										
Cotton (1st choice)	55	55	55	55	62					
(2nd choice)	45	45	45	45	45					
Sheanuts	22	23	25	27	43					
Sesame	45	64	91	70	84					

Source: Data for producer prices come from Ministere du Developpement Rural/DEP, Bulletin de Statistique Agricoles, Campagnes 1978/79, 1979/80, 1980/81, 1981/82, p. 113. Official consumer prices for millet, red and white sorghum and maize are taken from World Bank, "Upper Volta, Agricultural Issues Study," 1981, pp. 205-206 and from unpublished data collected in the Ministry of Rural Development.

A comparison of official prices in Table 6.10 with private market prices in Table 6.8 yields several interesting observations. First, with exception of the southwest region, private market prices exceeded official producer prices in 1980. This comparison is not entirely accurate since private market prices in Table 6.8 are annual averages, not harvest prices. The fact that OFNACER encounters difficulty in grain procurement, however, provides supporting evidence for the price data. This helps explain why OFNACER purchases most of its grain in the west, southwest and east regions (Table 6.3), where private market prices are lower. Also, the wide variation in prices, demand and trade highlight the need for a regionally disaggregated model to capture spatial differences in the agricultural economy.

Second, a comparison of official consumer prices (in 1980) with estimated annual prices (private market) in Table 6.8 suggests only consumers in Ouagadougou and the North region stand to gain from buying coarse grains on the official market. This conclusion is somewhat consistent with the market rationing scheme reported in Table 6.4, but likely under-estimates the implicit income transfers which actually occur. Official markets operate mainly during periods of peak seasonal prices (i.e., the soudure). Many OFNACER sales depots do not open until around June or July. Due to wide inter-seasonal variation in private market prices, sizable income transfers can accompany peak season rates, yet not show up in annual averages. It is important to bear this seasonal effect in mind when choosing levels of consumer prices for estimating income subsidies and demand in the next chapter.

CHAPTER VII

DEMAND

The analysis in Chapter VI highlighted the weaknesses of price and consumption data in Burkina Faso. Neither cross-sectinoal nor time series data are available which would permit econometric estimation of demand sub-models. Consumption estimates were calculated via a commodity balance sheet approach. The matrix of regional commodity prices were derived from various secondary sources and computed marketing margins. In this chapter, the price and consumption data are combined with estimates of regional income to estimate complete systems of commodity demand.

Attention is first given to the development of a theoretical model of consumer behavior. The model is an extension of the standard Linear Expenditure System with one major innovation. The System permits commodity purchases in two structurally different markets--a private market, where prices and quantities are unrestricted, and the official market, where prices are fixed and quantity demanded is constrained by market rations. The model is then empirically implemented. Demand parameters for the LES are derived from limited data using the Frisch procedure.

Theoretical Model

A demand system widely applied in empirical research is the Linear Expenditure System (LES). In keeping with the terminology used by Phlips (1974), the LES is derived from the utility function:

$$(1) \qquad U_g = \prod_k (C_{gk} - \gamma_{gk})^{B_{gk}} \qquad k = 1 \ldots s'$$

Utility of consumer 'g', (U_g), is a function of goods C_{gk}, k = 1...s', less a constant γ_{gk}. The term B_{gk} represents the elasticity of utility to changes in ($C_{gk} - \gamma_{gk}$). The term γ_{gk} is referred to as the minimum quantity of good 'k', consumer 'g' requires for subsistence consumption. Applying a logarithmic transformation, the following expression can be obtained:[1/]

$$(2) \qquad u^o = \sum_k B_k \log (C_k - \gamma_k)$$

This is the well-known Stone-Geary utility function. By maximizing (2) subject to the consumer's budget constraint and imposing the normalizing assumption, $\sum_k B_k = 1$, the LES in (3) can be obtained from manipulation of the first order conditions:

1/ Hereafter, the subscript 'g', denoting consumer, is dropped to simplify the presentation.

$$(3) \qquad C_k = \gamma_k + \frac{B_k}{P_k} (Y - \Sigma P_k \gamma_k)$$

where $C_k > \gamma_k$

$0 < B_k < 1$

$k = 1 \ldots . s'$

Demand for good C_k is a function of minimum consumption requirements (γ_k), marginal budget shares (B_k), prices (P_k) and total expenditure (Y). Tastes and preferences are assumed to remain constant, their effects implicit in the values of parameters B_k and γ_k. The demand for good C_k is composed of two parts. First, γ_k, refers to the minimum subsistence level of consumption mentioned earlier. Second, $\sum_k P_k \gamma_k$, measures subsistences expenditures so that $(Y - \sum_k P_k \gamma_k)$ is discretionary income which the consumer allocates among s' commodities in shares B_k/P_k. The term B_k is the marginal budget share of good 'k', estimated as $e_{ky} * (P_k C_k/Y)$, where e_{ky} is the income elasticity of demand and the second term is the average budget share. As Phlips (1974) points out, this system satisfies the general restrictions of demand theory.[2/] In particular it meets Euler's homogeneity conditions as well as adding-up and Slutsky conditions.

Two Market Economy

Equation (3) represents demand for commodity C_k in one market in the private sector of the economy. Now, attention is turned to

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2/ These are properties which take the form of mathematical restrictions on the derivatives of demand functions.

extending the consumer's utility maximization problem to incorporate demand in the government controlled "official" market. In the private market, quantity demanded of good C_k^m depends on prices P_k^m, (k=1,...,s'), set by 'free-market' forces, and income, Y. In the official market, prices P_k^o are fixed by the government, usually at levels lower than P_k^m, to support 'cheap-food' policies. The amount consumers can buy of the official market good C_k^o, however, is constrained by government supplies. The amount of good 'k' the government can sell depends on the level of official 'producer' prices and government procurements, organizational and infrastructural problems which limit purchases, financial limitations stemming from government budgetary problems, changes in stock levels and levels of food aid.

Algebraically, the consumer utility maximizing problem can be written:

$$(4) \quad \max \quad U^o = \sum_k B_k \log (C_k - \gamma_k)$$

subject to:

$$(5) \quad C_k^m + C_k^o \geq C_k$$

$$(6) \quad C_k^o \leq \bar{C}_k^o$$

$$(7) \quad \sum_k P_k^m C_k^m + P_k^o C_k^o \leq Y$$

The consumer's objective function is the same as in (2) with C_k defined as the total consumption of good 'k'. Consumer utility is maximized subject to three inequality constraints. Constraint (5) says that total consumption of good C_k is composed of consumption in the private market, C_k^m, and the official market, C_k^o. The next constraint (6), states that purchases of good C_k^o in the official market cannot exceed $\bar{C}_k^o$, representing fixed government rations. The last constraint (7) says expenditures on goods in the private market, $\sum_k P_k^m C_k^m$, plus expenditures in the official market, $\sum_k P_k^o C_k^o$, cannot exceed the consumer's fixed income, Y. Prices P_k^m and P_k^o, income Y and government fixed supplies $\bar{C}_k^o$ are constants.

Forming the Lagrangian for the problem,

$$(8) \quad \text{maximize } L = \sum_k B_k \log (C_k - \gamma_k) + \sum_k \lambda_k (C_k^m + C_k^o - C_k - S_k) + \sum \lambda_k' (\bar{C}_k^o - C_k^o - S_k') + \lambda_k^y (Y - \sum_k P_k^m C_k^m - \sum_k P_k^o C_k^o - S_k^y)$$

Kuhn-Tucker conditions in equations (9) to (18) can be derived.

$$(9) \quad \frac{dL}{dC_k} = \frac{B_k}{(C_k - \gamma_k)} - \lambda_k \leq 0 \qquad \frac{dL}{dC_k} C_k = 0$$

$$(10) \quad \frac{dL}{dC_k^m} = \lambda_k - \lambda_k^y P_k^m \leq 0 \qquad \frac{dL}{dC_k^m} C_k^m = 0$$

$$(11) \quad \frac{dL}{dC_k^o} = \lambda_k - \lambda_k' - \lambda_k^y P_k^o \leq 0 \qquad \frac{dL}{dC_k^o} C_k^o = 0$$

(12) $\frac{dL}{d\lambda_k} = C_k^m + C_k^o - C_k - S_k = 0 \qquad \frac{dL}{d\lambda_k}\lambda_k = 0$

(13) $\frac{dL}{d\lambda_k'} = \bar{C}_k^o - C_k^o - S_k' = 0 \qquad \frac{dL}{d\lambda_k'}\lambda_k' = 0$

(14) $\frac{dL}{d\lambda_k^y} = Y - \sum_k P_k^m C_k^m - \sum_k P_k^o C_k^o - S_k^y = 0$

$\frac{dL}{d\lambda_k^y}\lambda_k^y = 0$

(15) $\frac{dL}{dS_k} = -\lambda_k \leq 0 \qquad \frac{dL}{dS_k} S_k = 0$

(16) $\frac{dL}{dS_k'} = -\lambda_k' \leq 0 \qquad \frac{dL}{dS_k'} S_k' = 0$

(17) $\frac{dL}{dS_k^y} = -\lambda_k^y \leq 0 \qquad \frac{dL}{dS_k^y} S_k^y = 0$

(18) $S_k, S_k', S_k^y, C_k^m, C_k^o, C_k \geq 0 \qquad (k = 1, \ldots . s')$

The term λ_k^y can be interpreted as the marginal utility of money income, λ_k as the marginal utility of good C_k and λ_k' as the marginal utility of $\bar{C}_k^o$, the government's ration of commodity 'k'. Terms S_k, S_k' and S_k^y are slack variables converting inequalities to equalities.

The examination of three cases lends insight into the economic choices offered the consumer by the official market:

<u>Case 1</u>: Let $P_k^o > P_k^m$, and $C_k^m, C_k^o > 0$. Then from equations (10) and (11), λ_k' can be defined as:

(19) $\lambda'_k = \lambda^y_k (P^m_k - P^o_k)$

When P^o_k exceeds P^m_k and λ^y_k is positive from (17), λ'_k is negative, contradicting (16). This statement implies simply that when offered identical goods, the rational consumer will not choose the official market good if its price is higher .

<u>Case 2:</u> Let $P^o_k = P^m_k$. Then from case 1, $\lambda'_k = 0$, implying the constraint on government supplies $\bar{C}^o_k$ is not binding. The consumer may purchase from zero to $\bar{C}^o_k$ units in the official market; hence, purchases of C^o_k remain indeterminate.

<u>Case 3:</u> Let $P^o_k < P^m_k$ as a consequence of government enacted 'cheap-food' policies in Burkina Faso. Then from equation (19), λ'_k is greater than zero, consistent with equation (16). Assuming λ_k and $\lambda^y_k > 0$, then levels of all slack variables, S_k, S'_k, and S^y_k, are zero. From equation (13), $C^o_k = \bar{C}^o_k$, saying consumers are willing to buy as much of C^o_k as they can at price P^o_k, but are constrained by government rations. Substituting $\bar{C}^o_k$ for C^o_k in equation (14) then gives

(20) $Y - \sum_k P^o_k \bar{C}^o_k = \sum_k P^m_k C^m_k$

That is, expenditures on goods in the private market equals income left over after spending $\sum_k P^o_k \bar{C}^o_k$ on the

official market. In this case, consumer expenditures on C_k^m acts as a residual market, where

$$(21) \qquad C_k^m = C_k - \bar{C}_k^o$$

The implications of Case 3 can be extended to derive the demand system for goods on the private market. Conditions (9), (10) and (11) are equalities by right of assumption that C_k, C_k^m, and $(P_k^m - P_k^o)$ are > 0. Substituting equations (21) and (10) into (9) and rearranging terms gives the expression

$$(22) \quad C_k^m = \frac{B_k}{\lambda_k P_k^m} + \gamma_k - \bar{C}_k^o \qquad (k = 1, \ldots, s')$$

Substituting equation (22) into (20) and imposing the restriction, $\sum_k B_k = 1$, allows one to obtain the following expression for λ_k^y, the marginal utility of money income:

$$(23) \quad \lambda_k^y = \frac{1}{Y - \Sigma P_k^m \gamma_k + \bar{C}_k^o (P_k^m - P_k^o)} \qquad (k = 1, \ldots, s')$$

Substituting λ_k^y in (23) back into (22) gives an expression of C_k^m as a function of prices (P_k^m and P_k^o, k=1,...,s'), income (Y), marginal budget shares (B_k), and minimum subsistence requirements (γ_k):

$$(24) \quad C_k^m = \gamma_k + \frac{B_k}{P_k^m} \left(Y - \sum_j P_j^m \gamma_j + \sum_j \bar{C}_j^o (P_j^m - P_j^o)\right) - \bar{C}_k^o$$

$$(k = 1, \ldots, s')$$

This is the same LES obtained in (3) except for the added terms $\sum_j \bar{C}_j^o(P_j^m - P_j^o)$ and $\bar{C}_k^o$. The term $\sum_j \bar{C}_j^o(P_j^m - P_j^o)$ is the level of implicit income transfer to consumers purchasing $\bar{C}_k^o$ goods on the official market. If we redefine income as monetary income plus income transfers (i.e., $Y^* = Y + \sum_j \bar{C}_j^o(P_j^m - P_j^o)$), then equation (24) can be rewritten as:

$$(24') \quad C_k^m = \gamma_k + \frac{B_k}{P_k^m}\left(Y^* - \sum_j P_j^m \gamma_j\right) - \bar{C}_k^o \qquad (k = 1,\ldots,s')$$

The term $\sum_j P_j^m \gamma_j$ as noted earlier is total cost of the minimum consumption basket. Any excess of income plus subsidy payments, Y^*, over subsistence expenditures is allocated to various goods C_k^m in the private market according to the ratios (B_k/P_k^m), $k = 1,\ldots,s'$. As long as $P_k^m > P_k^o$, consumption of good $\bar{C}_k^o$ affects consumption in the private market in two ways. First, increasing $\bar{C}_k^o$ directly displaces consumption of C_k^m. However, because of the subsidy $(P_k^m - P_k^o)$ associated with the purchase of $\bar{C}_k^o$, there is a secondary income effect. An increase in availability and purchase of government supplies, $\bar{C}_k^o$, or a decrease in the good's 'official' price, P_k^o, raises the level of subsidy to consumers and leads to more consumption of C_k than would occur if the official market were non-existent.

Elasticities

The elasticity response of C_k^m to changes in own-price, cross-prices and income can be computed by taking derivatives of equation

(24). The own-price elasticity of demand, with respect to private market operations, can be written:

$$(25) \quad e^{P}_{kk} = \frac{dC^{m}_{k}}{dP^{m}_{k}} \cdot \frac{P^{m}_{k}}{C^{m}_{k}} = -1 + \frac{(1-B_k)(\gamma_j - \bar{C}^{o}_{k})}{C^{m}_{k}} \qquad (j=k)$$

If $\bar{C}^{o}_{k} = 0$, then expression (25) reduces to the uncompensated own-price elasticity for the ordinary LES in (3) (as shown in Phlips, 1974). However, as $\bar{C}^{o}_{j}$ $(j=k)$ increases, the term $(\gamma_j - \bar{C}^{o}_{k})$ falls but proportionately less than C^{m}_{k}, so e^{P}_{kk} will also tend to rise. When the expression $0 < (\gamma_j - \bar{C}^{o}_{j}) < C^{m}_{j}$, $(j=k)$ holds, then the own-price elasticity is smaller than one, so the good is price-inelastic. Conversely, if $(\gamma_j - \bar{C}^{o}_{j}) < 0$, then the good is price-elastic.

Cross-price effects associated with the private market are of the form:

$$(26) \quad e^{P}_{kj} = \frac{dC^{m}_{k}}{dP^{m}_{j}} \cdot \frac{P^{m}_{j}}{C^{m}_{k}} = -\frac{P^{m}_{j}B_k(\gamma_j - \bar{C}^{o}_{j})}{P^{m}_{k}C^{m}_{k}} \qquad (j \neq k)$$

Again, if $\bar{C}^{o}_{j} = 0$, $(j \neq k)$, expression (26) reduces to the uncompensated cross-price elasticity for the ordinary LES (single market). As long as $(\gamma_j - \bar{C}^{o}_{j}) > 0$ (which is normally the case when $\bar{C}^{o}_{j} = 0$) then the cross-price elasticity will be negative. This finding appears inconsistent with economic theory, but the discrepancy is resolved when consideration is given to the full Slutsky substitution effect.

The Slutsky equation for a change in good C^{m}_{k} to its own price, P^{m}_{k}, can be expressed in the form:

$$(27) \quad \left.\frac{dC_k^m}{dP_k^m}\right|_{Y'} = \frac{dC_k^m}{dP_k^m} + C_k^m \cdot \frac{dC_k^m}{dY}$$

Demand is decomposed into a direct substitution effect and an income effect. An increase in price P_k^m normally has a negative effect on C_k^m through the first term. But, a higher price, P_k^m, also lowers purchasing power of the consumer, further reducing demand for C_k^m through the second term. From equation (24) and (27), the income compensated own-price elasticity of demand for good C_k^m can be estimated as:

$$(27') \quad \left.\frac{dC_k^m}{dP_k^m} \cdot \frac{P_k^m}{C_k^m}\right|_{Y'} = \frac{(C_k^m + C_k^o - \gamma_k)(B_k - 1)}{C_k^m}$$

Similarly, the income compensated cross-price elasticity of demand is:

$$(28) \quad \left.\frac{dC_k^m}{dP_j^m} \cdot \frac{P_j^m}{C_k^m}\right|_{Y'} = \frac{dC_k^m}{dP_j^m} + C_j^m \frac{dC_k^m}{dY} = \frac{P_j^m}{C_k^m} \frac{B_k}{P_k^m} (C_j^m + C_j^o - \gamma_j)$$

The sign of equation (28) is positive, showing that all goods are gross substitutes for income.

Pseudo own-price and cross-price elasticities of the private market good C_k^m with respect to prices on the official market are represented by equations (29) and (30), respectively:

$$(29) \quad e_{kk}^o = \frac{dC_k^m}{dP_k^o} \cdot \frac{P_k^o}{C_k^m} = - \frac{B_k P_j^o C_j^o}{P_k^m C_k^m} \qquad (k=j), \text{ and}$$

$$(30) \quad e^{o}_{kj} = \frac{dC^{m}_{k}}{dP^{o}_{j}} \cdot \frac{P^{o}_{j}}{C^{m}_{k}} = - \frac{B_k P^{o}_{j} \bar{C}^{o}_{j}}{P^{m}_{k} C^{m}_{k}} \qquad (k \neq j)$$

A decrease in P^{o}, regardless of the commodity, increases consumption of C^{m}_{k}. This is not surprising, since decreasing any official price simply increases income, Y^{*}, by raising the income subsidy to consumers. However, the magnitude of the effect depends on levels of official rations, $\bar{C}^{o}_{j}$, $j = 1,\ldots,s'$.

To define the income elasticity, let income be redefined as Y^{*} in equation (24'). Then, the income elasticity of demand has the form:

$$(31) \quad e^{*}_{ky} = \frac{dC^{m}_{k}}{dY^{*}} \cdot \frac{Y^{*}}{C^{m}_{k}} = \frac{B_k Y^{*}}{P^{m}_{k} C^{m}_{k}}$$

This is the same expression obtained for the ordinary LES except income is redefined to include consumer subsidies.

Empirical Implementation

Advantages of the LES system are its ease in implementation and minimal data requirements. With data on quantities, prices, income elasticities and discretionary income, all remaining parameters of the LES can be derived. This section explains the implementation procedure, drawing heavily from Frisch (1959), Phlips (1974) and Taylor (1979):

1) Derivation of Income: Let income be defined as $Y^{*} = \pi + Y^{n} + \sum_{j} \bar{C}^{o}_{j}(P^{m}_{j} - P^{o}_{j})$. That is, income is composed of agricultural

earnings (profit), π, non-farm income, Y^n, and income subsidies, $\sum_j \bar{C}^o(P_j^m - P_j^o)$. Agricultural income, π, is computed from dual prices and activity levels associated with the right-hand-side of the supply problem. Non-farm income is computed in Table 7.1 from data on 'Personal Expenditures' in GDP, agricultural income, π, and estimates of urban income. Subsidy levels are computed from market rations, $\bar{C}_k^o$, in Table 6.4 less losses, private market prices P_k^m, in Table 6.8 and official consumer prices of 57 FCFA/kg. for coarse grains (47 FCFA for red sorghum) and 125 FCFA/kg. for wheat and rice.[3/] During model simulation, P in the official market may exceed P_k^m in the private market.[4/] For minor infractions, P_k^o is set equal to P_k^m to avoid income losses. This simply implies the government has accomplished its objective of holding down prices for consumers and sells at the lower price. For large infractions, however, the government would be expected to shift rations $\bar{C}_k^o$, (k=1,...,s') toward higher-priced markets.

2) <u>Average Budget Shares</u>: Average budget shares are calculated as $P_k^m C_k^m / Y^*$. Private market prices, P_k^m, are taken from Table 6.8 and $C_k^m = C_k - \bar{C}_k^o$. Total market demands, C_k were derived in Chapter VI and presented in Table 6.5. Official market

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3/ These prices are set lower than consumer prices offered by the government in 1980 (Table 6.10) to compensate for the seasonal effect of official market operations described in Chapter VI.

4/ This is already the case for coarse grains in the east, west and southwest regions, but rations are maintained to achieve expected outcomes in the supply/demand balance.

Table 7.1. Estimates of Farm and Non-Farm Income and Levels of Consumer Subsidies, Burkina Faso.

Region	Personal Consumption Expenditures[a/] (b. FCFA)	Farm[b/] Income, Y^A (b.FCFA)	Non-Farm Income, Y^N (b. FCFA)	Subsidy[e/] $\sum_k C_k^o (P_k^m - P_k^o)$ ('000 FCFA)	Expenditures[f/] per Capita (FCFA/person)
North	60.5	21.6	38.9	527,772	36,620
Central	78.5	29.0	49.5	11,279	36,665
East	16.2	5.8	10.4	2,125	36,570
West	35.2	12.4	22.8	290	50,865
Southwest	52.5	18.9	33.6	1,352	58,400
Ouagagoudou	10.3	-	10.3	134,674	55,000[c/]
Bobo-Dioulasso	7.5	-	7.5	15,272	60,000[c/]
	260.7	87.7	173.0		

a/ From item 'Personal Consumption Expenditure' (1979) in Appendix 1, Table A1.1 increased 8.5 percent, the average annual growth rate in GDP from 1968-79 (World Bank, 1981, p. 26). b/ Farm income includes net farm returns from production of crop commodities (5.5 percent production losses excluded). It excludes income from livestock and fisheries. c/ Estimates of urban income were taken from income figures reported by Savadogo (1986) for medium income households in Ouagadougou. d/ Rural expenditures are proportional with farm income shares in (b). e/ Subsidies are estimated from market rations in Table 6.4 (less 8 percent marketing losses, private market prices in Table 6.8 and official consumer prices of 57 FCFA/kg. for coarse grains and 125 FCFA/kg. for wheat and rice. f/ Subsidy levels are excluded from expenditure/capita calculations since subsidies do not affect expenditures, but instead affect levels of consumption for a given expenditure level.

rations are taken from Chapter VI, Table 6.4 less 8 percent marketing losses.

3) Marginal Budget Shares: Marginal budget shares are estimated from average budget shares in step (2) and estimates of income elasticities of demand:

$$B_k = e^*_{ky} \ (P^m_k C^m_k / Y^*)$$

A synthesis of income elasticity estimates reported by selected studies for various commodities in Africa are reported in Table 7.2. The estimates range from .09 for millet to 1.21 for wheat but tend to be grouped within a 0.50 to 1.20 range. Estimates reported by USDA (1981) based on aggregate data, show lower elasticity response for traditional cereals than consumer surveys used by Savadogo (1986) and Youngblood, et al. (1982). While elasticity comparisons are made between 'traditional' and 'modern' cereals in urban settings (Table 7.2), no rural-urban comparisons are made.

In rural areas of Burkina Faso, wheat and rice are consumed mainly for holidays and festive occasions, suggesting their consumption is more inelastic to income changes than traditional cereals. In urban areas, tastes and preferences have shifted to include more wheat and rice in the diet and consumption appears to be more elastic to income changes than traditional grain. Maize is an anomoly. Consumed as sweet corn (normally the case in rural areas) it is an imperfect substitute for rice, flour, wheat bread or sorghum and millet.

Table 7.2. Estimates of Own-Price and Income Elasticities Reported in Selected Studies.

		Own-Price Elasticity							Income Price Elasticity						
		SG	ML	MZ	RC	WT	PL	OTH	SG	ML	MZ	RC	WT	PL	OTH
Goureaux, L.M.[b/] (In USDA, 1965)	Egypt														0.92[b/]
	Ghana														0.81
USDA, 1981[c/]	Sahel		-.06	n.a.	-.35	-.30				.15	.46	.92	.93	-.14	
	West Africa		n.a.	-.05	-.53	-.15				.09	.15	.87	.65	.42	
Savadogo, 1986[d/] Ouagadougou	Low Income								1.13				.91		
	Medium								.99				.97		
	High								.63				1.21		
	Mean								.94				1.02		
Youngblood, et al.,[e/] Khartoum, 1982	Low 25%									.77			1.21		
	Middle 50%									.50			.90		
	Upper 25%									.57			.88		
	Mean									.59			.97		
Strauss, 1983[f/] Sierra Leone	Low	-.15		-1.26			-1.17								
	Middle	-.26		-.78			-.40								
	High	-.31		-.45			-1.05								
	Mean	-.22		-.74			-1.01								
Ministry of Ag.[g/]	Nigeria								.40					.40	

a/ SG stands for sorghum, ML for millet, MZ for maize, RC for rice, WT for wheat, PL for pulses, and OTH for other. b/ Total Food Expenditure to HHLD income. c/ Based on OLS estimation with a Cobb-Douglas equation using aggregate income and consumption data. d/ An "almost ideal demand system" using prices, income and demographic variables is estimated using OLS. In this case SG refers to domestic cereals, WT for imported cereals. e/ Estimates refer to bread (WT) and other cereals (ML). f/ Estimations are based on a Quadratic Expenditure System. SG refers to root crops and other cereals and OTH refers to non-foods. Strauss estimates "profit" effects in his study, but results are not comparable with income elasticities here. g/ Data were reported in Crawford (1982, p. 69) for grain (millet and sorghum) and groundnuts.

During the soudure, sweet corn is a staple in rural areas, indicating that demand for maize is probably inelastic. In urban areas and the southwest, maize (consumed as a flour) comprises a larger fraction of food budgets. In this case, maize flour may be preferred to millet or sorghum flour, however, wheat bread and rice are probably preferred to maize.

Income elasticities, e^*_{ky}, $k = 1,\ldots,s'$, used for estimating marginal budget shares, B_k, $k=1,\ldots,s'$, are reported in Table 7.3. The elasticities are summarized from empirical estimates in Table 7.2 plus observations on rural-urban consumption patterns mentioned above. Estimates labeled 'rural' in Table 7.3 were used for all five rural regions; estimates labeled 'urban' were used to calculate marginal budget shares, B_k, $k=1,\ldots,s'$, for Ouagadougou and Bobo Dioulasso.[5/]

In rural areas, the income elasticity for millets and sorghums (0.95) is relatively elastic compared with estimates assumed for urban zones (0.70). Income elasticities for wheat and rice in urban zones (0.95) are relatively elastic compared with rural areas (0.60). The income elasticities assumed for maize and groundnuts, compared with sorghums and millet, are relatively less elastic in rural areas, but more elastic in

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5/ Deriving elasticities from empirical studies is a difficult procedure because empirical studies are scarce, results are inconsistent and consumer preferences and estimation procedures vary among samples.

Table 7.3. Income Elasticities Used in the LES Estimation Procedure.

	Rural	Urban
Sorghum and millet	0.95	0.70
Maize	0.75	0.80
Wheat and rice	0.60	0.95
Groundnuts	0.80	0.85
Other Goods	1.05	1.05

a/ The elasticities are adapted from empirical results reported in Table 7.2 plus observations on rural-urban consumption patterns in Burkina Faso.

urban areas. 'Other Goods' are assumed to be elastic (1.05), but only moderately so.

4) Minimum Subsistence Requirements: An expression for γ_k, the minimum subsistence requirement, can be obtained by substituting equation (24) for C_k^m in equation (20) and rearranging terms:

$$\gamma_k = (Y^*/P_k^m)(P_k^m C_k^m/Y^* - B_k\ \sigma) + \bar{C}_k^o$$

The derivation of Y^* was explained in step (1). Average budget shares, $(P_k^m C_k^m/Y^*)$, and marginal budget shares, B_k, (k = 1,....,s') were explained in steps (2) and (3). The term σ is defined as

$$\sigma = \frac{Y^* - \sum_j P_j^m \gamma_j^m}{Y^*}$$

which is the inverse of the "Frisch parameter" (see Frisch, 1959). The coefficient, σ, provides a relative measure of the excess of consumer's income over subsistence expenditures and controls the level of substitution within the demand system. The term σ is expected to be smaller for low income groups, rising with income levels. Based on incomes reported in Table 7.1, values of σ were chosen as 0.50 for the north, central

and east regions, 0.55 for the west and southwest, and 0.60 for the urban cities of Ouagadougou and Bobo-Dioulasso.[6/]

Given estimates of prices (P_k^m, P_k^o, k=1,...,s'), quantity demanded (C_k^m, C_k^o, k=1,...,s'), income elasticities of demand (e_{ky}^*, k = 1,...,s'), income (Y^*) and the Frisch parameter ($1/\sigma$), remaining parameters--B_k and γ_k (k=1,...,s')--can be derived via the Frisch procedure. Own-price and cross-price elasticities of demand can then be calculated from equations (25) and (26).

Estimation Results

Table 7.4 reports results of the estimation procedure for the central region, including levels of demand, C_k^m, and prices, P_k^m, in the private market, rations in the official market, $\bar{C}_k^o$, average and marginal budget shares ($P_k^m C_k^m / Y^*$ and B_k) and minimum subsistence needs, γ_k. Estimates of demand parameters for remaining regions can be found in Appendix 9. Levels of γ_k are roughly half of C_k^m because market rations are small and the Frisch parameter was set around $\sigma = 0.50$. All cotton is traded on the official market, so demand on the private market is zero. An aggregate good called "other" is created as a catch-all for expenditures on other goods and services in the consumer's consumption bundle. It represents nearly 70 percent of total expenditures, so roughly a third of discretionary income is allocated to grains and groundnuts.

6/ In empirical studies, σ normally has a value of 0.50 for middle income groups (Phlips, 1974, p. 130; Taylor, 1979, p. 221), rising with higher income and falling with lower income.

Table 7.4. Estimated Parameters for the Linear Expenditure System, Central Region, Burkina Faso.

	Total Market Demand (C_k)	Official Market Ration (C_k^o)	Private Market Demand (C_k^m)	Minimum Sub. Req. (Ψ_k)	Average Budget Share ($P_k^m C_k^m/y$)	Mar. Budget Share (E_k)	Prices P_k^m
White Sorghum	114634.9	5400.4	109234.5	62748.5	0.0807	0.0767	58.0
Red Sorghum	65634.9	0.0	65635.0	34458.4	0.0443	0.0421	53.0
Millet	147759.8	0.0	147760.0	77574.0	0.1110	0.1055	59.0
Maize	21200.0	3615.6	17584.4	14605.8	0.0125	0.0094	56.0
Rice	16040.0	736.0	15304.0	11448.8	0.0250	0.0150	128.0
Groundnuts	14340.0	0.0	14340.0	8604.0	0.0239	0.0191	131.0
Wheat	5660.0	305.9	5354.1	4053.8	0.0093	0.0056	137.0
Other	1295787.5	0.0	1295789.7	616639.1	0.6932	0.7266	42.0

Uncompensated own-price, cross-price and income elasticities are reported in Table 7.5. As noted earlier, income elasticities (e^*_{ky}), k=1,...,s', are exogenous to the estimation procedure. Own-price and cross-price elasticities are derived by the Frisch method. Own-price elasticities are inelastic, ranging from -.38 to -.51 for traditional cereals, -.30 to -.31 for wheat and rice, and -.41 for groundnuts. In contrast, own price elasticities for the city of Ouagadougou in Appendix 9, range from -.42 to -.48 for traditional cereals, -.58 to -.59 for wheat and rice, and -.52 to -.67 for groundnuts and cotton. The difference in relative magnitudes of elasticities between the two groups stems from different assumptions concerning income elasticities of demand.

Uncompensated cross-price elasticities are negative as predicted by equation (26). However, examination of the income-compensated elasticities in Table 7.6 (computed from equations 27' and 28) reveals that gross substitution elasticities are positive, though small due to the large budget share of the 'other good' in the demand system.

This completes the discussion on demand. Attention now turns to validation of the complete sector model and evaluation of its performance.

Table 7.5. Uncompensated Own-Price (e^p_{kk}), Cross-Price (e^p_{ij}) and Income (e^*_{ky}) Elasticities, Linear Expenditure System, Central Region, Burkina Faso. a/

	Income Elasticity b/	WS	RS	ML	MZ	RC	PN	WT	OT
		Uncompensated own-price and cross-price elasticities							
WS	0.9500	-0.5152	-0.0221	-0.0554	-0.0074	-0.0166	-0.0136	-0.0062	-0.3134
RS	0.9500	-0.0402	-0.4971	-0.0554	-0.0074	-0.0166	-0.0136	-0.0062	-0.3134
ML	0.9500	-0.0402	-0.0221	-0.5304	-0.0074	-0.0166	-0.0136	-0.0062	-0.3134
MZ	0.7500	-0.0318	-0.0174	-0.0437	-0.3809	-0.0131	-0.0108	-0.0049	-0.2474
RC	0.6000	-0.0254	-0.0140	-0.0350	-0.0047	-0.3105	-0.0086	-0.0039	-0.1979
PN	0.8000	-0.0339	-0.0186	-0.0466	-0.0063	-0.0140	-0.4115	-0.0052	-0.2639
WT	0.6000	-0.0254	-0.0140	-0.0350	-0.0047	-0.0105	-0.0086	-0.3039	-0.8699
OT	1.0482	-0.0444	-0.0244	-0.0611	-0.0082	-0.0183	-0.0150	-0.0069	-0.8689

a/ WS = white sorghum; RS = red sorghum; ML = millet; MZ = maize, RC = rice; PN = groundnuts, WT = wheat; and OT = other.

b/ Income elasticities are taken from Table 7.3. They are adapted from empirical studies, not derived from the estimation procedure.

Table 7.6. Income Compensated Own-Price ($e^p_{kk}|_{y'}$) and Cross-Price ($e^p_{kj}|_{y'}$) Elasticities, Linear Expenditure System, Central Region, Burkina Faso. a/

	WS	RS	ML	MZ	RC	PN	WT	OT
WS	-0.4366	0.0200	0.0501	0.0045	0.0071	0.0091	0.0027	0.3452
RS	0.0364	-0.4550	0.0501	0.0045	0.0071	0.0091	0.0027	0.3452
ML	0.0364	0.0200	-0.4249	0.0045	0.0071	0.0091	0.0027	0.3452
MZ	0.0287	0.0158	0.0396	-0.3715	0.0056	0.0072	0.0021	0.2725
RC	0.0230	0.0126	0.0316	0.0028	-0.2955	0.0057	0.0017	0.2180
PN	0.0307	0.0168	0.0422	0.0038	0.0060	-0.3923	0.0022	0.2907
WT	0.0230	0.0126	0.0316	0.0028	0.0045	0.0057	-0.2983	0.2180
OT	0.0402	0.0221	0.0553	0.0049	0.0078	0.0100	0.0029	-0.1433

a/ WS = white sorghum; RS = red sorghum; ML = millet; MZ = maize, RC = rice; PN = groundnuts, WT = wheat; and OT = other.

CHAPTER VIII

BASE MODEL SOLUTION

The purpose of this chapter is to present results for the base model solution. The agricultural sector model for Burkina Faso contains two major components: the LP which forecasts production; and the LCP which estimates prices, quantity demanded and trade. The presentation first focuses on supply forecasts from the LP models, covering production, area harvested and shadow prices of resources. Then, solution values from the LCP are covered, including prices, trade flows and market demand. The solution values validated in these sections are for the annual model. A final section deals with the model's dynamic performance.

Parameters of the LES demand system in the LCP were derived using the Frisch procedure from 'base' period consumption, prices and income data. Trade equations were estimated as continuous functions of 'base' period prices and quantities. As long as the model solution for the transportation sector and LPs are accurate then demand, prices and international trade in the LCP will exhibit low margins of error.

The difficult part involves benchmarking the LPs. As noted repeatedly in this study, the diverse commodity and technology mix incorporated in the LPs, plus their implicit stepped-supply function

characteristics, make the process of benchmarking results to actual data a difficult procedure.

As explained in Chapter VI, official production estimates were adjusted to correct for perceived errors in official statistics. Data on commodity utilization were estimated using a commodity balance sheet approach, since official data on consumption are unavailable. 'Base' period prices were derived from price data reported in various studies and from estimates of marketing margins. Consequently, the model cannot truly be benchmarked, except with prices and quantities that are themselves estimated in this study. Nevertheless, the consistency checks and accounting rules employed in estimating the data provide a consistent series with which to compare the model solution. Also, using consistent data to empirically implement the model is essential for ensuring satisfactory model performance.

LP: Production

Estimates of crop production generated by the model for the base 1980 season are compared with actual crop production data (1979-81 average) in Table 8.1. Recall that output of producers in the LP is sold either on the private or official markets, depending on where returns are highest. Data marked 'private' production in Table 8.1 represents output sold on the private market. Data labelled 'official', represents output sold to government marketing boards--OFNACER in the case of cereals and SOFITEX in the case of cotton. Total production then equals output sold on private plus official markets.

Table 8.1. Production Base Model Results, Burkina Faso.

Region: Commodity	Actual[a] (1979-1981 Average)	Base Model[b] Private	Base Model[b] Official	Percent[c] Error
	(metric tons)			
North				
White Sorghum	52,990[d]	50,156	650[x]	3.8
Red Sorghum		2,387[ℓ]		
Millet	151,090	150,567	500[x]	0.0
Maize	7,310	7,320[ℓ]		0.1
Paddy	3,700	3,730		0.8
Groundnuts[e]	19,410	18,897		-2.6
Cotton	1,850		3,330	80.0
Cowpeas	-	7,644		-
Fonio	150	159[ℓ]		-
Straw	-	440,242		-
Central				
White Sorghum	197,740[d]	119,899	2,300[x]	1.7
Red Sorghum		75,881[ℓ]		
Millet	165,780	166,080		0.2
Maize	15,720	15,791[ℓ]		0.5
Paddy	14,690	15,124		3.0
Groundnuts[e]	21,480	18,748		-12.7
Cotton	6,020		2,316	-61.5
Cowpeas	-	31,664		-
Straw	-	834,737		-
East				
White Sorghum	50,060[d]	43,586	2,080[x]	-0.2
Red Sorghum		4,290[u]		
Millet	31,320	31,686		1.2
Maize	6,330	8,124		28.3
Paddy	3,400	3,538		4.1
Groundnuts[e]	5,490	7,215		31.4
Cotton	240		446	85.8
Cowpeas	-	7,405		-
Soybeans	-	772[ℓ]		-
Straw	-	209,835		-

Table 8.1. (Continued)

Region: Commodity	Actual[a] (1979-1981 Average)	Base Model[b] Private	Base Model[b] Official	Percent[c] Error
	(metric tons)			
West				
White Sorghum	106,110[d]	77,757	3,300[x]	0.7
Red Sorghum		25,791[ℓ]		
Millet	51,350	51,333	400[x]	0.7
Maize	12,140	11,877[ℓ]		-2.2
Paddy	4,740	5,150		8.6
Groundnuts[e]	6,200	7,760		25.2
Cotton	28,390		26,237	-7.6
Cowpeas	-	8,392		-
Fonio	870	577[ℓ]		-
Straw	-	386,670		-
Southwest				
White Sorghum	152,680[d]	134,239	1,370[x]	0.2
Red Sorghum		17,439[ℓ]		
Millet	50,590	51,985		2.8
Maize	69,030	67,658	1,200[x]	0.2
Paddy	22,000	19,253	2,310[x]	2.0
Groundnuts[e]	26,620	26,511		0.4
Cotton	31,590		31,459	0.4
Cowpeas	-	12,440		-
Fonio	4,030	4,011[ℓ]		-
Starchy Tubers	-	26,159[u]		-
Straw	-	543,393		-

a/ Production figures are taken from Table 7.1.

b/ A 'u' implies solution values are constrained by upper bounds, an 'ℓ' by lower bounds and an 'x' by fixed bounds.

c/ Percent error is the percentage difference in production on the private plus official markets in the base model solution, relative to actual production data (1979-81 average).

d/ Estimates are labeled simply 'sorghum'.

e/ Includes bambara nuts which are bounded in the solution.

Cereals production on the official market is bounded to reflect fixed procurement and capacity constraints of OFNACER. The marketing infrastructure for cotton is relatively well developed and integrated with international markets. It does not appear to face the same degree of restrictions on market capacity. Hence, production activities are left unrestrained. This implies production, processing and export of cotton abroad are permitted to move freely with price adjustments in the model.

The model appears to estimate production patterns well. The absolute percentage error between 'observed' and 'predicted' results for sorghum and millet ranges from 0.2 to 3.8 percent across all regions. For maize, the absolute percentage error ranges between 0.1 and 2.2 percent except in the "east" where maize appears to be relatively more profitable.[1/] Large percentage errors are shown for cotton and groundnuts, although absolute differences in production are not unreasonable. The large errors are due to low base values. For example, actual production of cotton in the east region is 240 tons. Estimated production is only 446 tons, but the percentage error is greater than 80 percent. In the southwest region, where groundnuts and cotton are major production activities, the margin of error is less than 1 percent.

1/ This does not imply maize production should be expanded in the east. Decreasing the area of higher quality land or increasing labor requirements at first weeding by several hours in the model would eliminate profit margins. These adjustments are well within the range of possibilities.

Lower bounds are imposed on maize production in the north and central regions, reflecting minimum requirements for food during the "hungry" season. Red sorghum is bounded in all regions, representing fixed demands for beer making and livestock feed. Minor crops--bambara nuts, fonio and soybeans--are also bounded at fixed levels, because they tend to fluctuate widely with changes in prices. The problem of minor crops becoming dominant in the solution is pervasive in farm models (see Balcet and Candler, 1981), suggesting activities are not properly constrained or modelled (i.e., failing to incorporate price endogenous adjustments; modelling the problem linearly; or failing to impose marketing restrictions).

While the model appears to perform well in estimating crop production, it is important to recognize the difficulties of using 'actual' data to validate solution results for production. As may be recalled from Chapter VI, 'actual' production data in Table 8.1 underwent considerable manipulations during the derivation of a commodity balance sheet for the country. Millet production, for example, was increased in the north, central and east regions while sorghum was decreased to compensate for discrepancies between government statistics and independent sources. Under these conditions, model results are difficult to validate since the 'actual' data themselves are in part estimated in this study. This does not detract from the quality of the model's performance, but rather highlights the difficulties of trying to validate the model with weak and unreliable data.

LP: Area Harvested

Solution values for area harvested by region and crop are reported in Table 8.2. Model results are compared with official estimates of cropped area for the period 1979-81 (three-year average). With the exception of irrigated rice and land under AVV reclamation schemes, activities for crop area are unconstrained. Minimum or maximum constraints related to production are imposed directly on production activities rather than on area.

The model appears to estimate crop area poorly. The percentage error between 'predicted' results in the model solution and 'actual' results exceeds 30 percent in many cases. There are a number of explanations for this.

First, the data for millet and sorghum reflect the modifications made to published government statistics in Chapter VI to adjust for missing values and inconsistencies. In the north and central regions, for example, estimates of sorghum production in the commodity balance sheet were lowered and millet raised to reconcile differences between government estimates of crop production and those of independent sources. Consequently, the solution values for sorghum underestimate 'actual' production by 52 percent in the north and 20 percent in the central region, while solution values for millet overestimates actual production by 64 percent in the north and 65 percent in the central region. These results reflect in part the magnitude of adjustments made to 'actual' data. Also, production of paddy was increased in the east region to compensate for apparent errors in data reporting. This

Table 8.2. Area Harvested, Base Model Results, Burkina Faso.

Region: Commodity	Actual (1979-1981 Average)	Base Model	Percent Error
	--------(hectares)--------		
North			
White Sorghum	232,517	106,556	-52.4
Red Sorghum		4,180	
Millet	277,523	454,745	63.9
Maize	16,569	14,412	-13.0
Paddy	2,341	3,048	3.0
Groundnuts (incl. Bambara nuts)	50,304	49,761	-1.1
Cotton	5,072	8,294	63.5
Fonio	736	636	-13.6
Total	585,062	641,632	9.7
Central			
White Sorghum	423,662	231,311	-20.2
Red Sorghum		106,774	
Millet	315,507	488,471	54.8
Maize	27,647	10,612	-61.6
Paddy	14,094	13,251	-6.0
Groundnuts (incl. Bambara nuts)	55,308	38,643	-30.1
Cotton	6,737	2,677	-60.3
Total	842,955	891,739	5.8
East			
White Sorghum	97,739	70,413	-28.0
Red Sorghum		6,042	
Millet	67,265	77,281	14.9
Maize	11,116	7,731	-30.5
Paddy	395	2,960	649.4
Groundnuts (incl. Bambara nuts)	11,120	15,456	39.0
Cotton	655	1,170	78.6
Soybeans	n.a.	2,059	-
Total	188,290	183,112	-3.1
West			
White Sorghum	134,317	107,172	3.5
Red Sorghum		31,905	
Millet	75,000	101,414	35.2
Maize	13,530	9,481	-29.9
Paddy	4,585	4,311	-6.0
Groundnuts (incl. Bambara nuts)	11,987	13,023	8.6
Cotton	31,571	30,761	-2.6
Fonio	1,435	1,442	0.5
Total	272,425	299,509	9.9

Table 8.2. (Continued)

Region: Commodity	Actual (1979-1981 Average)	Base Model	Percent Error
	--------(hectares)--------		
Southwest			
White Sorghum	188,908	189,661	6.3
Red Sorghum		11,185	
Millet	82,751	85,529	3.4
Maize	62,057	64,690	4.2
Paddy	14,445	9,829	-3.2
Groundnuts (incl. Bambara nuts)	32,801	41,015	25.0
Cotton	29,366	27,963	-4.8
Fonio	8,096	8,913	10.1
Tubers		4,756	-
Total	418,424	443,541	6.0

a/ Figures are three-year averages (missing values excluded) computed from official crop reports. In Republique de Haute-Volta, Ministere du Developpement Rural, Bulletin de Statistique Agricoles, Campagnes 1978/79, 1979/80, 1980/81, 1981/82, pp. 58-97.

explains the large difference between 'actual' production of 395 tons and the figure of 2960 tons estimated by the model.

Second, crop yields in the model were estimated from on-farm data rather than from public data sources where production and crop area are taken. In fitting the model to aggregate production data, crop area is treated as a residual, compensating for differences in yields between the two data sources. The effect is most apparent for the area of millet in the model. In the north, a millet yield of 325 kg./ha. (Appendix 2, Table A2.1) was assumed for bush land in the model, while the average yield in official data (three-year averages computed from data reported for the Sahel, Yatenga and Centre Nord ORDs) is 385 kg./ha. In the central region, the yield of millet was assumed to be 340 kg./ha. (Table 5.1) for bush land in the model compared with an average yield of 476 kg./ha. in national accounts. The effect in the model solution is overestimation of millet area in the north and central regions relative to official production statistics. Similar yield differences occur for maize and groundnuts. Whether model assumptions for yields are higher or lower than 'actual' yields, however, depends on the individual case. In the west and southwest regions, aggregate yield estimates were used to benchmark yield assumptions in the model due to limited farm management data. The margins of error in area estimates for those regions are generally less than 10 percent.

The above results point out the difficulty of working with high levels of disaggregation of yields in the model while attempting to benchmark area and production results in the model solution with

actual data. In the model, yields for a given crop vary depending on whether the crop is grown in sole stands or mixtures, type of soil, and whether it is fertilized or cultivated with animal traction. Even under normal circumstances, where official data were of good quality, attempting to converge average weighted yields in the model (defined as production divided by area summed over all technologies and land types) with yield data in official accounts is a difficult procedure because of the diversity in the technology set. The greater the degree of divergence in 'average' yields, the greater the margin of error that can be expected in fitting the model to production data.

LP: Technology Set

Values for area harvested by crop activity and technology, in the base model solution, are reported in Table 8.3. The summation of areas across crop activities equals the estimates of area harvested in Table 8.2.

Several observations are noteworthy. First, production is determined by a broad set of technologies in the model solution. Some 118 activities for the five regions (from 22 to 27 activities per region) are involved in the production of 11 primary commodities (soybeans and starchy tubers excluded). For major commodities like sorghum and millet, the technology mix can be quite diverse. Millet, for example, is produced in the north with six different technology regimes, including hand and animal cultivation on various types of soil quality. In the east, white sorghum is produced with 9 different crop technologies in the model solution. On average, millet and sorghum are

Table 8.3. Area Harvested, Hand Tillage Technologies, Base Model Results, Burkina Faso.

Land[1/]	Tillage[2/]	Crop Mixture	North	Central	East	West	Southwest
SWP:	Hand	PD		7,296	391		
	Hand	TB					4,756
CPD:	Hand	MZ					17,115
HQ:	Hand	MZ/RS					32,870
		RS/MZ		45,395			
		RS/CP			6,042	4,162	3,443
		WS/CP		79,949	14,050	6,117	
LQ:	Hand	RS/CP				18,324	
		WS/CP	40,613	111,102			55,468
		WS/ML/CP			21,771		
		CT			163		
		PN	41,601				
		BN	6,007	7,975			
Bush:	Hand	NWS/CP		10,383	22,571	31,170	19,435
		NML/CP	7,974				
		NPN					27,225
		WS					101,742
		ML	376,696		33,377	100,651	54,851
		ML/CP		488,471			
		ML/WS/CP			43,063		
		PN	636			1,442	8,913
		PN			7,933	6,839	3,476
		BN			1,001	4,314	8,620
		SB			2,059		

Table 8.3. (Continued)

Land[1/]	Tillage[2/]	Crop Mixture	North	Central	East	West	Southwest
SWP:	Donkey	PD	2,525	1,184	1,890		
CPD:	Donkey	MZ	5,664	7,494			454
		RS	1,528	46,498			
HQ:	Donkey	MZ					1,666
		RS/CP		4,597			
		WS/CP	16,332	25,088		8,953	
LQ:	Donkey	RS/CP				1,233	
		WS/ML/CP			6,303		
		ML/CP	27,546				
		CT			1,007		
		PN	676				
		BN	1,477				
Bush:	Donkey	WS				15,897	
		ML	16,637			763	
		PN		26,681	4,743		1,694
SWP:	Oxen	PD		3,325	284	3,861	5,718
CPD:	Oxen	MZ	8,748	2,504		9,481	6,452
		MZ/WS			7,731		
		RS	2,652			6,100	
		WS	20,858		2,283		
HQ:	Oxen	MZ					6,133
LQ:	Oxen	RS/CP				2,086	
		WS/ML/CP			1,853		
		ML/CP	21,143				
		CT	8,294			27,229	
Bush:	Oxen	WS				24,073	
		ML			285		30,678
		ML/CP	4,749		556		
		PN		3,987	1,779	1,870	

Table 8.3. (Continued)

Land[1/]	Tillage[2/]	Crop Mixture	North	Central	East	West	Southwest
HQ:	Hand	RS/CP-50		10,284			
		WS/CP-50	28,753		1,582		
		RS -100					7,742
		WS -100					13,016
		WS/CP-150				20,962	
LQ:	Hand	CT -100					17,282
	Donkey	CT -100					1,087
	Oxen	CT -100				3,532	9,594
AVV:	Oxen	MZ -100		614			
		WS/CP-100		4,789			
		CT -100		2,677			
IR1:	Hand	PD -150	245	1,088	262	450	2,500
IR2:	Hand	PD -150	278	358	133		
		PD -200					383
IR3:	Hand	PD -400					1,228

1/ SWP refers to swampy lowland, CPD to compound land; HQ to high quality village soils, LQ to low quality village soils; AVV to the government's land reclamation scheme; IR1 to bottomland rice irrigation, IR2 to single-crop rice irrigation and IR 3 to double crop rice irrigation.

2/ WS refers to white sorghum, RS to red sorghum, ML to millet, MZ to maize, PD to paddy, PN to groundnuts, CT to cotton, CP to cowpeas, BN to bambara nuts, SB to soybeans, FN to fonio, and TB to starchy tubers.

each produced with 4 to 5 different modes of cultivation in each region.

Second, crop activities on higher quality soils, particularly swampy lowlands and compound land, are cultivated primarily with animal traction. Crops on these soils are higher yielding but also have higher labor requirements, making returns to labor-saving technologies relatively more profitable. While the economics appear correct, the magnitude of the effect is not. Since resources are assumed to be perfectly mobile within a region, draft services are allocated freely to the highest quality soils, where returns are highest. The same effect is true for fertilizer. In reality, animal traction services are constrained to land controlled by the household owning the traction unit. Consequently, returns to animal traction and fertilizer in the model will be over-estimated.

The problem is most severe in cases where input use is low, with the distortion diminishing as the utilization of animal traction and fertilizer in the sector increase. From a sectoral perspective, shadow prices of resources would be overestimated, biasing upward economic returns of the technologies. Production of crops employing the technology (mainly paddy, maize and red sorghum) will also be overestimated, although at the sectoral level the effect is small because of the low levels of input use in the agricultural economy of Burkina Faso.

LP: Shadow Prices of Fixed Resources

Shadow or dual prices associated with the right-hand side solution of the supply problem are reported in Table 8.4. The shadow price represents the marginal value of an additional unit of a resource to agriculture in a region. In the case where slack (unutilized) resources are held, the marginal value of an additional unit of resource is zero. Conversely, if a resource constrains the model solution, a positive shadow price is expected.

Human Labor: The shadow price of human labor behaves consistently across regions. Labor is constraining mainly at first weeding of sorghum and millet (periods 4, 5 and 6), corresponding to the peak period of labor demand. Surplus labor generally exists in other periods. The result--zero shadow prices in off-peak periods of labor demand--stems from the assumption that labor supply is constant across periods while labor flows are seasonal.

During the first weeding period, shadow prices range from a peak of 225 FCFA/hour in the southwest to 506 FCFA/hour in the north, averaging around 375 FCFA/hour overall. These costs are consistent with empirical observations of intense labor requirements at the time of first weeding, but are considerably greater than the average wage rate of 50 FCFA/hour (300 FCFA per six hour

Table 8.4. Shadow Prices of Fixed Resources, Base Solution, Burkina Faso.

Resources		Units	North	Central	East	West	Southwest
Human labor, Period:	1	(FCFA/hr.):					95
	2				188		
	3						
	4			391	28		205
	5		170	347		394	179
	6		506	18	374	375	224
	7				174		
	8-10						
Donkey Labor, Period:	1	(FCFA/hr.):					47
	2		94		661		
	3		60	237			
	4			1225		389	1003
	5		543	746	130	1043	460
	6		1255		994	842	397
	7				445		
	8-10						
Oxen Labor, Period:	1	(FCFA/hr.):	211		19	100	
	2		485		1007		72
	3		535	522			
	4			2162		856	1891
	5		1341	1292	817	1172	597
	6				1112		511
	7				520	976	
	8-10						

Table 8.4. (Continued)

Resources	Units	North	Central	East	West	Southwest
Land, SWP	(FCFA/ha.):	52,742	40,300	1,563	36,020	17,551
CPD		13,518	18,068	4,778	36,824	9,903
HQ		11,613	15,441	1,811	30,453	8,410
LQ		2,189	0	617	19,409	6,537
Bush		0	0	0	0	0
IR1		22,392	39,328	0	32,468	0
IR2		130,023	0	0	0	0
IR3		0	0	0	0	187,025
AVV		0	0	0	0	0
Male Workers	(FCFA/person)	29,370	32,392	38,888	32,512	45,828
Female Workers	(FCFA/person)	20,458	22,425	23,355	22,366	31,774
Child Worker	(FCFA/person)	13,571	15,177	15,570	14,988	21,387
Donkey Team	(FCFA/team)	54,400	65,876	54,761	69,814	77,287
Oxen Team	(FCFA/team)	72,547	111,975	90,705	89,163	113,207
Additional Manure	(FCFA/ton)	1,289	1,714	287	3,380	981
Cotton Fertilizer	(FCFA/ton)	134,941	143,505	117,648	117,650	105,776

day) reported in empirical studies.[2/] While these results suggest producers should hire labor during critical periods to alleviate the high opportunity costs, no labor is available for hire because producers are busy capturing rents by working their own fields. A significant landless labor class does not exist in Burkina Faso to provide this supply of labor.

The shadow prices for human labor are likely overstated due to fixed labor schedules assumed in the model. Normally, the timing of crop operations (advancing or delaying labor activities) would be adjusted to reduce the high opportunity costs, but this flexibility was not incorporated in the model's technology set due to model size limitations. However, acute labor shortages at peak periods of labor demand are widely observed phenomena in Africa (Cleave, 1974), suggesting farmers themselves may have little flexibility in modifying cropping patterns. (Delaying crop operations, for example, incur penalty costs in terms of lower yields.) The fact that farmers choose to work their own fields, however, rather than hiring their labor-services to others (refer to Chapter V) provides further evidence for the high shadow prices observed in the model.

2/ Ford (1982) reports a wage rate of 175-300 FCFA/day. McIntire reports the following wage rates: Hounde: 250 FCFA/day for weeding of cereals; Kougny: 250-300 FCFA/day for land preparation, weeding, and ridging; Dori: 500-600 FCFA/day for weeding; and Djibo: 350-500 FCFA/eight hours for first weeding and 300-500 FCFA/day for land preparation.

Agricultural Population (workforce): The shadow prices associated with the supply of able-bodied workers provides a more meaningful evaluation of the economic returns to labor in agriculture. The shadow price of labor associated with seasonal labor constraints provides an estimate of labor's value for only a short time period during the agricultural season. The returns to able-bodied workers captures all economic rents accruing to a worker for the entire year.

The shadow costs appear reasonable and consistent with expectations of productivity differences among regions. In the arid north, where agricultural productivity is poor, returns to an additional male worker in the model solution is 29,370 FCFA, 20,458 FCFA for a female worker and 13,571 FCFA for a child. Economic returns to labor are slightly higher in the central region and higher still in the east, consistent with higher yields existing in these regions. In the humid southwest, where physical productivity of land is superior to other zones, the returns to labor are highest. There, the value of an additional male adult worker is 45,828 FCFA, 31,774 FCFA for a female adult worker and 21,387 FCFA for a child.

The one exception is in the west where economic returns to labor are roughly the same as the central region, even though yield levels are higher (second only to those in the southwest). This discrepancy is explained by two factors: crop labor requirements and work intensity of labor per day. As explained in Chapter V, labor requirements of crops were assumed to increase

from the north to central to east to west to southwest regions. Thus, while land productivity is higher in the west, so are labor requirements. Second, the amount of time a male worker can work per day was assumed a 7.3 hours in the north, 7.2 hours in the central, 7.4 hours in the east, 7.5 hours in the southwest, but only 7.1 hours in the west.[3/] Thus, not only are labor requirements assumed higher in the west, the amount of labor supplied by workers is less, lowering economic returns per worker.

The variance in returns among age/sex groups also stems from assumptions of daily work intensity. A male adult in the central region is assumed to work 7.2 hours per day, a female adult works 5.0 hours and a child works 3.4 hours. These same proportions were applied in other regions, explaining the consistency in returns across age/sex groups.

According to the labor theory of migration, population movements among regions are determined by expected returns to labor. Based on results in Table 8.4, sizable migration of the population from the north and central regions to the southwest would be expected, with perhaps some movement to the east. An examination of migration rates taken in the 1975 population census (Figure 8.1) supports this conclusion. Internal migration appears to be heaviest from areas in the north to the southwest, although

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3/ Differences in work intensity came about in the process of fitting respective LP models to production data. Rates of work intensity were raised or lowered to increase or decrease production in the model until model convergence was reached.

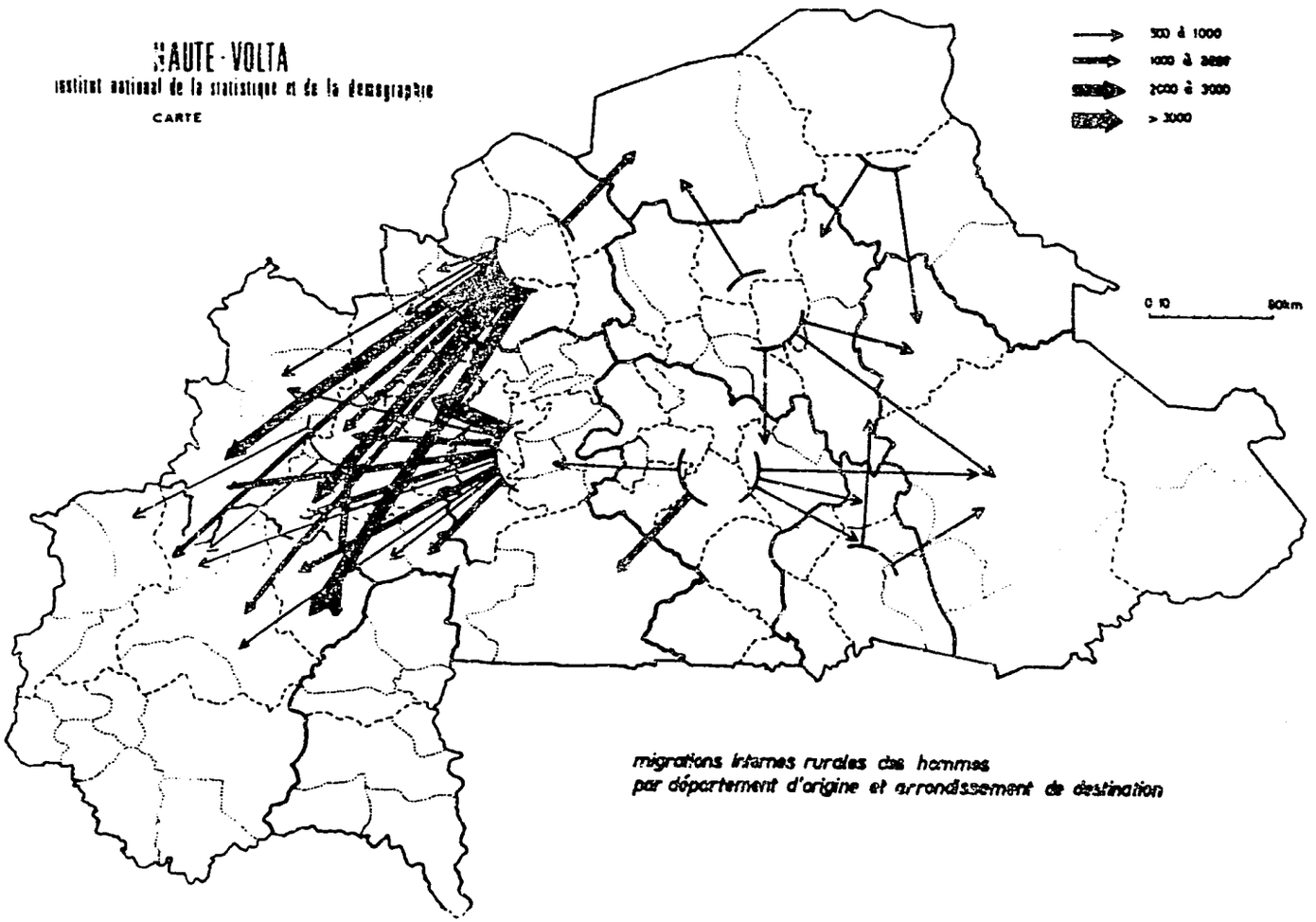

Figure 8.1. Internal Population Migration, 1975 Population Census, Burkina Faso.

migration from the central region to west and southwest zones is also sizable. Minor population movements to the east are also apparent, although poor infrastructure impedes settlement of the zone. The results of the model and Figure 8.1 indicate Burkina's labor markets are in a state of disequilibrium. In a purely competitive, unrestricted market, labor demand should migrate between regions until marginal returns equate. This process is occurring, but adjustments are slow.

Land. The shadow prices of traditional land resources are difficult to evaluate because values depend on crops, yields and labor schedules assumed for different land types by region. Land values in Table 8.4 reflect the influence of three main factors: prices, yields and crop labor requirements.

The value of land should be positively correlated with prices. Thus, land in regions where market prices are highest--north, central and west in sequential order--should have higher land values than regions where prices are lower--east and southwest.

Land values should also be correlated with physical productivity. In regions where the productivity of land resources is highest--southwest, west and east--land values are expected to be higher than for soils in the north and central zone which experience low rainfall and low incidence of land fallow. Yields should also explain differences in land value

among soil types. Thus, swampy lowlands (SWP) and soils surrounding the compound (CPD) should exhibit higher shadow prices than those of lower quality village soils (LQ) or bush land.

Prices and yields tend to counteract the influence of each other, leading to similar land prices across regions. The third factor--labor requirements--complicates this relationship. Labor requirements are a physical characteristic of land type. An increase in labor requirements of crop activities on a given type of soil lowers its land value relative to other soil types. If the extreme case is taken where labor requirements of crops on high quality soils are made arbitrarily high, production would shift completely to bush soils, where yields per unit of labor are more economical. Although yields are lowest there, less labor must be expanded per unit of production than on higher quality soils. This relationship is especially important since bush land is not constrained in the model.

The shadow prices of land resources in Table 8.3 reflect the confluence of these factors. Shadow prices indeed fall with lower soil quality, with fairly uniform results across regions. Land prices are lowest in the east and southwest, highest in the west, with land values in the north and central regions falling in between.

Taking a simple average across regions, the average shadow price of swampy lowland is 29,635 FCFA/ha., 16,618 FCFA/ha. for compound land, 13,646 FCFA/ha. for higher quality village soils and 5,750 FCFA/ha. for lower quality village soils. Lack of land

markets in Burkina Faso prevents comparison of shadow prices with market prices. However, the relative magnitudes are consistent with empirical evidence on land quality differences and farmers' subjective evaluation of land types (Chapter V).

Animal Traction Labor. Compared with human labor, the shadow prices associated with animal traction appears more broadly distributed through the agricultural season. The use of animal traction tends to smooth out the seasonal distribution of human labor due to the technology's labor-saving effects. This finding is consistent with empirical observations that first-weeding becomes less critical and planting more constraining with animal traction adoption (Chapter V).

Still, the highest shadow prices are observed during first weeding of sorghums and millet with peak rates ranging from 94 FCFA/hour (east) to 1255 FCFA/hour (north) for donkey traction and 1112 FCFA/hour (east) to 2,162 FCFA/hour (central) for oxen. For the sake of comparison, McIntire (1982) observed a market rate of 1000 to 2000 FCFA/day for rental of a traction unit. The high shadow prices stem from the technology's labor-saving effects and the assumption that oxen traction is more efficient than donkey traction.

Manure. The shadow prices associated with manure of traction animals--1,289 FCFA/ton (north), 1,714 FCFA/ton (central) and 3,380 FCFA/ton (west)--compare reasonably well with estimates of 1,900 FCFA/ton by ICRISAT (1980) and 2,000 FCFA/ton by Delgado. Benefits to manure are incorporated in the model by augmenting

the supply of higher quality land. The low shadow prices of manure in the east and southwest regions then result from low shadow prices of land endowments in these zones.

Animal Draft Units. The shadow prices associated with the stock of animal traction units incorporates the full benefits associated with the technology (i.e., labor-saving, yield-augmenting and manure effects). For donkey technology, the value of an additional unit ranges from 54,400 to 77,287 FCFA/team, increasing the value from north to southwest. Benefits to oxen traction are higher--72,547 to 113,207 FCFA/team--due to their superior efficiency assumed in the model.

The higher benefits of animal traction in the west and southwest stem from the labor-saving benefits associated with the technology. Adoption of animal traction enables the expansion of cultivated area, due to the abundance of bush soils in the model. Since crop yields on these soils are higher in the west and southwest, returns to the technology are also higher.

Benefits to animal traction are likely to be somewhat overstated because: 1) the model incorporates only wet season activities, excluding labor costs of caring for animals during the dry season; and 2) the free-mobility assumption in the model permits allocation of animal traction services to the most lucrative activities (paddy and maize which are high yielding but also possess high labor requirements during certain periods).

Benefits appear high compared with the annualized cost of animal traction ownership (i.e., 24,000 FCFA/donkey team and

35,000 FCFA/oxen team, Table 5.17). Taking benefits (shadow costs) at only half their current value, simple returns to investment (benefits/annual costs) would range from 13 to 61 percent for donkey traction and 4 to 62 percent for oxen traction, with returns highest in the southwest. Based on these estimates alone, the government (who regulates the supply of animal traction units) appears to be under-investing in animal traction services (particularly in the southwest).

In the southwest animal traction has high payoff, but consumers in the region are relatively well off. On the Central Plateau, where agricultural productivity is poor and 'need' the greatest, returns are low. These results highlight the dilemma faced by policy-makers concerning growth-equity issues in investment planning. The investment in animal traction projects redistributes income from rich to poor and attempts to increase production and rural incomes. If resources are limited, however, investment on the Central Plateau has a high opportunity cost in terms of production benefits that exist elsewhere in the country.

Irrigation. Simple bottomland irrigation (IR1) of rice is financially profitable only in the north, central and west regions. Since irrigation costs and yields are assumed to be roughly the same across regions, the difference is due mainly to commodity prices. The same effect holds for large-scale dam irrigation (IR2), but only in the north is the price sufficiently high to make dam irrigation profitable. In the southwest where investment in irrigation infrastructure is heaviest, only schemes with

double cropped rice (IR2) are profitable at current financial prices.

Land Reclamation (AVV). The government's program of transferring population from high density areas to fertile disease-freed areas along river valleys is not economically profitable. The shadow price on AVV land is zero at current financial prices. The benefits of higher agricultural output are not sufficiently great to offset the high costs associated with the program. However, benefits do not take into account the multiplier effect of settling a few households on migration rates into AVV areas in the longer run. There is no empirical information to the author's knowledge of how large this effect might be.

Cotton Fertilizer. Compared with the official subsidized price of fertilizer (45,000 FCFA/ton), the shadow price of fertilizer across regions is high. Even with the 56 percent subsidy removed (to 95,000 FCFA/ton) the shadow prices, ranging from 105,776 (southwest) to 143,505 FCFA/ton (north), compare favorably. Marginal returns are highest in the north and central regions (where fertilizer response rates are low, but commodity prices are high) and lowest in the east, west and southwest (where response rates are high but output prices are low).

Several factors contribute to the high shadow prices. First, foreign exchange constraints and market restrictions on input distribution result in low fertilizer rations (fertilizer constraints) in the model. Second, production functions in the analysis, estimated from on-farm data, show a moderate but

profitable production response to fertilizer. Because of low rations, fertilizer is allocated to the most profitable activities, resulting in high shadow prices.

In summary, the production model appears to perform reasonably well in estimating output for the 1980 base period. Resource allocation in the sector appears consistent with the economic behavior of producers. Shadow prices seem to capture the economic rents accruing to scarce factors. The only area in which the model appears to perform poorly is in the estimation of crop area. This problem, however, has more to say about data sources used to validate the model than about actual model performance. The aspect most critical to the final outcome of the complete sector model is the regional LPs estimation of output. In this regard, the model performs well.

The sector model contains two main components: the LPs used to estimate regional output; and the LCP used to estimate prices, quantity demanded and trade in the private sector of the economy. The previous sections evaluated the performance of the LPs. Following sections present the competitive private market solution for the LCP, validating the results where possible.

LCP: Prices

Table 8.5 contains solution values for retail prices generated by the LCP for commodities and regions. Comparisons are made with 'actual' prices in 1980 (derived in Chapter VI) to validate the estimated prices in the model solution. The LCP's estimate of prices

closely resembles observed values. In most cases, the margin of error is less than 7 percent.

With the exception of the east region, the absolute difference between estimated and 'actual' prices of millets and sorghums are small, generally less than 7 percent. The higher price of white sorghum in the east results from exports to Niger and the transmission of higher prices back to the region. The absolute percentage error for maize is generally less than 8 percent except for the central region, where due to relatively inelastic supply response, grain is imported from the east at relatively high prices.

Prices of wheat and rice are world prices less tariffs, handling and transportation charges. The estimated prices for wheat closely resemble actual prices (less than 2 percent error). The percentage error for rice is also small except in the central region where again, rice supply is highly inelastic and expensive imports from Bobo-Dioulasso are needed to meet excess demand. Estimates of groundnut prices are reasonably close to actual prices, with absolute errors less than 8 percent.

If estimated prices were equal to expected prices of producers, the model would be in dynamic equilibrium. That is, the use of estimated prices from the LCP, used to update expected prices of producers, would lead to a similar price series generated by the LCP, <u>ceteris paribus</u>. Estimated prices, however, diverge slightly, indicating the market is in dynamic disequilibrium (depending on what extent prices from the LCP are allowed to influence price expectations of producers).

This situation arises from the recursive structure of the sector model. Since production is forecast with expected prices and production influences private market equilibrium prices in the LCP, then several problems may contribute to a dynamic disequilibrium. First, the procedure used to capture producers' price expectations in the model influences production. The definition here is that expected prices equal the previous period's prices generated by the LCP. This definition will be changed shortly for dynamic analysis to demonstrate the model's sensitivity to alternative means of estimating producers' price expectations.

Second, the empirical estimation of the LPs may lead to imprecise forecasts of production due to inappropriate model specification, inaccurate technical parameters, or discontinuities in the production possibility surface, due to the stepped supply function characteristics of LP. Further, imprecise estimates of marketing margins, imports and exports can lead to inaccuracies in private market trade. Fourth, estimation errors could be a problem for econometrically estimated demand systems. However, since LES systems in this analysis are derived from benchmarked demand data and the Frisch procedure, this problem is of minor importance. As a result of these factors, it is improbable that estimated prices from the LCP would exactly equal expected prices of producers. However, the small margins of error suggest that production and trade problems in the model perform reasonably well.

LCP: Trade

International and domestic trade quantities generated by the model for the private market are summarized in Tables 8.6 and 8.7. Positive figures represent net imports to a region, negative figures imply net exports. Trade estimates associated with Niger, Mali, and Abidjan represent international imports to Burkina Faso (if negative) and exports (if positive). No trade for cotton is reported because it is marketed through official channels, entirely for exports abroad.

Note that no trade flows for the official market are endogenously solved for in the LCP. Supply in the official market is determined from production in the LP plus imports of food aid. Demand for official market goods is determined from fixed market rations set by the government. The mechanism for getting goods from points of supply to points of demand in the official market is assumed to take place outside the model.

The north represents the largest net importer, importing 56,943 tons of coarse grains, 6,929 tons of rice and 3,159 tons of wheat flour on the private market. The southwest is the largest net exporter, exporting 70,375 tons of coarse grains, 3,977 tons of rice and 8,096 tons of groundnuts. These estimates correspond closely to the net trade data presented in Chapter VI, Table 6.2, used in calculating the aggregate commodity balance sheet for the country (note, official market trade is not included, so comparisons are not entirely valid). Trade in the official market is equivalent to official market demands, presented in the next section.

Table 8.6. Net Trade FLows (Imports Minus Exports) in the Private Market, Base Model Solution, Burkina Faso, 1980.[a/]

Region	White Sorghum	Red Sorghum	Millet	Maize	Rice	Ground-nuts	Wheat Flour	Cotton	Other
	(metric tons)								
North	31,573	32	15,862	9,476	6,929	-	3,159	-	-
Central	-	-32		1,966	5,616	2,435	5,256	-	-122,303
East	-2,711	-	-1,142	-2,162	-191	-979	647	-	4,072
West	-6,626	-	-2,976	-2,058	-282	1,406	1,085	-	19,825
Southwest	-34,285	-	-25,935	-10,155	-3,977	-8,096	2,082	-	31,863
Ouagadougou	9,247	0[c/]	-9,775	387	4,244	2,705	2,294	-	-
Bobo-Dioulasso	7,989	-	25,935	4,101	3,100	2,529	1,736	-	7,677
Niger[b/]	2,711	-	1,142	863	98	-		-	-4,072
Mali[b/]	-7,898	-	-3,111	-2,397	-88	-		-	9,063
Abidjan[b/]	-	-	-	-	-15,749	-	-16,259	-	53,875

a/ Positive values indicate net imports. Negative vlaues indicate net exports. A '-' indicates zero trade.

b/ Figures indicate international imports (+) or exports (-) in trade with outside countries.

c/ A zero implies trade passed through the region.

Table 8.7. International Imports and Exports, Base Model Results, Burkina Faso.

Country:	Commodity	Actual[a]	Estimated Private	Estimated Official	Percent Error
		(metric tons)			
Imports					
Niger:	'Other'	4150	4072		-1.9
Mali:	W. Sorghum	8850	8585		-3.0
	Millet	3450	3382		-2.0
	Maize	2700	2605		-3.5
	Rice	100	96		-4.0
Abidjan	W. Sorghum	15,370		15,370	0.0
	Maize	16,430		16,430	0.0
	Rice	23,600	17,118	5,500	-4.2
	Wheat Flour	20,125	17,673	2,450	0.0
Exports					
Niger	W. Sorghum	2,950	2,711		-8.1
	Millet	1,150	1,142		-0.7
	Maize	900	863		-4.1
	Rice	100	98		-2.0
Mali	'Other'	8,800	9,063		3.0
Abidjan	'Other'	45,500	53,875		18.4
	Cotton	24,369	23,602		-3.1

a/ Actual figures represent 1980 base quantities used for estimating import supply and export demand equations.

Table 8.7 presents import and export quantities estimated by the model and compares the results with actual trade flows in 1980. The accuracy of the model in estimating prices leads to the small margin of error between estimated and actual trade flows. Excluding exports of white sorghum to Niger and 'other' commodities to Abidjan, the percentage error is less than 5 percent across countries and commodities.

LCP: Quantity Demanded

Quantity demanded equals production plus imports minus exports net of production, marketing and processing losses. Stock adjustments are assumed to be zero. Estimates of quantity demanded in the private and official markets are compared with actual (total) demand in Table 8.8. The solution quantities in the model correspond closely to actual values with small margins of error (less than 5 percent).

The LES demand system employed in the LCP was derived from demand data generated from the commodity balance sheet and base period income and prices. Import demand and export supply equations representing international trade were also estimated as continuous functions of base period prices and quantities. As long as the transportation sector and regional production models perform reasonably well, then demand, prices and international trade in the LCP will exhibit low margins of error. Since the solution results of the LCP appear to match the market equilibrium reasonably well, this substantiates the quality of production estimates by the LP.

Table 8.8. Quantity Demanded, Base Model Results, Burkina Faso, 1980.

Country: Commodity	Actual	Estimated Private	Estimated Official	Percent Error
	----------(metric tons)--------			
North				
White Sorghum	83,895	74,992	10,580	2.0
Red Sorghum	2,065	2,096	-	1.5
Millet	143,780	146,074	829	1.6
Maize	23,140	15,807	7,638	1.3
Rice	10,270	9,026	1,265	0.2
Groundnuts (shelled)	11,060	11,442	-	3.5
Wheat Flour	3,340	3,159	177	-0.1
Other	879,311	879,310	-	0.0
Central				
White Sorghum	114,635	103,586	5,399	-4.9
Red Sorghum	65,605	65,606	-	0.0
Millet	147,760	143,659	-	-2.8
Maize	21,200	15,625	3,616	-9.2
Rice	16,040	14,419	736	-5.5
Groundnuts	14,340	13,787	-	-3.9
Wheat Flour	5,660	5,256	306	-1.7
Other	1,295,788	1,173,482	-	-9.4
East				
White Sorghum	38,550	34,876	920	-7.1
Red Sorghum	3,710	3,711	-	0.0
Millet	26,400	26,266	-	-0.5
Maize	5,910	4,845	920	-2.5
Rice	2,000	1,799	184	-0.9
Groundnuts	3,410	3,390	-	-0.6
Wheat Flour	710	647	64	0.3
Other	221,930	225,994	-	1.8
West				
White Sorghum	58,500	60,451	920	4.9
Red Sorghum	22,310	22,309	-	0.0
Millet	39,800	41,405	-	4.0
Maize	8,790	8,215	920	3.9
Rice	2,760	2,614	184	1.4
Groundnuts (shelled)	5,810	6,105	-	5.1
Wheat Flour	1,170	1,085	97	0.9
Other	388,766	408,590	-	5.1

Table 8.8. (Continued)

Country; Commodity	Actual	Estimated Private	Estimated Official	Percent Error
	----------(metric tons)--------			
Southwest				
White Sorghum	77,195	81,756	92	6.0
Red Sorghum	15,085	15,085	-	0.0
Millet	29,830	31,281	-	4.9
Maize	46,050	48,303	183	5.3
Rice	6,830	6,765	184	1.8
Groundnuts (shelled)	7,555	7,956	-	5.3
Wheat Flour	2,140	2,082	96	1.8
Other	542,616	574,478	-	5.9
Ouagadougou				
White Sorghum	13,160	9,247	4,140	1.7
Red Sorghum	-	-	-	-
Millet	2,440	2,474	-	1.4
Maize	2,220	388	1,839	0.3
Rice	6,820	4,244	2,599	0.3
Groundnuts (shelled)	2,630	2,705	-	2.9
Wheat Flour	3,200	2,294	902	-0.1
Other	154,030	154,030	-	0.0
Bobo-Dioulasso				
White Sorghum	8,630	7,989	1,013	4.3
Red Sorghum	-	-	-	-
Millet	1,380	1,438	-	4.2
Maize	5,000	4,101	1,105	4.1
Rice	4,280	3,100	1,288	2.5
Groundnuts (shelled)	2,395	2,529	-	5.6
Wheat Flour	2,300	1,736	612	2.1
Other	89,914	97,591	-	8.5

In light of these results, several observations concerning the model's overall performance merit mentioning. First, quantities in the commodity balance equation--private market supply, private market demand, official market supply, official market demand, trade and losses--appear to have received proper accounting in the model. Further, the quality of the results support the notion that accurate 'Commodity Balance Sheets' are essential to the analysis. Second, the LPs used to estimate supply and the LCP to estimate prices, trade flows and quantity demanded in the private market performed well in obtaining a short-run (annual) market equilibrium solution. Margins of error are low and the market solution matches actual market conditions well.

Dynamic Equilibrium

Choosing the set of prices to represent producers' price expectations was a problem alluded to in the previous analysis. A related problem is concerned with how well the market performs when using its recursive structure to run iteratively through time.

Producers' price expectations are represented by the equation:

$$P^{m}_{hk(t)} = \lambda \, \bar{P}^{m}_{hk} + (1-\lambda) \, \tilde{P}^{m}_{hk(t-1)}$$

where P^{m}_{hk} are producers' expected prices incorporated in the LP, $\bar{P}^{m}_{hk}$ are producers' long run prior expectations of prices which remain constant (i.e., actual prices used to solve the model in the initial period) and $\tilde{P}^{m}_{hk}$ are private market prices generated by the LCP. When

$\lambda=1$, expected prices of producers remain constant, equalling long run price expectations, regardless of price levels $\tilde{P}^m_{hk}$. When $\lambda=0$, price expectations of producers equal the previous period's prices. That is, expected prices P^m_{hk} adjust fully to the price change (e.g., levels of $\tilde{P}^m_{hk}$). In this case, prices from the LCP are entered directly into the objective function of the LP problem, without modification.

Whether or not the 'base' model is in dynamic equilibrium depends on how closely the long-run expected price $\tilde{P}^m_{hk}$ matches P^m_{hk}, assuming that $P^m_{hk} = \tilde{P}^m_{hk}$. If the two sets of prices ($\tilde{P}^m_{hk}$ and P^m_{hk}) match closely, the model is close to a state of dynamic equilibrium. If prices diverge, the model is in disequilibrium. A dynamic equilibrium can be imposed by setting $\lambda=1$, which is the same as setting $\tilde{P}^m_{hk}$ to P^m_{hk}. However, in so doing, the possibility of producers altering their long-run price expectations, due to price changes accompanying policy shocks, is prohibited.

As shown in Table 8.9, the model is very sensitive to parameter values chosen for λ. The results are solution values for prices from the LCP for year 5 (the LPs generate quantity supplied, the LCP estimates prices, expected prices are computed, the objective functions are updated in the LPs and the process repeated, through 5 iterations). For levels of λ between .80 and .85, prices fluctuate widely compared with the case where $\lambda = 1.0$. Thus, the model exhibits a state of dynamic disequilibrium with low levels of λ. However, for $\lambda = .90$, estimated prices remain constant throughout the 5 years (i.e., when $\lambda = 1.0$).

Table 8.9. Commodity Prices Estimated by the LCP, Five Year Solution, Burkina Faso.[1/]

Region: Commodity	λ=.80	λ=.85	λ=.90	λ=1.00
	(FCFA/kg.)			
North				
White Sorghum	109	105	80	80
Millet	63	68	82	82
Maize	38	39	78	78
Rice	153	154	153	153
Groundnuts	52	56	144	144
Central				
White Sorghum	84	82	60	60
Millet	54	59	58	58
Maize	29	29	68	68
Rice	143	144	143	143
Groundnuts	14	18	134	134
East				
White Sorghum	71	67	54	53
Millet	47	47	47	48
Maize	21	20	46	46
Rice	121	122	121	121
Groundnuts	30	34	101	101
West				
White Sorghum	80	76	51	51
Millet	34	39	53	53
Maize	9	10	49	49
Rice	124	125	124	124
Groundnuts	31	35	111	111

1/ Producers' price expectations are updated with the equation: $P^m = \lambda\bar{P}^m + (1-\lambda)\tilde{P}^m$, where P^m is the updated price entered into the objective function of the LP, $\bar{P}^m$ are the long run expected prices of producers and $\tilde{P}^m$ are previous period prices, estimated by the LCP. The coefficient 'λ' is the price adjustment factor. When λ=1, producers' price expectations remain constant regardless of market effects. When λ=0, producers' expectations are based entirely on the previous period's price.

Several factors contribute to the volatility in prices (and quantities) in the model. First, the LPs are very sensitive to price changes. This problem is due in part to the step-supply function implicit in the LP formulation and high substitutability among crops and technologies in the model. Second, the LCP is sensitive to quantity changes. The own-price elasticities of demand computed by the LES are on the order of -0.50, implying a price flexibility coefficient in the neighborhood of -2.00. A one percent change in quantity then would change prices 2 percent, given the small cross-price effects in the LES.

For low levels of λ, the updated prices in the LPs (with prices from the LCP) are large enough to create significant changes in quantity supplied. The change in quantity then has a magnifying effect on prices in the LCP, which in turn creates a larger distortion in quantity supplied in the LPs, and so on. By year (iteration) three, prices and quantities oscillate widely; in one year, high production of, say, white sorghum in the LPs leads to low prices in the LCP; in the following year low price expectations of producers (influenced by low prices in the previous period) lead to low production in the LPs, then high prices in the LCP. Only with expected prices dampened at $\lambda = .90$ or higher is the model solution stable over time.

This oscillation pattern holds major implications for long run policy simulations. In the case where fertilizer policy leads to a supply response and changed prices, model oscillations in prices and quantities will hamper the long term evaluation of changes in fertilizer demand to the changes in price. Raising the value of λ is one

alternative for stabilizing the model, but it effectively limits the extent of resource adjustment.

It is important to recognize that the issue of price expectations and model instability goes beyond the simple mechanics of the model. Clearly, producers base their crop production decisions on their expectations of post-harvest prices. It is not clearly understood, however, how these expectations are formed. There is reason to believe farmers do not change their expectations quickly due to future uncertainty. However, instances can arise where producers may change their expectations drastically as when the government offers guaranteed prices. This problem receives further treatment in the long-run policy simulations in the next chapter.

This completes the model validation section. Attention now shifts to the application of the model for policy analysis.

CHAPTER IX

POLICY ANALYSIS

The purpose of this chapter is to present and evaluate the results of policy simulations with the sector model. The analysis focuses on the effects of the World Bank policy which recommends that the government of Burkina Faso eliminate its fertilizer subsidies and increase output prices.

In the first section, the analysis looks at the impacts associated with removing fertilizer subsidies. It examines the separate and joint effects of increasing fertilizer prices and reducing restrictions on the government's ability to supply and distribute additional fertilizer.

Following that, commodity price policy of the government is examined. The analysis looks at the direct effect of government action to increase prices of cotton and cereals on the official market plus the indirect effect of raising prices through reduced levels of food aid imports. Price policy is then integrated with the government's removal of fertilizer subsidies. The third section looks at agricultural technology, examining the regional variation in profitability of fertilizer and animal traction resources.

Fertilizer Policy

Fertilizer in Burkina Faso is sold mainly on the official market at prices set annually by the government. Theoretically, fertilizer is sold at fixed official prices nationwide, although the ORDs modify prices to cover transport costs. The price of Urea to producers is subsidized 28 to 40 percent, depending on the region, while cotton fertilizer is subsidized 53 to 56 percent.

To increase fertilizer utilization, the government may lower fertilizer prices, raise commodity prices, increase the availability of fertilizer on the official market, or some combination of all three options. Nearly all fertilizer sold in the country is channeled through the official market. Hence, the amount of fertilizer the government makes available and the rationing of fertilizer among regions are important policy issues. Fertilizer purchases by producers depend on the economic profitability of fertilizer, but fertilizer supply may be constrained by budgetary restraints of the government or capacity restrictions in the government's input distribution system.

An alternative proposal would be to give private entrepreneurs a freer hand in fertilizer marketing activities. Official prices of fertilizer may remain intact, but sales by traders would depend on the profit maximizing decisions of producers. This would shift the supply of fertilizer away from the government where capacity constraints may exist, but would reduce the government's ability to regulate fertilizer prices. An equivalent effect would be produced by simply relaxing fertilizer constraints on the official market.

International financial authorities (IMF, the World Bank) have directed the government of Burkina Faso to phase out its program of fertilizer subsidies (see Chapter II for details). The directive came in response to a burgeoning fiscal crisis in the mid to late 1970s. Proponents for the elimination of subsidies argue: 1) benefits accrue primarily to better farmers using modern inputs; 2) subsidies are inferior to higher commodity prices as a means for attaining higher agricultural output; and 3) the cost of subsidies will grow increasingly difficult to pay with the technological evolution of agriculture. The problem of subsidy cost is exacerbated by the government's monopoly control over fertilizer distribution, which links fertilizer availability and use to government budgetary and foreign exchange problems.

Opponents to the elimination of subsidies argue that higher fertilizer prices to producers would lead to diminished fertilizer use and have profound impacts on agricultural output. Furthermore, the policy runs counter to the country's goal of food security and stifles efforts to transform the agricultural sector and reverse trends of falling productivity.

Three alternative scenarios are evaluated with the model to address the issues of this debate. Each scenario employs different assumptions concerning the price and availability of fertilizer:

> Scenario I: The government eliminates the fertilizer subsidies, charging farmers the world price plus transportation cost adjustments. The government, however, has capacity constraints on the amount of fertilizer it can make available to producers.

Scenario II: The government maintains the fertilizer subsidy at current levels, but removes all restrictions on fertilizer availability. Producers may buy as much fertilizer as they wish (capacity constraints are relaxed) and payment-in-kind restrictions imposed on fertilizer purchases are removed.[1/]

Scenario III: The government eliminates the fertilizer subsidy and removes all restrictions on fertilizer availability (Scenarios I and II combined).

The alternative assumptions concerning fertilizer prices and rations under the three policy scenarios are compared with the 'base' case in Table 9.1. The model's solution for agricultural output and retail prices are reported in Tables 9.2 and 9.3, while model results for demand and international trade are reported in Tables 9.4 and 9.5. The effects of the three alternative policies on cropping income of producers and cereals utilization per capita are summarized in Table 9.6.

Fertilizer Scenario I: Removing fertilizer subsidies in the model but maintaining fertilizer rations at current levels, does not alter the utilization of fertilizer (Table 9.1) or agricultural output (Table 9.2). This effect is a consequence of the fixed rations which limit the amount of fertilizer supplied in the model. As explained in the previous chapter, the shadow prices associated with these fixed rations are sizable. Increasing fertilizer prices in the model does not sufficiently reduce these shadow costs to bring about diminished fertilizer use.

1/ As explained in Chapter IV, a portion of input sales are based on the condition that repayment be made with sales of commodities to the government on the official market.

Table 9.1. Input Prices, Quantities and Subsidies, Alternative Fertilizer Scenarios, Annual Model, Burkina Faso, 1980.

Details	Base Case	No Fert. Subsidy (I)[a]	No Quantity Restriction (II)	Combination (III)[a]
Urea Price (FCFA/kg.):[b]				
North	79	109	79	109
Central	79	104	79	104
East	79	109	79	109
West	60	100	60	100
Southwest	60	100	60	100
Cotton Fert. Price (FCFA/kg.):[b]				
North	45	99	45	99
Central	45	95	45	95
East	45	99	45	99
West	40	91	40	91
Southwest	40	91	40	91
Urea Quantity (mt.)[c]				
North	28	28	28	28
Central	36	36	36	36
East	13	13	13	13
West	-	-	401	394
Southwest	284	284	656	589
Cotton Fert. Quantity (mt.)[c]				
North	1530	1530	54,937	26,431
Central	1355	1355	87,083	39,000
East	145	145	13,717	8,225
West	3565	3565	20,890	19,493
Southwest	5815	5815	37,323	36,571
Govt. Fert. Subsidies (mil. FCFA)[d]				
North	83.5	-	2967.4	-
Central	68.7	-	4355.1	-
East	8.2	-	741.1	-
West	181.8	-	1081.4	-
Southwest	307.9	-	1929.7	-

a/ Economic (distortion free) prices were computed by the World Bank (1981, p. 209).

b/ Prices in the base case and Scenario (II) are fixed subsidized prices charged by the ORDs in 1980; prices in Scenarios (I) and (III) are unsubsidized rates assumed for the model.

c/ Quantities of Urea and cotton fertilizer are model solution values.

d/ Computed as economic price less the subsidized price times the level of fertilizer usage.

Table 9.2. Total Production of Agricultural Commodities, Alternative Fertilizer Scenarios, Annual Model, Burkina Faso.

Region: Commodity	Base Case	No Fert. Subsidy (I)	No Quantity Restriction (II)	Combination (III)
	(metric tons)			
North				
Sorghum[a/]	53,192	53,192	78,294	78,145
Millet	151,067	151,067	161,212	157,839
Maize	7,320	7,320	7,320	7,320
Paddy	3,730	3,730	3,730	3,730
Groundnuts	18,897	18,897	24,571	23,403
Cotton	3,330	3,330	-	-
Central				
Sorghum[a/]	198,079	198,079	231,258	264,526
Millet	166,080	166,080	184,619	174,989
Maize	15,791	15,791	15,791	15,791
Paddy	15,124	15,124	15,569	15,693
Groundnuts	18,748	18,748	31,789	7,113
Cotton	2,316	2,316	62,620	6,615
East				
Sorghum[a/]	49,956	49,956	63,140	64,739
Millet	31,687	31,687	39,479	33,168
Maize	8,125	8,125	6,306	6,306
Paddy	3,538	3,538	4,885	4,168
Groundnuts	7,215	7,215	8,829	8,839
Cotton	446	446	214	214
West				
Sorghum[a/]	106,848	106,848	126,870	138,572
Millet	51,733	51,733	54,292	53,473
Maize	11,877	11,877	11,877	11,877
Paddy	5,150	5,150	4,941	4,956
Groundnuts	7,760	7,760	747	3,348
Cotton	26,237	26,237	48,280	31,167
Southwest				
Sorghum[a/]	153,049	153,049	254,445	253,934
Millet	51,985	51,985	54,891	54,724
Maize	68,858	68,858	13,208	10,829
Paddy	21,563	21,563	21,563	21,563
Groundnuts	26,511	26,511	32,425	31,884
Cotton	31,459	31,459	39,709	42,602

a/ White sorghum and red sorghum combined. Changes in production of "sorghum" refer to white sorghum.

Table 9.3. Retail Prices, Alternative Fertilizer Scenarios, Annual Model, Burkina Faso.

Region: Commodity	Base Case	No Fert. Subsidy (I)	No Quantity Restriction (II)	Combination (III)
	(FCFA/kg.)			
North				
W. Sorghum	80.0	79.7	39.0	39.0
Millet	81.9	81.7	77.2	78.7
Maize	78.5	78.2	104.9	104.9
Rice	153.2	153.1	153.6	153.2
Groundnuts	144.1	143.9	69.2	140.6
Wheat	145.0	145.0	145.4	145.2
Other	43.4	43.4	47.7	45.6
Central				
W. Sorghum	60.0	60.0	29.0	14.0
Millet	58.0	58.1	52.2	55.5
Maize	68.5	68.2	88.9	88.9
Rice	143.2	143.1	143.6	143.2
Groundnuts	133.8	133.5	67.2	161.6
Wheat	135.0	135.0	135.4	135.2
Other	46.4	46.3	51.2	48.7
East				
W. Sorghum	53.2	53.2	30.7	25.2
Millet	47.6	47.6	39.2	45.5
Maize	46.5	46.2	66.9	66.9
Rice	121.2	121.1	121.6	121.2
Groundnuts	100.8	100.5	48.2	128.6
Wheat	157.0	157.0	157.4	157.2
Other	53.2	53.2	58.9	56.2
West				
W. Sorghum	51.0	50.7	10.0	10.0
Millet	52.9	52.7	48.2	49.7
Maize	49.5	49.2	83.9	83.9
Rice	124.2	124.1	124.6	124.2
Groundnuts	110.8	110.5	84.2	138.6
Wheat	129.0	129.0	129.4	129.2
Other	66.4	66.3	71.2	68.7
Southwest				
W. Sorghum	41.0	40.7	0.0	0.0
Millet	42.9	42.7	38.2	39.7
Maize	39.5	39.2	97.9	97.9
Rice	114.2	114.1	114.6	114.2
Groundnuts	89.8	89.5	63.2	117.6
Wheat	138.0	138.0	138.4	138.2
Other	75.4	75.3	80.2	77.7

Table 9.3. (Continued)

Region: Commodity	Base Case	No Fert. Subsidy (I)	No Quantity Restriction (II)	Combination (III)
	----------(FCFA/kg.)----------			
Ouagadougou				
W. Sorghum	68.0	67.7	27.0	27.0
Millet	69.9	69.7	65.2	66.7
Maize	66.5	66.2	92.9	92.9
Rice	141.2	141.1	141.6	141.2
Groundnuts	130.8	130.5	87.2	158.6
Wheat	133.0	133.0	133.4	133.2
Other	54.2	54.2	55.8	55.2
Bobo-Dioulasso				
W. Sorghum	57.0	56.7	16.0	16.0
Millet	58.9	58.7	54.2	55.7
Maize	55.5	55.2	81.9	81.9
Rice	130.2	130.1	130.6	130.2
Groundnuts	113.8	113.5	87.2	141.6
Wheat	122.0	122.0	122.4	122.2
Other	59.4	59.3	64.2	61.7

Table 9.4. Commodity Utilization in Rural and Urban Markets, Alternative Fertilizer Scenarios, Annual Model, Burkina Faso.

Region: Commodity	Base Case	No Fert. Subsidy (I)	No Quantity Restriction (II)	Combination (III)
	(metric tons)			
Rural				
White Sorghum	373,504	373,445	504,459	510,877
Red Sorghum	108,806	108,806	108,803	108,802
Millet	389,514	389,501	425,405	408,012
Maize	106,072	106,052	76,019	74,005
Rice	37,178	37,156	38,235	37,692
Groundnuts	42,680	42,671	51,650	40,447
Wheat	12,970	12,962	13,340	13,146
Other	3,261,854	3,261,406	3,273,834	3,267,180
Urban				
White Sorghum	22,389	22,425	26,800	26,778
Red Sorghum	-	-	-	-
Millet	3,912	3,918	4,050	4,008
Maize	7,432	7,444	6,529	6,534
Rice	11,231	11,236	11,286	11,284
Groundnuts	5,234	5,242	5,964	4,712
Wheat	5,543	5,545	5,572	5,567
Other	251,621	251,839	247,452	249,950

Table 9.5. International Trade, Alternative Fertilizer Scenarios, Annual Model, Burkina Faso.

Region: Commodity		Base Case	No Fert. Subsidy (I)	No Quantity Restriction (II)	Combination (III)
		-(Net Imports to B.F.: metric tons)[a]			
Private Market:					
Niger:	White Sorghum	-2711	-2712	-3457	-3636
	Millet	-1142	-1142	-1248	-1169
	Maize	- 863	- 866	- 646	- 645
	Rice	- 98	- 98	- 98	- 98
	Other	4072	4071	4320	4202
Mali:	White Sorghum	7898	7875	4636	4636
	Millet	3111	3104	2970	3014
	Maize	2397	2391	3253	3254
	Rice	88	88	89	88
	Other	-9063	-9074	-8710	-8898
Abidjan:	Maize	-	-	17,685	17,732
	Rice	15,749	15,731	15,975	15,755
	Wheat	16,259	16,252	16,663	16,464
	Other	-53,875	-54,094	-46,665	-50,514
Official Market					
Abidjan:	Groundnuts	-	-	-	-
	Cotton	-23,602	-23,602	-55,805	-29,821

a/ Negative figures imply net exports from Burkina Faso.

Table 9.6. Agricultural Income, Demand and Trade Balance, Alternative Fertilizer Scenarios, Annual Model, Burkina Faso.

	Base Case	No Fert. Subsidy (I)	No Quantity Restriction (II)	Combination (III)
I. Producers Expected Net Ag. Income (mil. FCFA)				
North	21,622	21,539	24,237	22,558
Central	28,980	28,912	34,475	30,744
East	5,848	5,840	6,727	6,162
West	12,441	12,259	14,108	13,043
Southwest	18,865	18,558	21,472	19,420
II. Producers Realized Net Ag. Income (mil. FCFA)				
North	20,779	20,316	17,928	18,110
Central	29,229	29,195	27,903	22,790
East	6,253	6,240	5,323	5,342
West	12,055	11,823	10,285	8,455
Southwest	17,974	17,581	10,501	9,896
III. Cereals Consumption per Capita (kg.)				
North	164	164	183	179
Central	167	167	190	191
East	168	168	198	196
West	200	200	240	236
Southwest	207	207	226	221
Ouagadougou	150	150	162	162
Bobo-Dioulasso	179	179	190	190
IV. Official Mkt. External[a/] Trade (mil. FCFA)				
Cotton Exports	6498	6498	15,365	8211
Fertilizer Imports	-937	-937	-15,743	-9576
Ratio Exports to Imports	6.9	6.9	1.0	0.9
V. Current Acct. Adjustment (mil. FCFA)[b/]				
Niger	141	141	73	81
Mali	86	90	319	290
Abidjan[c/]	7723	7737	345	381

a/ Calculations are based on 275,329 FCFA/m.t. cotton (CAF Abidjan), 81,916 FCFA/m.t. Urea and 73,150 FCFA/m.t. cotton fertilizer (CAF Bobo).

b/ Calculations are based on trade values and prices endogenous to the model. Positive values indicate net surpluses in trade.

c/ Includes official net trade from item IV.

Higher fertilizer costs, however, lower the cropping income of rural producers (Table 9.6). For the sector as a whole, net agricultural income falls from 87.8 billion FCFA to 87.1 billion FCFA, causing quantity demanded by rural households to slacken slightly for nearly all commodities. The leftward shift in demand (supply has remained constant) reduces prices in the private sector, although the reduction is generally less than one percent for all commodities and regions. The overall effect of lower incomes and prices for rural households is a 124 ton reduction in total cereals demand (Table 9.4). Urban households increase their consumption of cereals by 60 tons due to constant incomes and lower prices.

The reduction in domestic commodity prices relative to the rest of the world leads to a slight expansion in exports, fewer imports and an improvement in the country's current account (Tables 9.5 and 9.6). The net trade balance (exports less imports) rises from 7.95 to 7.97 billion FCFA. The government's financial statement also improves slightly. Even though cotton exports remain constant at 6.50 billion FCFA (Table 9.6), the government no longer pays the input subsidies which amounted to 650 million FCFA in the base solution.

The finding that agricultural output is unaffected by the elimination of fertilizer subsidies is somewhat unrealistic. Certainly, some fertilizer is applied at the margin which would cease to be profitable at higher prices. However, the model solution suggests that current government rations underestimate potential fertilizer utilization, given production functions to fertilizer

assumed in the analysis. Some redistribution of fertilizer to alternative profitable uses would thus be possible, although poor physical infrastructure may impose high costs on market redistribution.

Fertilizer Scenario II: The resiliency of agricultural output to higher fertilizer prices in Scenario I, plus high shadow costs associated with fertilizer use begs an examination of the potential impact of removing restrictions on fertilizer availablity. This scenario merits caution, because it assumes all producers within a region can acquire as much fertilizer as they can afford, regardless of problems--poor physical and marketing infrastructure, informational costs and financial constraints of producers--which impose important constraints on fertilizer distribution and use. Nevertheless, it provides an estimate of the potential supply response of the sector to fertilizer, hence the benefits to eliminating the restrictions.

Making unlimited fertilizer available has the greatest impact on the north and central regions, where it was observed in Chapter VIII that shadow prices of fertilizer are highest. Fertilizer utilization increases from 1,530 to 54,937 metric tons in the north and from 1,355 to 87,083 metric tons in the central region, although fertilizer use expands in all zones (Table 9.1). Total fertilizer use for the country--213,950 metric tons--is 17 times the 1980 utilization rate, indicating a strong latent demand for fertilizer at subsidized prices.

Several factors contribute to the sharp rise in fertilizer use on the Mossi Plateau (north and central regions). First, the agricultural population and number of farms there are greater than in the west and southwest, providing a larger area which potentially could be

fertilized. Second, prices are higher on the Mossi Plateau. While the physical response to fertilizer in the north is 30 to 40 percent lower than in the southwest, commodity prices are twice as great (Table 9.3).[2/] The higher prices more than proportionately offset the lower physical yield response, contributing to higher financial returns overall.

White sorghum experiences the greatest change in production among cereals in response to additional fertilizer availability. This is evident in the solution values for production in Table 9.2 and for fertilized area in Table 9.7.[3/] White sorghum production increases by 17 percent in the central region, 19 percent in the west, 26 percent in the east, 47 percent in the west and 66 percent in the southwest.

There is also fertilization of maize and red sorghum in the model (Table 9.7), although little effect is apparent in production data in Table 9.2. The area of these crops declines in the model as land is reallocated to other crops. The reason for this stems from the high shadow costs associated with production constraints, particularly minimum maize requirements for the soudure. In this case, maize is fertilized to reduce the high shadow costs associated with minimum consumption requirements, but only until the constraint is met.

2/ On higher quality village soils, the response of white sorghum per kilogram NPK (based on a 100 kg. appplication) is assumed to be 4.8 in the north and 6.9 in the southwest. On lower quality village soils, response rates of 3.5 in the north and 5.7 in the southwest were assumed (Appendix 2, Table A2.4).

3/ Note that red sorghum is combined with white sorghum in production statistics, but remains constant across the various scenarios because of bounds placed on its production.

Table 9.7. Fertilized Area, Alternative Fertilizer Scenarios, Annual Model, Burkina Faso.

Region: Commodity	Base Case	No Fert. Subsidy (I)	No Quantity Restriction (II)	Combination (III)
	(hectares)			
North				
W. Sorghum	28,753	28,753	109,619	109,619
Millet			323,220	57,398
Maize			11,431	11,431
Paddy	523	523	523	523
Groundnuts			41,827	42,093
Cotton				
Central				
W. Sorghum	4,789[a/]	4,789	199,699	246,777
R. Sorghum	10,284	10,284	45,080	57,333
Millet			429,346	
Maize	614[a/]	614	614	614
Paddy	1,446	1,446	1,446	1,446
Cotton	2,677[a/]	2,677	81,648	2,677
East				
W. Sorghum	1,582	1,582	52,929	51,528
Millet			44,532	
Maize			4,275	859
Paddy	395	395	2,960	
Cotton			315	315
West				
W. Sorghum	20,962	20,962	78,337	95,796
R. Sorghum			20,935	20,903
Maize			8,022	7,888
Paddy	450	450	450	450
Cotton	3,532	3,532	50,877	31,125
Southwest				
W. Sorghum	13,016	13,016	228,335	230,424
R. Sorghum	7,742	7,742	12,850	12,894
Maize			7,439	6,100
Paddy	4,111	4,111	4,111	4,111
Groundnuts			3,232	
Cotton	27,963	27,963	32,363	35,330

a/ Areas within the AVV.

Thereafter, expanded maize production is not profitable.

The supply response of millet and groundnuts in the model is more moderate than for sorghum. The increase in millet production ranges from 5 percent in the west to 25 percent in the east. The increase in groundnut production ranges from 22 percent (east and southwest) to 70 percent (central), calculated on a smaller base. By themselves, these responses represent sizable gains in production.

Soil quality is an important factor explaining the production response to increased fertilizer availability. Physical response rates to fertilizer are highest on better quality soils closest to the family compound. They decline as one moves onto the bush areas. Higher quality soils (where sorghums and maize are normally cultivated) are the first to be fertilized and receive the highest fertilizer dosages. This explains the high supply response of sorghum in the model. Millet and groundnuts tend to be fertilized on the poorer quality soils in the north and central zones; sorghum and groundnuts are fertilized in the west and southwest.[4/]

Total production of cereals nationwide rises from 1,175 to 1,354 thousand metric tons, a 15 percent increase. Cotton production increases from 63.7 to 150.8 thousand tons and groundnuts from 79.1 to 98.3 thousand tons, representing increases of 138 and 24 percent, respectively.

[4/] Higher millet production in the east is due to the fertilization of millet-sorghum grown in association. The shift from millet in the north to sorghum in the southwest stems from different response rates to fertilizer assumed in the model.

Agricultural income for the sector measured at producers' expected prices increases 15.8 percent, from 87.8 to 100.1 billion FCFA (Table 8.9). However, the short-run shock of higher agricultural output has a large depressing effect on agricultural prices. Taking prices in Ouagadougou as 'national' prices, the price of white sorghum declines 60.3 percent, millet by 6.7 percent and groundnuts by 33.3 percent. The price of maize increases 39.7 percent due to the shortfall of production in the west and southwest regions. In the southwest, the price of white sorghum falls to 0.0. Prices are constrained to be non-negative in the LCP. Consequently, the large production response from white sorghum led to zero prices and surplus residual stocks in the region.

When actual prices from the LCP are used (instead of expected prices) to estimate 'realized' agricultural income of producers, net income for the sector falls 16.6 percent, from 86.3 to 71.9 billion FCFA. Since fertilizer prices are still subsidized, this effect is due to lower commodity prices and higher output in the model solution. In the longer-run, fertilizer utilization should fall with lower commodity prices. The effect of this scenario will be covered shortly.

Private market demand for cereals increases for all consumer groups (Table 9.6), but proportionately more for rural producers, due to higher expected income. The increase in per capita cereal consumption is greatest in the east (30 kg./person) and west (40 kg./capita) where the production response to fertilizer is high (relative to the

Mossi Plateau)[5/] and lowest in Ouagadougou (12 kg./ person) and Bobo-Dioulasso (11 kg./person) which receive only the benefit of lower prices (urban incomes are constant).

While producers and consumers benefit greatly from the program, the government's subsidy payments rise to 11,075 million FCFA, six times the 1980 level. The size of this expense lends credence to worries of international authorities concerning the government's ability to support the subsidies with expanded fertilizer utilization.

Fertilizer Scenario III: In the third scenario, the government eliminates its fertilizer subsidies to producers and removes all restrictions on fertilizer distribution. The fixed official fertilizer price charged to farmers is the world price, less transportation cost adjustments. As with 'Scenario II', fertilizer availability is unrestricted. Sales by the government are determined by the fertilizer demand schedule of producers and prices. This scenario, then, is closely related to a private market solution.

The policy change substantially reduces the amount of fertilizer demanded by producers, compared with subsidized prices in Scenario II. Total fertilizer utilization drops from 213,950 to 129,720 tons (Table 9.1). This level is still 10 times greater than the 1980 rate of fertilizer utilization (base case solution), indicating there is considerable scope for the government to expand its fertilizer marketing activities. Fertilizer utilization drops in all regions, but

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5/ The southwest might also be included if it were not for the allocation of fertilizer to cotton and groundnuts.

especially in the north (from 54.9 to 26.4 thousand tons) and central regions (from 87.1 to 39.0 thousand tons), where fertilizer is only marginally profitable on poorer quality soils at subsidized prices.

Since the physical yield response to fertilizer is lowest on poorer quality soils, crops fertilized on these lands are the first to be affected by higher fertilizer prices. This is particularly evident in the solution values for millet in Tables 9.3 and 9.7. Compared with Scenario II, the area of fertilized millet in the north drops from 323.2 to 57.4 thousand hectares while production declines by 2 percent. In the case of the central and east regions, fertilization of millet ceases, causing production to fall by 5 percent and 16 percent, respectively. White sorghum production increases in the central, east and west regions due to its substitution for cotton and maize in the model.

The above results point out the difficulties of evaluating the 'pure' supply response of a crop to fertilizer when using a multi-commodity framework. Expanding production of one commodity may alter crop area, which in turn affects area and production of other crops through competing demands for land and labor. In the central region, for example, the area of fertilized white sorghum increases from 199.7 to 246.8 thousand hectares, even though fertilizer prices are higher due to the decline in fertilized cotton from 82 to 3 thousand hectares.[6/]

6/ Weeding of sorghum competes with planting of maize and cotton at the critical peak periods of labor demand.

Net expected agricultural income of producers (91.9 billion FCFA) is less than the 101.0 billion FCFA reported for Scenario II, but is superior to the income of 87.8 billion FCFA in the base case solution. Due to the lower price of white sorghum in the central and east regions (Table 9.3) plus higher fertilizer costs, realized income of producers also falls from 71.9 to 64.6 billion FCFA (compared with 86.3 billion FCFA in 1980 base solution).

The cost of government fertilizer subsidies falls to zero with the policy change, but foreign exchange constraints emerge. The value of fertilizer imports increases from 0.9 billion FCFA (base case) to 9.6 billion FCFA, while the value of cotton exports rises more moderately from 6.5 to 8.2 billion FCFA. Overall, the ratio of cotton exports to fertilizer imports falls from 6.9 to 0.9. The country also imports slightly higher levels of wheat and rice and becomes a net importer of maize. The net effect of these trade adjustments is a 6.5 million FCFA fall in the trade balance.

Fertilizer Policy: Long-Term Impacts

The removal of restrictions on the availability of fertilizer (simulated in Scenarios II and III) led to increased agricultural output and sharply reduced commodity prices in the private market. Recall that producers base their fertilizer purchases and cropping decisions on prices they expect to receive in the marketplace at some future date. Given these price expectations, fertilizer use and output are endogenously determined from the regional LPs. The actual selling price producers receive in the private market, however, is set

by market forces of supply and demand, after production is determined. These prices are endogenously determined within the LCP. The positive supply response to fertilizer (estimated by the LPs) that led to lower commodity prices (determined by the LCP) in the previous section represents an annual, short-term effect of the policy change.

The short-term analysis offers little insight into adjustments in fertilizer use that may occur in response to lower commodity prices in the longer run. If the naive assumption is made that producers do not alter their expectations of prices in response to lower prices received for their goods over the long run, then financial returns to fertilizer will be over-estimated and fertilizer use will exceed the optimal allocation. A more reasonable assumption would involve lowering producers' price expectations in accordance with lower commodity prices. The critical question, in this case, involves the rate at which this adjustment occurs. Certainly, some downward adjustment would be expected, but wide variability in historical yield and price data suggest producers may be unwilling to greatly alter their expectations, at least in the intermediate run. To complicate matters, the validation of the dynamic model solution in Chapter VIII showed the LP models to be highly sensitive to changes in the parameter 'λ' governing the degree of adjustment in expected prices in the model.[7/]

7/ As noted in Chapter VIII, producers' price expectations are updated with the equation: $P^m = \lambda \bar{P}^m + (1-\lambda)\tilde{P}^m$, where P^m is the updated price entered into the objective function of the LP, $\bar{P}^m$ are the long run expected prices of producers and $\tilde{P}^m$ are the previous period's prices, estimated by the LCP. When $\lambda=1$, producers' price expectations remain constant regardless of market effects. When $\lambda=0$, producers' expectations are based entirely on the previous period's prices.

Fertilizer Scenario IV: The fourth scenario (complementary to Scenario III) examines the effect of lower prices on fertilizer utilization in the longer run. The model is run recursively for a period of five years under three different assumptions concerning price adjustment in the model: $\lambda=1$, indicating producers' price expectations remain constant with time (equivalent to Scenario III), $\lambda=.80$, and $\lambda=.60$. As λ declines, price changes from policy shocks have greater influence on formation of expected prices in the model.

Table 9.8 reports the results of solution values for fertilizer, production and agricultural income. Results are averages of the fourth and fifth year model solutions to compensate for the wide year-to-year variability in production and prices, explained in Chapter VIII.

In the case that $\lambda=1.0$, fertilizer utilization remains constant over time, totalling 129,720 tons for the country. When $\lambda=0.80$, fertilizer utilization by the fifth year (two-year average) drops to 118,880 tons, representing an 8 percent decline. If $\lambda=0.60$ is assumed, fertilizer utilization in year 5 is 125,760 tons, representing a more moderate decline of 3 percent.

Thus, the incorporation of lower prices (stemming from the positive supply response to fertilizer) into producers' price expectations reduces fertilizer demand over the longer run. But, the effects are not always consistent or clearcut. In the north, fertilizer shows little variation for alternative assumptions of 'λ'. In the central region, fertilizer use increases from 39,000 tons ($\lambda=1.0$) to 47,776 tons ($\lambda=0.60$). Fertilizer utilization in the southwest drops from

Table 9.8. Fertilizer Quantity, Production and Income, Alternative Assumptions Concerning Producers' Price Expectations, Fertilizer Scenarios.

		Scenario III	-----Scenario IV----	
		λ=1.0	λ=0.80	λ=0.60
Fertilizer Utilization (metric tons)				
North		26,431	25,646	26,532
Central		39,000	39,756	47,776
East		8,225	7,987	8,069
West		19,493	15,016	16,274
Southwest		36,571	30,475	27,109
Production (metric tons)				
North:	Cereals	247,035	227,645	232,220
	Groundnuts	23,402	23,388	19,190
	Cowpeas	10,880	14,932	15,164
	Cotton	-	-	-
Central:	Cereals	470,999	432,817	450,602
	Groundnuts	7,113	35,924	4,778
	Cowpeas	39,908	33,083	42,273
	Cotton	6,615	12,948	3,295
East:	Cereals	108,381	107,526	97,637
	Groundnuts	8,839	7,983	11,309
	Cowpeas	9,325	9,266	9,098
	Cotton	215	215	215
West:	Cereals	208,878	197,558	188,745
	Groundnuts	3,348	4,108	7,988
	Cowpeas	11,102	9,860	8,941
	Cotton	31,167	31,821	39,991
Southwest:	Cereals	341,050	332,308	330,994
	Groundnuts	31,884	31,553	24,339
	Cowpeas	15,696	14,062	10,438
	Cotton	42,602	44,888	39,323
Expected Ag. Income (mil. FCFA)				
North		22,558	23,747	27,382
Central		30,744	32,832	38,548
East		6,162	6,545	7,796
West		13,043	13,343	14,571
Southwest		19,420	20,397	22,171

36,571 tons (λ=1.0) to 27,109 tons (λ=0.60), the sharpest decline among regions.

The reason for the wide variability in rates of fertilizer utilization stems from regional adjustments in output, prices and trade in the model. For surplus regions like the west and southwest zones, low commodity prices from the policy shock in year 1 lead to less fertilizer use, lower output and higher prices by year 5. As shown in Table 9.8, production of cereals falls from 341.1 to 331.0 thousand tons in the southwest and from 208.9 to 188.7 thousand tons in the west, although high cotton production in the west is partially responsible for the fall in cereals production. The price of white sorghum, the crop demonstrating the greatest response to fertilizer policy, increases from 0.0 to 49.2 FCFA in the southwest and from 10.0 to 55.8 FCFA in the west (comparisons are between scenarios λ=1.0 and λ=0.6) (Table 9.9).

For deficit regions in the north and central zones, the response to fertilizer policy over time is different. Prices also increase in these zones, but the rise is due to the higher cost of imported cereals. Higher prices in the west and southwest are transmitted to the north and central regions through trade. The price of white sorghum in the north increases from 39.0 to 68.8 FCFA/kg. and from 14.0 to 63.8 FCFA/kg. in the central zone. The shifts in price relatives are sufficient to maintain fertilizer utilization at current levels in the north and increase fertilizer utilization in the central

Table 9.9. Retail Prices, Selected Markets, Alternative Assumptions Concerning Producers' Price Expectations, Fertilizer Scenarios.

	Scenario III	-----Scenario IV----	
	λ=1.0	λ=0.80	λ=0.60
North			
White Sorghum	39.0	57.6	68.8
Millet	78.7	95.9	96.5
Maize	104.9	72.2	72.3
Rice	153.2	153.4	156.1
Groundnuts	140.6	94.4	163.2
Wheat	145.2	145.2	145.4
Other	45.6	45.7	48.1
Central			
White Sorghum	14.0	45.1	63.8
Millet	55.5	78.5	79.0
Maize	88.9	57.1	59.3
Rice	143.2	143.4	146.1
Groundnuts	161.6	92.8	166.3
Wheat	135.2	135.2	135.4
Other	48.7	48.5	50.6
West			
White Sorghum	10.0	47.8	55.8
Millet	49.7	67.2	69.5
Maize	83.9	47.2	47.4
Rice	124.2	124.4	127.1
Groundnuts	138.6	91.8	146.8
Wheat	129.2	129.2	129.4
Other	68.7	68.5	70.6
Southwest			
White Sorghum	0.0	38.1	49.2
Millet	39.7	66.4	65.5
Maize	97.9	49.2	49.3
Rice	114.2	114.4	117.1
Groundnuts	117.6	70.7	129.2
Wheat	138.2	138.2	138.4
Other	77.7	77.5	79.6

region. Cereals production falls, however, due to the shift in cropping patterns, from cereals sole crops to more labor-intensive cereals-cowpeas mixtures.

Summary: Fertilizer Scenarios

Table 9.10 provides a comparison of summary statistics for the six alternative fertilizer scenarios. Compared with the base case solution, raising the prices of fertilizer to world levels (Scenario I) shows no effect on fertilizer utilization, due to the stepped-supply function characteristics of LP and high shadow prices associated with fertilizer rations. Holding the price of fertilizer constant at current subsidized levels, but removing restrictions on fertilizer availability (Scenario II), generates a large increase in fertilizer utilization, from 12.4 to 214.0 thousand tons for the country. The level of fertilizer subsidies, however, increases from 650 million FCFA (base case) to 11,075 million FCFA, substantially increasing the government's financial burden for subsidy payments. When fertilizer subsidies are removed in Scenario III, the quantity of fertilizer demanded by the country drops sharply from 214.0 thousand tons (Scenario II) to 129.7 thousand tons. The utilization of Urea increases due to the expansion of fertilized cotton hectarage in the model.

The higher utilization of fertilizer associated with Scenario III (economic prices, no fertilizer restrictions) increases production of cereals to 1,376.3 thousand tons, a 17 percent increase over base period production. The rightward shift in supply relative to demand

Table 9.10. Summary Statistics Comparing Alternative Fertilizer Scenarios, Burkina Faso.

	Base Case	No. Fert. Subsidy (I)	No Quantity Restrictions (II)	Combination =1.0 (III)	Combination =0.80 (IV)	Combination =0.60 (IV)
Fertilizer (metric tons)						
Cotton Fertilizer	12,410	12,410	213,950	129,720	118,880	125,760
Urea	361	361	1,134	1,060	4,322	4,030
Govt. Subsidies (mil. FCFA)	650	-	11,075	-	-	-
Production (thousand metric tons)						
Cereals	1174.8	1174.8	1353.7	1376.3	1297.9	1300.2
Groundnuts	79.1	79.1	77.5	74.6	103.0	67.6
Cowpeas	67.5	67.5	91.7	86.9	81.2	85.9
Cotton	63.8	63.8	150.8	80.6	89.9	82.8
Prices Ouagadougou (FCFA/kg.)						
White Sorghum	68.0	67.7	27.0	27.0	57.6	68.8
Millet	69.9	69.7	65.2	66.7	84.0	84.5
Maize	66.5	66.2	92.9	92.9	60.2	60.3
Rice	141.2	141.1	141.6	141.2	141.2	144.1
Groundnuts	130.8	130.5	87.2	158.6	94.4	163.3
Wheat	133.0	133.0	133.4	133.2	133.2	133.4
Other	54.2	54.2	55.8	55.2	53.7	54.2
Demand (kg./person)						
Coarse Grains	165	165	188	186		
Wheat and Rice	8	8	11	11		
Groundnuts	8	8	9	7		
International Trade (metric tons)						
Coarse Grains	8690	8650	23,193	23,186		
Wheat	16,259	16,252	16,663	16,464		
Rice	15,739	15,721	15,966	15,569		
Cotton	-23,602	-23,602	-55,805	-29,821		
Groundnuts	-	-	-	-		
Other	-58,866	-59,097	-51,055	-55,210		
Current Acct. Adjustment (mil. FCFA)	7950	7968	737	752		

results in lower prices, particularly for white sorghum which shows the greatest response to fertilizer price and quantity shocks in the model. In the Ouagadougou market, the price of white sorghum drops from 68.0 (base case) to 27.0 FCFA/kg. The prices of maize and groundnuts increase due to their displacement by expanded white sorghum production.

Lower commodity prices in Scenario III are shown in Scenario IV to have a negative impact on fertilizer utilization in the longer run. Scenario III assumes price expectations of producers remain constant, regardless of commodity price adjustments which may occur with time. (Consequently, solution values for quantities and prices remain constant over time.) Scenario IV allows producers' price expectations to adjust downward with declining commodity prices, enabling an economic evaluation of fertilizer demand over the longer run. Fertilizer demand in Scenario IV declines 3 to 8 percent (depending on the value of λ assumed) over a five-year period, although fertilizer use (e.g., approximately 120,000 tons) still remains 10 times higher than in the 'base' period.

Cereals production also decreases slightly over Scenario III, from 1,376.3 to 1,299.1 tons (average of λ=.80 and λ=.60). Production, however, is still 11 percent higher than in the 1980 base period. Production of cowpeas and cotton are 24 and 35 percent higher, on average, while groundnut production rises moderately (8 percent).

As explained in an earlier section, estimates of cereals demand and international trade for longer term model solutions are imprecise

due to wide fluctuations of prices in the model. Thus, estimates for these variables have been excluded from Scenario IV. However, the comparison of short-term effects in Scenario III with the base case solution reveals per capita demand for cereals rises 13 percent, a favorable prospect considering the country's primary objective of food security.

The country's trade balance worsens as a result of the policy (Scenario III). While maize imports increase sharply from 8.7 to 23.2 thousand tons and wheat and rice imports remain roughly constant, cotton exports increase only moderately, from 23.6 to 29.8 thousand tons. Also, the large increase in fertilizer imports imposes greater demands on foreign exchange earnings. The overall effect is a net reduction in the trade balance by 7,198 million FCFA. Considering the scarce availability of foreign exchange Burkina already experiences, a worsening trade balance will present problems in maintaining fertilizer imports (at the level suggested by Scenario III) over the long run. The second component of the World Bank policy, involving combining commodity price policy with the removal of fertilizer subsidies, addresses this issue.

Price Policy

Besides the elimination of government subsidies for fertilizer, the World Bank proposes to raise prices of sorghum and cotton to producers, thus offsetting the higher fertilizer costs. The policy has two objectives: increase the profitability of agriculture by

providing price incentives for agricultural production; and improve the fiscal position of the government.

As the World Bank recognizes in its proposal, eliminating subsidies alone may not necessarily improve the government's financial accounts. Depending on prices and the production response to fertilizer, the elimination of subsidies may lead to lower production of export crops, as was apparent in lower cotton exports in Scenario III of the previous section.

Alternatively, policies which raise output prices received by producers can offset the higher fertilizer costs and improve crop returns, if commodity prices are raised sufficiently. Several means may be employed to raise prices. One obvious mechanism is the manipulation of 'producer' prices offered to producers for goods purchased by the government on the official market. Another is the elimination of food aid imports which depress prices of domestic cereals.

The World Bank recommends both higher official 'producer' prices and elimination of food aid imports as part of its proposal. Details for implementing the price policy remain vague. The government, for instance, may raise 'producer' prices uniformly around the country, with one official price set nationwide, as is now the case. Or, the government may employ a variable price structure, where 'producer' prices by region incorporate transportation cost adjustments. The former approach reflects equity considerations imposed by the political process. The latter emphasizes economic efficiency by setting prices to producers according to 'true' opportunity costs.

Assuming the government requires a fixed margin to cover its marketing activities, increasing the 'producer' price to producers would also require increasing the 'consumer' price to consumers. It is a widely held view that 'consumer' prices in African economies are kept low to benefit the urban consumer (and the needy in severe grain deficit regions). As a consequence, producer prices are depressed, decreasing incentives for higher agricultural production. The margin between 'producer' and 'consumer' prices could be "squeezed" to improve prices for both groups, but government payments to support the income transfers also rise, placing greater demands on the budget. Alternatively, the government may increase its reliance on foreign aid. If aid is provided without restrictions, sales revenues may be used to offset losses from domestic market operations.

If the government buys at higher prices and sells at lower prices than traders on the private market, it is either more efficient or it runs a financial loss (or both), and thus requires outside financial assistance for support. While data are incomplete, OFNACER appears to operate its marketing operations with negative balances. Thus, an increase or decrease in 'producer' prices, ceteris paribus, results in larger or smaller deficits.

For cereals, the government's marketing activities are limited by capacity constraints. Its procurements are limited by size of truck fleet, warehousing and distribution facilities, number of buying agents and geographical constraints. Procurements are also constrained by the government's financial ability to provide the initial cash outlay for grain procurements (commodities are sold from 6 to 12

months later). Thus, higher 'producer' prices are effective only as long as the government is able to purchase grain. The levels of capacity constraints are not known with certainty, but likely fall in the range of the 30,000 to 40,000 ton grain procurement targets set annually by the government and public storage capacity, around 72,500[8/] tons (World Bank, 1981, p. 226).

Three additional scenarios are evaluated with the model. These look at commodity price policy, separately and jointly with the elimination of input subsidies:

> Scenario V: The government eliminates food aid imports consisting of 15,370 tons of white sorghum, 16,430 tons of maize, 5,500 tons of rice and 3,500 tons of wheat at 1980 base levels.
>
> Scenario VI: The government raises the official 'producer' and 'consumer' prices of sorghums, maize, millet and cotton. A capacity constraint of 50,000 tons of grain is imposed on OFNACER's marketing operations.
>
> Scenario VII: The government increases its distribution of fertilizer according to fertilizer demand, but eliminates fertilizer subsidies (as in Scenario IV); eliminates imports of food aid (Scenario V); and raises 'producer' and 'consumer' prices in the official market (Scenario VI). Scenario VII, then, represents the composite World Bank policy.

8/ Includes 27,500 tons of permanent storage, 16,000 tons of temporary storage, and 29,000 tons of ORD storage capacity.

Details concerning the implementation of each policy scenario in the model are covered in subsequent sections. As with the fertilizer policy scenarios, results are for the annual model, representing a short term analysis. The alternative price assumptions are compared with the 'base' case in Table 9.11. The model's solution for agricultural output and prices are reported in Tables 9.12 and 9.13, while results for demand and international trade are summarized in Tables 9.14 and 9.15. The effects of the three alternative policies on producer's income, consumer subsidies, government finances, and trade balance are reported in Table 9.16.

Price Scenario V: In Scenario V, the government is assumed to eliminate all imports of food aid. The action may come about either voluntarily through cuts on the part of the government, or from mandatory cuts imposed by donors. At 1980 'base' levels, these cuts amount to 15,370 tons of white sorghum, 16,430 tons of maize, 5,500 tons of rice and 3,500 tons of wheat. The elimination of food aid first impacts on prices, demand and trade in the LCP. In the following year, prices modify producers' price expectations, affecting production decisions in the LP. The purpose of the scenario is to examine the effects of eliminating food aid imports on prices and incentives for agricultural production.

The solution results for agricultural output in Table 9.12 are for the cropping season that follows the marketing year in which food aid is cut. Outside of slightly higher sorghum production in the west and southwest regions and higher production of maize and groundnuts in the southwest, production is not significantly affected by the change.

Table 9.11. Input and Official Producer Prices, Input Quantities and Producer Subsidies, Alternative Price Policies, Annual Model.

Details	Base Case	Eliminate Food Aid (V)	Higher Output Prices (VI)	Fert. + Price Policy (VII)
I. Cotton Fert. Price (FCFA/kg.)				
North	45	45	45	99
Central	45	45	45	99
East	45	45	45	99
West	40	40	40	91
Southwest	40	40	40	91
II. Urea Quantity (mt.)				
North	28	28	28	28
Central	36	36	36	36
East	13	13	13	13
West	-	-	-	400
Southwest	284	284	284	900
III. Cotton Fert. Quantity (mt.)				
North	1530	1530	1530	25,387
Central	1355	1355	1355	63,358
East	145	145	145	8,296
West	3565	3565	3565	18,707
Southwest	5815	5815	5815	36,121
IV. Govt. Fert. Subsidies (mil. FCFA)				
North	83.5	83.5	83.5	-
Central	68.7	68.7	68.7	-
East	8.2	8.2	8.2	-
West	181.7	181.7	181.7	-
Southwest	307.9	307.9	307.9	-
V. Off. Producer Prices (FCFA/kg.)				
W. Sorghum, Maize, Millet	45	45	55	55
Red Sorghum	37	37	47	47
Paddy	63	63	63	63
Groundnuts	56	56	56	56
Cotton	55	55	67	67

Table 9.12. Total Production of Agricultural Commodities, Alternative Price Policies, Annual Model, Burkina Faso.

Region: Commodity	Base Case	Eliminate Food Aid (V)	Higher Output Prices (VI)	Fert. + Price Policy (VII)
	----------(metric tons)----------			
North				
Sorghum[a]	53,192	53,192	53,221	78,144
Millet	151,067	151,067	150,074	154,650
Maize	7,320	7,320	7,320	7,320
Paddy	3,730	3,730	3,730	3,730
Groundnuts	18,897	18,897	18,927	23,476
Cotton	3,330	3,330	4,531	4,193
Central				
Sorghum[a]	198,079	198,079	150,584	193,233
Millet	166,080	166,080	128,322	148,184
Maize	15,791	15,791	15,791	15,791
Paddy	15,124	15,124	15,693	15,693
Groundnuts	18,748	18,748	47,836	48,040
Cotton	2,316	2,316	71,844	111,281
East				
Sorghum[a]	49,956	49,674	45,442	65,137
Millet	31,687	31,953	35,113	32,993
Maize	8,125	8,411	6,306	6,384
Paddy	3,538	3,513	3,474	4,723
Groundnuts	7,215	7,053	3,638	8,464
Cotton	446	446	6,917	215
West				
Sorghum[a]	106,848	108,230	90,057	97,267
Millet	51,733	51,810	51,407	52,153
Maize	11,877	11,877	11,877	11,877
Paddy	5,150	5,150	5,150	5,150
Groundnuts	7,760	7,308	11,579	8,924
Cotton	26,237	25,096	41,630	71,855
Southwest				
Sorghum[a]	153,049	147,887	115,149	236,295
Millet	51,985	51,531	47,868	53,369
Maize	68,858	72,591	62,205	10,289
Paddy	21,563	21,563	21,563	21,522
Groundnuts	26,511	28,899	31,466	34,378
Cotton	31,459	30,276	69,957	57,910

[a] White sorghum and red sorghum combined. Changes in production of "sorghum" refer to white sorghum.

Table 9.13. Retail Prices, Alternative Price Policies, Annual Model, Burkina Faso.

Region: Commodity	Base Case	Eliminate Food Aid (V)	Higher Output Prices (VI)	Fert. + Price Policy (VII)
	(FCFA/kg.)			
North				
White Sorghum	80.0	83.7	94.3	55.9
Millet	81.9	81.1	86.6	82.1
Maize	78.5	90.6	84.1	113.6
Rice	153.2	161.2	152.4	160.7
Groundnuts	144.1	142.1	65.1	51.9
Wheat	145.0	147.3	144.9	147.6
Other	43.4	42.9	43.1	45.0
Central				
White Sorghum	60.0	63.4	85.2	45.9
Millet	58.0	57.8	76.6	72.1
Maize	68.5	80.6	74.1	103.6
Rice	143.2	151.2	142.4	150.7
Groundnuts	133.8	132.8	27.1	14.5
Wheat	135.0	137.3	134.9	137.6
Other	46.4	46.1	45.7	48.4
East				
White Sorghum	53.2	54.3	63.2	23.9
Millet	47.6	47.4	54.6	50.1
Maize	46.5	58.6	96.1	81.6
Rice	121.2	130.7	120.4	128.7
Groundnuts	100.8	99.8	60.1	0.0
Wheat	157.0	159.3	156.9	159.6
Other	53.2	52.9	51.8	57.4
Southwest				
White Sorghum	41.0	44.7	79.3	16.9
Millet	42.9	42.1	47.6	43.1
Maize	39.5	51.6	45.1	106.6
Rice	114.2	122.2	113.4	121.7
Groundnuts	89.8	88.8	23.1	10.5
Wheat	138.0	140.3	137.9	140.6
Other	75.4	75.1	74.7	77.4
Ouagadougou				
White Sorghum	68.0	71.7	83.2	43.9
Millet	69.9	69.1	74.6	70.1
Maize	66.5	78.6	72.1	101.6
Rice	141.2	149.2	140.4	148.7
Groundnuts	130.8	129.8	47.1	34.5
Wheat	133.0	135.3	132.9	135.6
Other	54.2	53.4	54.1	55.0

Table 9.14. Total and Per Capita Utilization, Alternative Price Policies, Annual Model, Burkina Faso.

Region:	Commodity	Base Case	Eliminate Food Aid (V)	Higher Output Prices (VI)	Fert. + Price Policy (VII)
Total Quantity Demanded (mt.)					
North:	Coarse Grains	257,946	254,720	247,029	269,256
	Rice	10,291	10,114	10,286	10,255
	Wheat	3,336	3,308	3,330	3,353
	Groundnuts	11,442	11,442	13,652	14,214
Central:	Coarse Grains	337,490	332,731	288,481	334,249
	Rice	15,155	14,845	15,051	15,069
	Wheat	5,562	5,527	5,517	5,595
	Groundnuts	13,787	13,803	18,295	19,238
East:	Coarse Grains	71,538	70,471	62,814	83,258
	Rice	1,983	1,935	1,972	1,991
	Wheat	712	708	707	724
	Groundnuts	3,390	3,396	3,915	4,885
West:	Coarse Grains	134,221	131,418	124,875	147,127
	Rice	2,799	2,740	2,816	2,818
	Wheat	1,181	1,173	1,186	1,203
	Groundnuts	6,105	6,113	7,562	8,005
Southwest:	Coarse Grains	176,701	167,159	136,728	170,054
	Rice	6,950	6,766	6,942	6,835
	Wheat	2,179	2,158	2,172	2,175
	Groundnuts	7,956	7,942	10,208	10,716
Ouagadougo and Bobo-Dioulasso	Coarse Grains	33,733	29,610	31,838	35,161
	Rice	11,231	10,103	11,254	11,055
	Wheat	5,543	5,472	5,545	5,523
	Groundnuts	5,234	5,220	6,722	6,999
Cereals Consumption (kg./capita):					
North		164	162	150	171
Central		167	165	144	166
East		168	165	148	194
West		200	196	186	218
Southwest		207	196	162	199
Ouagadougou		150	147	145	156
Bobo-Dioulasso		179	173	171	180

Table 9.15. International Trade, Alternative Price Policies, Annual Model, Burkina Faso.

Region:	Commodity	Base Case	Eliminate Food Aid (V)	Higher Output Prices (VI)	Fert. + Price Policy (VII)
		---(Net Imports to B.F.: m.t.)[a] ---			
Private Market					
Niger:	White Sorghum	-2711	-2674	-2383	-3680
	Millet	-1142	-1145	-1053	-1110
	Maize	- 863	- 734	- 335	- 489
	Rice	- 98	- 93	- 98	- 94
	Other	4072	4060	4012	4255
Mali:	White Sorghum	7898	8196	9039	6302
	Millet	3111	3088	3255	3118
	Maize	2397	2698	2537	3469
	Rice	88	91	88	91
	Other	-9063	-9089	-9118	-8921
Abidjan:	Millet & Sorghum	-	1,233	11,761	-
	Maize	-	4,958	-	25,427
	Rice	15,749	19,730	15,378	19,455
	Wheat	16,259	18,347	16,203	18,575
	Groundnuts				-10,349
	Other	-53,875	-54,407	-54,995	-50,970
Official Market:					
Abidjan:	Cotton	-23,602	-23,601	-72,105	-90,818

[a] Negative figures imply net exports from Burkina Faso.

Table 9.16. Agricultural Income, Consumer Subsidies and Trade Balance, Alternative Price Policies, Annual Model, Burkina Faso.

Region: Commodity	Base Case	Eliminate Food Aid (V)	Higher Output Prices (VI)	Fert. + Price Policy (VII)
I. Producers' Expected Net Ag. Income (mil. FCFA):				
North	21,622	21,481	21,675	22,418
Central	28,980	29,157	29,380	31,555
East	5,848	5,978	5,854	6,315
West	12,441	12,445	12,891	13,821
Southwest	18,865	18,888	19,743	20,330
II. Off. Consumer Prices (FCFA/kg.)				
W. Sorghum, Maize, Millet	57	57	67	67
R. Sorghum	47	47	57	57
Rice	125	125	125	125
Groundnuts	-	-	-	-
Cotton	-	-	-	-
III. Consumer Subsidies (mil. FCFA)				
North	527.8	156.6	578.0	337.6
Central	11.3	23.3	5.4	0.0
East	2.1	0.3	2.1	0.0
West	0.3	0.6	0.3	0.0
Southwest	1.4	-	1.4	0.0
Ouagadougou	134.7	39.8	95.6	41.2
Bobo-Dioulasso	15.3	5.9	7.1	0.0
IV. Off. Market External Trade (mil. FCFA):				
Cotton Exports	6498	6498	19,853	25,005
Fertilizer Imports	-937	-937	-937	-11,222
Ratio Exports to Imports	6.9	6.9	21.2	2.2
V. Current Acct. Adjustment (mil. FCFA):				
Niger	141	144	139	67
Mali	86	-2	-137	91
Abidjan	7723	6791	20,644	14,093

a/ Calculations are based on 275,329 FCFA/ton cotton (CAF Abidjan), 81,916 FCFA/ton Urea and 73,150 FCFA/ton cotton fertilizer (CAF Bobo).

b/ Calculations are based on trade values and prices endogenous to the model. Positive values indicate net surpluses in trade.

The reason for this phenomena is explained by prices in Table 9.13. For white sorghum, prices increase 3 to 4 FCFA/kg. in nearly all regions. This is the margin of difference between 'actual' prices and producers' expected prices, estimated in the base model solution. Thus, the elimination of food aid simply raises prices of white sorghum to levels of price expectations held by producers. Due to the stepped-supply function characteristics of LP, where quantity adjustments are not continuous in prices, the small changes in prices do not affect production.

The price of maize increases sharply (around 12 FCFA/kg.) in all regions, due to the high ratio of food aid imports to total maize supply (12.6 percent of supply based on 1980 levels). However, with the exception of the southwest, the higher prices are not sufficient to offset the high costs associated with minimum maize requirements in the model, implying it is still more profitable to cultivate other crops. In the southwest, maize production does increase from 68.9 to 72.6 thousand tons in response to higher maize prices.

The response of wheat and rice to the policy shock is different than for sorghum and maize, because their prices are set by international trade. The price of coarse grains in Burkina Faso is less than import parity prices (with respect to Abidjan), but higher than export parity prices.[9/] Domestic prices of coarse grains thus fall within

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9/ The import parity price is defined as the international price (Abidjan) plus transfer costs. The export parity price is the international price less transportation costs.

the price "wedge" formed by transportation costs to international markets. Since transfer costs are large to the Abidjan port, prices of domestic coarse grains may swing considerably, without trade emerging.

Before the elimination of food aid imports, total imports amounted to 15,370 tons of white sorghum (15,370 tons of which are aid), 16,430 tons of maize (16,430 tons aid). 21,249 tons of rice (5,500 tons aid) and 19,759 tons of wheat (3,500 tons aid). After elimination of food aid, Burkina Faso imports 1,233 tons of white sorghum, 4,958 tons of maize, 19,730 tons of rice and 18,347 tons of wheat. Thus, imports of traditional cereals increase, but greatly fall short of pre-policy levels of food aid. Higher imports of wheat and rice on the private market nearly offset the loss of food aid imports. Prices of wheat rise by 2 FCFA/kg. in all zones of the country. Prices of rice rise 8 to 10 FCFA/kg., depending on the region.

Higher rice prices do not stimulate production, however, due to the inelastic nature of rice production in the LPs. Traditional rice cultivation is constrained by fixed endowments of swampy lowland in the model, while irrigated rice is constrained by the capacity of irrigation schemes. It was shown in Chapter VIII that investment in irrigated rice (large scale dam irrigation) was unprofitable at 1980 price levels (except in the north), requiring minimum constraints to be placed on the area under irrigation. At post-policy prices, investment in dam irrigation still remains unprofitable (e.g., shadow

prices of irrigated land remain zero), although the margin of unprofitability declines.

As noted earlier, model results fail to show a significant production response to eliminating food aid imports, due to the stepped-function characteristics of LP and the recursive structure of the sector model. However, the higher prices--3 to 4 FCFA/kg. for white sorghum, 12 FCFA/kg. for maize and 8 to 10 FCFA/kg. for rice--are significant and should improve production incentives to producers. Conversely, solution results imply increasing food aid shipments will depress prices by a similar order of magnitude and decrease producers' incentives, unless the government can target food aid towards populations with low effective demand.

The quantity demanded of cereals drops with the policy shock, since production does not measurably change and imports only partially replace pre-shock levels of food aid imports. Per capita consumption of cereals declines 2 to 6 kg./capita across zones. The trade balance experiences a decline of 932 million FCFA due to higher imports of wheat and rice.

Producers' income increases slightly with the somewhat higher prices associated with reduced food aid, while consumer subsidies drop sharply (Table 9.16), from 527.8 to 156.6 million FCFA in the north and from 134.7 to 39.8 million FCFA in Ouagadougou. These are the two regions which receive the highest rations of official market commodities and the greatest income transfers associated with the government's official price policy (e.g., through official consumer prices). The elimination of food aid has two immediate effects on the

government's official market activities: it directly reduces the amount of cereals the government can sell through the official market; and, indirectly it reduces the government's capacity to direct implicit income transfers to target groups in the economy.

These transfers in the base case solution amount to less than one percent of total income (refer to Table 7.1) in the north and 1.5 percent in Ouagadougou. Consequently, the reduction in income subsidies does not markedly affect demand through the income effect. As noted earlier in Chapter VI, however, estimates of consumer subsidies are underestimated due to the seasonal nature of private market prices and OFNACER sales (mainly during the soudure when prices are highest). Moreover, there are adverse political consequences to reducing supplies of food aid due to the reduction in income transfers to urban groups, however small they might be.

Price Scenario VI: This scenario evaluates the effect of higher 'producer' and 'consumer' prices offered by the government in the official market. The 'producer' prices of white sorghum, millet and maize are raised from 45 to 55 FCFA/kg.; the producer price for red sorghum is raised from 37 to 47 FCFA/kg. and for cotton from 55 to 67 FCFA/kg. The prices are applied uniformly nationwide to remain in conformity with the present pricing system employed by the government. This system is less efficient than a variable pricing system, but the latter is less likely to be adopted due to political considerations.

Price levels were chosen by setting the official 'consumer' price equal to the private market price in Ouagadougou using 'base' period

prices in the model.[10/] In setting prices in this manner, consumer subsidies for domestically procured cereals are eliminated in urban areas. However, 'consumer' prices still permit implicit income transfers to consumers in the north, where grain deficits and high transport costs result in high commodity prices. Producer prices then are calculated from "consumer" prices less fixed marketing margins employed by OFNACER. For sake of comparison, the official 'producer' price for white sorghum (55 FCFA/kg.) is slightly less than the import parity price of 64 FCFA/kg. calculated by the World Bank for the southwest region.

The 'producer' price for cotton is the export parity price, calculated as the world price less transfer costs to the west and southwest regions (calculated in Appendix 8). Since the world price remains unchanged, the difference between the old (55 FCFA/kg.) and new (67 FCFA/kg.) cotton price implies higher costs to SOFITEX. Marketing revenues per unit of cotton exported decline with the policy, although revenues may be regained through declining average costs associated with economies to scale in marketing or smaller per unit profits taken over a greater quantity marketed. Only the latter

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10/ The problem of setting the appropriate level of 'producer' price is difficult since domestic prices are higher than export parity prices, making it too costly to export, and lower than import parity prices, making imports too expensive. Hence, the standard prescription of setting price levels at 'border' prices is irrelevant. As noted in Table 6.9, transport costs to Abidjan are 26 FCFA, indicating that the price wedge (price level at which the country ceases to import to the price level at which it can export) is 52 FCFA.

effect can be evaluated in this analysis.

Proponents of higher prices to stimulate agricultural supply response in Africa often ignore the fact that the government may lack the resources or capacity to conduct the policy. Unless the government enforces official prices in the private sector of the economy, the price effect is limited by the capacity of the marketing board. As noted earlier, this appears to be about 50,000 tons of grain for OFNACER.

To operationalize the policy, fixed procurement constraints for OFNACER in the base case are relaxed and set at 50,000 tons for the country (compared with 13,300 tons in the base case). Also, OFNACER is only permitted to buy grain in excess of 180 kg./capita gross cereals production per region to ensure minimum regional cereals needs are met. Thus, procurement quotas are set at 0 tons of grain in the north, 4,500 tons in the central and 12,000 tons in the east.

OFNACER is permitted to buy as much grain as they wish (up to a total of 50,000 tons) in the grain surplus areas of the west and southwest. Also, maximum procurements of 3,400 tons of millet, 4,500 tons of maize and 5,600 tons of rice are imposed in accordance with past buying patterns. Cotton procurements are considered to be unrestricted, since they are immediately exported abroad after processing. No information was available to assess ginning capacity to determine if processing constraints may exist.

Since fertilizer rations have not been relaxed in this scenario, fertilizer utilization remains unaltered (Table 9.11). A shift is apparent in production towards less sorghum and more cotton in the

cropping plan. Production of sorghum drops from 198.1 to 150.6 thousand tons in the central region, 50.0 to 45.4 thousand tons in the east, 106.8 to 90.1 thousand tons in the west and 153.0 to 115.1 thousand tons in the southwest. Cotton production, in contrast, increases from 2.3 to 71.8 thousand tons in the central region, 0.4 to 6.9 thousand tons in the east, 26.2 to 41.6 thousand tons in the west and 31.5 to 70.0 thousand tons in the southwest. The government purchases 4,500 tons of maize in the east and 45,500 tons of white sorghum in the southwest.[11/]

Even though the government increases the official 'producer' price of coarse grains, capacity constraints of OFNACER inhibit the effectiveness of the policy. The higher price and unrestricted export market for cotton greatly shift incentives in favor of cotton production. In the short run, prices of coarse grains rise and demand falls. In the long run, higher prices would encourage greater cereals production, lessening incentives for cotton. This scenario is examined more fully in the next section.

An examination of national prices (in Ouagadougou) in Table 9.13 shows that prices of white sorghum rise from 68.0 to 83.2 FCFA/kg. as a result of the policy. Millet prices rise from 69.9 to 74.6 FCFA/kg. while the price of maize rises from 66.5 to 72.1 FCFA/kg. The price

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11/ Even without higher producer prices, the government would procure these quantities. due to low financial prices in the east and southwest. The increased marketing operations of OFNACER are caused by relaxing procurement constraints, not raising prices.

of groundnuts drops sharply from 130.8 to 47.1 FCFA/kg. due to expanded groundnut production. This effect stems from changes in the shadow prices of labor in the model.[12/]

Prices of white sorghum increase the most in the southwest (by 38 FCFA/kg.) and the least in the north and central regions (by 14 to 15 FCFA/kg.). The reason for this differential is explained by the operation of the official market. The increase in government procurements in the southwest decreases supply in the region, while supply increases relatively in the north and central regions, due to the regional bias of fixed official market rations assumed in the model. This same phenomenon is apparent in the east, where the price of maize increases from 46.5 to 96.1 FCFA/kg. These results highlight the regional impact that a marketing board can have on prices and quantities. They also reflect the difficulties of evaluating public marketing activities with fixed rations. Clearly, rations may be adjusted in accordance with price levels, but the question remains "by how much and where?" This problem is not limited to the model, but reflects the reality of problems the cereal board faces in setting cereals rations.

The quantity demanded of cereals declines as a consequence of the policy. The extent to which per capita demand falls is greatest in rural areas (14 to 45 kg./person), where coarse grains are the most important staple in consumer diets. The high proportion of wheat and

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12/ As cotton production increases, shadow prices of labor at critical periods change, increasing the profitability of groundnuts and decreasing the profitability of cereals.

rice in urban diets dampens the decline to between 5 and 8 kg./person (Table 9.14). Imports of wheat and rice do not change measurably, although the country becomes a net importer of sorghum. Still, the increase in cotton exports, from 23.6 to 72.1 thousand tons, more than sufficiently offsets higher costs of cereals imports. The trade balance increases by 12,921 million FCFA. The effect on the government is uncertain. If cotton exports are taxed 10 percent, export revenues of 19,853 million FCFA would more than cover the cost of fertilizer imports amounting to 937 million FCFA (Table 9.16).

Price Scenario VII: This scenario examines the composite effect of removing fertilizer subsidies, increasing official market prices and eliminating food aid, representing the complete World Bank policy. Details concerning the removal of fertilizer subsidies parallel those of Scenario III, where the government is assumed to charge farmers the full cost of fertilizer, but sales are based on fertilizer demanded by producers (fertilizer rations are eliminated). Details concerning the elimination of food aid imports correspond to Scenario V, where imports amounting to 15,370 tons of white sorghum, 16,430 tons of maize, 5,500 tons of rice, and 3,500 tons of wheat are eliminated. The procedure for raising commodity prices in the official market is the same as Scenario VI. Prices for sorghum, millet, maize and cotton in the official market are raised by about 20 percent. Cereals procurements are constrained, however, by capacity constraints of OFNACER.

The combination of price policy and relaxing constraints on the supply of fertilizer leads to a large increase in fertilizer utilization. Fertilizer use increases from 12,410 tons in the base

case to 151,869 tons, again showing a strong latent demand for fertilizer in the country. When fertilizer policy was implemented alone (Scenario III), fertilizer use was estimated at 129,720 tons. The additional fertilizer use of 22,149 tons then can be attributed to commodity price policy.

In Scenario III, the fertilizer policy led to a large increase in white sorghum production and moderately higher cotton production. The reverse was true in Scenario VI. Higher prices in the official market led to a substantial increase in cotton production, but lower production of white sorghum.

The model solution for the composite policy reflects a balancing of these effects. Overall, both sorghum and cotton production increase as a result of the policy. White sorghum production increases from 53.2 to 78.1 thousand tons in the north, 50.0 to 65.1 thousand tons in the east and 153.0 to 236.3 thousand tons in the southwest. Cotton production increases from 3.3 to 4.2 thousand tons in the north, 2.3 to 111.3 thousand tons in the central region, 26.2 to 71.9 thousand tons in the west and 31.5 to 57.9 thousand tons in the southwest. Groundnut production also increases in most zones, while millet increases slightly, due to its poor fertilizer response, as compared with other crops. Millet production actually declines in the central region due to sharply higher cotton production. Like Scenario III, white sorghum production substitutes for maize in the southwest, causing maize production to decline from 68.9 to 10.3 thousand tons.

Due to higher white sorghum production in the model, prices of white sorghum decrease by 15 to 30 FCFA/kg., depending on the region.

Maize prices increase sharply by 35 to 67 FCFA/kg. across regions, due to the severe cutback in maize production in the southwest and elimination of food aid maize.

Maize imports rise in response to higher maize prices (Table 9.14). Compared with the base case, in which the country imported no maize (except for food aid), the country now imports 25,427 tons as a consequence of the policy. Rice imports also increase from 15.7 to 19.5 thousand tons and wheat imports increase from 16.3 to 18.6 thousand tons, due largely to the elimination of food aid.

The level of fertilizers imports also increases from a value of 937 to 11,222 million FCFA. However, cotton exports receive a large boost from 6,498 to 25,005 million FCFA, more than compensating for the higher import bill. The trade balance improves by 6,370 million FCFA, due to the emphasis given to cotton exports.

While fertilizer policy led to sharply higher fertilizer imports in Scenario III, exports did not exhibit the same response, resulting in a worsening of the trade balance and lower foreign exchange earnings. However, with higher prices in the official market, cotton exports expand and the trade balance improves considerably.

Food consumption also increases as a consequence of the policy. Cereals consumption per capita rises in the north, east, west and urban areas. Cereals consumption in the central region remains constant, while lower consumption is experienced in the southwest. Income is redistributed from urban to rural areas. Consumer subsidies decrease from 134.7 million to 41.2 million FCFA in Ouagadougou and 15.3 to 0.0 million FCFA in Bobo-Dioulasso. Rural producers cum

consumers also receive lower consumer subsidies through official commodity programs, but input subsidies are eliminated. Net agricultural income of producers increases in all regions. Total income for the country increases from 87.8 billion FCFA (base case) to 94.4 billion FCFA.

Summary: Commodity Price Policy

Table 9.17 provides a comparison of summary statistics for five alternative policy scenarios. Compared with the 'base' case solution, eliminating food aid (Scenario V) increases national prices in Ouagadougou by 5 percent for white sorghum, 18 percent for maize, 2 percent for wheat and 6 percent for rice. The model failed to show a significant production response, due to the stepped-function characteristics of LP and the recursive structure of the sector model. However, these price changes are significant and should stimulate production in reality.

Eliminating food aid imports (Scenario V) leads to higher imports of cereals on the private market, although the increase does not completely offset the food aid lost. Wheat imports increase from 16.3 to 18.3 thousand tons. Rice imports increase from 15.7 to 19.7 thousand tons. Imports of maize and sorghum increase from 8.7 to 15.6 thousand tons. Private market imports increase, due to higher domestic prices and highly elastic import supply equations assumed in the analysis. As a result, the trade balance worsens by 1.0 billion FCFA, increasing demands on scarce foreign exchange.

Table 9.17. Summary Statistics Comparing Alternative Fertilizer and Price Policy Scenarios, Burkina Faso.

	Base Case	Fertilizer Policy (III)	Eliminate Food Aid (V)	Higher Output Prices (VI)	Fertilizer & Price Policy (VII)
Fertilizer (metric tons)					
Cotton Fertilizer	12,410	129,720	12,410	12,410	151,869
Urea	361	1,060	361	361	1,377
Govt. Subsidies (mil. FCFA)	650	-	650	650	-
Production (thousand metric tons)					
Cereals	1,174.8	1,376.3	1,174.6	1,020.3	1,213.9
Groundnuts	79.1	74.6	80.9	113.4	123.3
Cotton	63.8	80.6	61.5	194.9	245.5
Prices, Ouagadougou (FCFA/kg.)					
White Sorghum	68.0	27.0	71.7	63.2	43.9
Millet	69.9	66.7	69.1	74.6	70.1
Maize	66.5	92.9	78.6	72.1	101.6
Rice	141.2	141.2	149.2	140.4	148.7
Groundnuts	130.8	158.6	129.8	47.1	34.5
Wheat	133.0	133.2	135.3	132.9	135.6
Other	54.2	55.2	53.4	54.1	55.0
Demand (kg./person)					
Coarse Grains	165	186	161	145	169
Wheat and Rice	8	11	11	11	11
Groundnuts	8	7	8	10	10
International Trade (metric tons)					
Coarse Grains	8,690	23,186	15,620	22,821	33,037
Wheat	16,259	16,464	18,347	16,203	18,575
Rice	15,739	15,569	19,728	15,368	19,452
Cotton	-23,602	-29,821	-23,601	-72,105	-90,818
Groundnuts	-	-	-		
Other	-58,866	-55,210	-59,436	-60,101	-55,636
Current Acct. Adjustment (mil. FCFA)	7,950	752	6,933	20,646	14,251

Raising commodity prices in the official market (Scenario VI), increases cotton production from 63.8 to 194.9 thousand tons. Production of cereals falls from 1,174.8 to 1,020.3 thousand tons, due to area displacement by cotton. Even though the government increases official 'producer' prices for cereals, a capacity constraint of 50,000 tons limits grain procurements by OFNACER and limits the effectiveness of the cereals price policy reform.

Higher cotton prices and unconstrained cotton marketing activities stimulate higher cotton production, from 63.8 to 194.9 thousand tons. Since fertilizer imports are constrained at 'base' period levels, the trade balance improves by 12.7 billion FCFA. Consumption of millet, sorghum and maize drop sharply, from 165 to 145 kg./person. The dramatic decline in cereals consumption raises questions over the viability of the proposal, given minimum caloric requirements of the population and national objectives of food self-sufficiency.

Raising commodity prices, removing input subsidies and eliminating food aid (Scenario VII) increases fertilizer utilization to 151.9 thousand tons, 12 times the 1980 'base' rate of utilization. Fertilizer utilization is 22.1 thousand tons higher than the fertilizer policy scenario alone (Scenario III), demonstrating the effect of higher commodity prices on fertilizer demand. Cereals production increases from 1,174.8 to 1,213.9 thousand tons largely due to the production response of sorghum to fertilizer policy reform. Cotton production increases from 63.8 to 245.5 thousand tons, mainly in response to the commodity price policy. National prices of white

sorghum in the Ouagadougou market fall from 68.0 to 43.9 FCFA/kg. Maize prices increase from 66.5 to 101.6 FCFA/kg. due to the substitution of white sorghum for maize in the southwest.

Imports of cereals (mainly maize) increase, from 8.7 to 33.0 thousand tons, due to higher domestic prices (mainly for maize). Wheat imports increase from 16.3 to 18.6 thousand tons and rice imports increase from 15.7 to 19.5 thousand tons, due to the elimination of food aid. Cotton export revenues increase from 6.5 to 25.0 billion FCFA, however, more than compensating for the higher import bill. Overall, the trade balance improves by 6.3 billion FCFA.

Thus, fertilizer policy alone was shown to increase agricultural output, lower prices for consumers and reduce costs of government input and commodity subsidy programs. However, higher fertilizer imports are not accompanied by growth in exports, leading to balance of payments and foreign exchange problems. Without capital inflows from abroad, the country would probably be unable to achieve its objectives of expanding the use of modern inputs and sustaining efforts to transform agriculture over the long run.

With both fertilizer and price policy reform, cereal production and consumption rise. The improved profitability of new agricultural technologies leads to expanded use of modern inputs. Moreover, the policy has a favorable effect on the external trade balance. However, the policy is heavily dependent on cotton cultivation, which is incompatible with national objectives of food self-sufficiency. Also, the viability of the policy crucially depends on the production response of cotton in agriculture.

Solution results are very sensitive to changes in relative prices as indicated by the increase in cotton production in the central region, from 2.3 to 111.3 thousand tons, in response to the new fertilizer and price policy (Scenario VII). This region is an insignificant cotton producer at present, suggesting that supply is probably more inelastic than model results suggest, due to technical and processing constraints (not included in the model). Further analysis may consider constraining cotton production in the model. However, the procedure warrants caution because it creates model rigidity and ignores investment decisions that might be made to relax current constraints.

Food-First Strategy

Raising the price of cotton on the official market was shown in Scenario VII to increase cotton production and exports. Foreign exchange earnings improve, enabling higher fertilizer imports. While the complete World Bank policy increases food production, it places heavy emphasis on cotton production for export earnings. Considering the emphasis given to food security by the government, this outcome may not represent a viable option to the government.

Instead, the government may wish to redirect its price policy towards a food-first strategy. This may be engineered by raising commodity prices of cereals on the official market to stimulate domestic grain production, while cotton prices are left at 'base' period levels. The results of this scenario would be akin to those of Scenario III. Cereals production, particularly white sorghum, would

increase sharply, as would fertilizer utilization. However, the country's balance of payments situation would worsen, unless the country becomes a net exporter of grain.

Alternatively, the government could raise prices of cereals, to increase domestic food production, and the price of cotton, to gain export revenues (from cotton). The effects of this policy were evaluated in Scenario VII. Due to market constraints of OFNACER, the government does not have the capacity to enable a greater price effect for cereals on the market. To gain a greater effect from prices, the government must expand the scope of its marketing activities. Costs of government marketing operations will increase with this scenario, but these may be partially offset with export taxes on cotton. (Note that increasing taxes is equivalent to lowering the 'producer' price, and would decrease incentives for production.) Overall, this policy --higher cereals and cotton prices--appears superior to the policy of higher cereal prices alone.

Technology Evaluation

Previous sections dealt with the projected impacts of eliminating fertilizer subsidies and removing restrictions on fertilizer availability. This section extends the analysis to the evaluation of animal traction technology. The analysis has three objectives: a) to evaluate the profitability of fertilizer and animal traction resources; b) to evaluate projected impacts on agriculture from relaxing constraints on the supply of these modern inputs; and c) to

examine investment priorities, given the scarce availability of resources.

The government holds considerable regulatory power over the supply and distribution of modern inputs. SOFITEX and the ORDs have monopoly control over the distribution of pesticides and fertilizers. ARCOMA and COREMMA centers are responsible for the manufacture and assembly of animal traction equipment. The government also trains and markets animal traction units through the ORDs. The government's effectiveness in meeting input demand is constrained by: foreign exchange constraints, limiting imports of intermediate imputs and capital equipment; budget constraints on the fabrication and distribution of modern inputs; and market restrictions imposed by capacity constraints and poor marketing infrastructure. Poor physical infrastructure is a major impediment to input marketing activities in most zones of the country.

Alternatively, the government could encourage greater private market participation in input supply and distribution. Exploiting the market infrastructure of private traders could circumvent capacity and infrastructural constraints of the government. Traders, however, may still face problems of scarce foreign exchange. While the improved fertilizer policy plus price policy in Scenario VII relaxes foreign exchange constraints by enabling higher import revenues from cotton, the government maintains monopoly control over cotton exports, limiting trader access to foreign exchange. Consequently, some combination of market participation in exports and fertilizer marketing would be required for effective trader participation.

Until capacity and infrastructural constraints are resolved, excess demand for inputs will exist in the economy. Since the government has only limited resources available, its allocation of agricultural inputs among regions is an important issue. Fertilizer is a land intensive technology; it increaess yields per unit of land. Animal traction is primarily a land extensive technology. Higher yields with plowing may be expected, but on-farm research has shown that the greatest gains come from reducing human labor requirements at critical periods, enabling extensification of crop area. Given these technical characteristics, should the government invest in better fertilizer distribution facilities in the southwest where the yield response is higher? Should the government emphasize animal traction in the west, east and southwest zones, due to land constraints on the densely populated Central Plateau?

From an economic perspective, answers to the above questions depend on the following factors: a) production function for the inputs; b) input prices; and c) commodity prices. Since prices, output and input demand are simultaneously determined, answers to these questions require a sector perspective. Three scenarios are evaluated with the model to address this:

> Scenario III: As explained earlier, the government eliminates the fertilizer subsidy and removes all restrictions on fertilizer availability (Scenarios I and II combined).

Scenario VIII: Market restrictions on the supply of animal traction resources are removed. Animal traction resources currently are not subsidized by the government.

Scenario IX: National fertilizer and animal traction resources are constrained at one-third optimal resource levels in Scenario III and Scenario VIII. Resource constraints are placed at the national level; resources are allocated among regions based on economic profitability.

Resource utilization, crop area and national prices in the Ouagadougou market are reported in Table 9.18 for alternative technology scenarios. Model results for crop production are reported in Table 9.19.

Technology Scenario III: Relaxing market rations on fertilizer and raising fertilizer prices increases fertilizer utilization nationwide, from 12.4 to 129.7 thousand tons. Fertilizer utilization is 10.5 times 'base' period usage, indicating a strong latent demand for fertilizer in the country. Fertilizer use increases in all zones, although the greatest gains are experienced in the north and central regions. In the north, fertilizer use increases from 1.5 to 26.4 thousand tons. In the central region, utilization increases from 1.4 to 39.0 thousand tons.

Sorghum experiences the greatest production response. Its production increases from 53.2 to 78.1 thousand tons in the north, 198.1 to 264.5 thousand tons in the central region, 50.0 to 64.7 thousand tons in the east, 106.8 to 138.6 thousand tons in the west and 153.0 to 253.9 thousand tons in the southwest. Smaller production increases are observed for millet. The production responses for groundnuts and cotton are mixed. Maize production falls from 68.9 to

Table 9.18. Input Use, Area and Prices, Various Technology Scenarios, Annual Model, Burkina Faso.

	Base Case	No Fert. Restric. (III)	No AT Restric. (VIII)	National Restrictions on Inputs (IX)
Fertilizer Utilization (metric tons)				
North	1,530	26,431	1,530	8,472
Central	1,355	39,000	1,355	13,628
East	145	8,225	145	2,233
West	3,565	19,493	3,565	11,005
South	5,815	36,571	5,815	7,902
Donkey Traction (teams)				
North	9,935	9,935	24,625	39,305
Central	16,260	16,260	86,397	-
East	2,070	2,070	13,077	2,989
West	2,890	2,890	17,347	7,745
South	715	715	14,138	1,822
Oxen Traction (teams)				
North	7,755	7,755	156,277	10,000
Central	3,290	3,290	120,682	63,175
East	865	865	16,294	10,487
West	8,625	8,625	39,529	15,791
South	5,620	5,620	33,906	22,776
Crop Area ('000 hectares)				
North	641.6	633.0	964.2	713.0
Central	891.7	904.2	1,167.8	1,013.2
East	183.1	182.4	242.6	219.0
West	299.5	301.5	354.7	329.9
South	443.5	456.1	546.5	502.9
Prices: Ouagadougou (FCFA/kg.)				
White Sorghum	68.0	27.0	99.8	54.8
Red Sorghum	62.1	65.6	68.7	62.1
Millet	69.9	66.7	44.5	59.4
Maize	66.5	92.9	13.0	64.3
Rice	141.2	141.2	142.1	141.4
Groundnuts	130.8	158.6	18.0	24.0
Wheat	133.0	133.2	133.5	133.3
Other	54.2	55.2	54.3	55.5

Table 9.19. Total Production of Agricultural Commodities, Alternative Resource Scenarios, Annual Model, Burkina Faso.

Region: Commodity	Base Case	No Fert. Restric. (III)	No AT Restric. (VIII)	National Restrictions on Inputs (IX)
North				
Sorghum[a/]	53,192	78,145	31,486	68,137
Millet	151,067	157,839	236,085	174,749
Maize	7,320	7,320	21,690	7,320
Paddy	3,730	3,730	3,730	3,730
Groundnuts	18,897	23,403	61,572	22,854
Cotton	3,330	-	-	-
Central				
Sorghum[a/]	198,079	264,526	155,491	254,042
Millet	166,080	174,989	152,927	139,957
Maize	15,791	15,791	56,215	15,791
Paddy	15,124	15,693	16,354	16,354
Groundnuts	18,748	7,113	149,008	59,480
Cotton	2,316	6,615	78,763	59,413
East				
Sorghum[a/]	49,956	64,739	65,966	64,888
Millet	31,687	33,168	38,172	37,753
Maize	8,125	6,306	6,306	6,306
Paddy	3,538	4,168	3,746	3,746
Groundnuts	7,215	8,839	20,861	13,259
Cotton	446	214	214	215
West				
Sorghum[a/]	106,848	138,572	78,858	101,614
Millet	51,733	53,473	67,510	61,684
Maize	11,877	11,877	17,128	11,877
Paddy	5,150	4,956	5,150	5,150
Groundnuts	7,760	3,348	40,691	14,018
Cotton	26,237	31,167	47,620	57,038
Southwest				
Sorghum[a/]	153,049	253,934	97,948	152,627
Millet	51,985	54,724	71,323	65,764
Maize	68,858	10,829	114,205	80,616
Paddy	21,563	21,563	21,563	21,563
Groundnuts	26,511	31,884	74,453	42,264
Cotton	31,459	42,602	69,357	47,864

a/ White sorghum and red sorghum combined. Changes in production of "sorghum" refer to white sorghum.

10.8 thousand tons in the southwest, due primarily to substitutions for labor in the model.

National prices of white sorghum in Ouagadougou fall from 68.0 to 27.0 FCFA/kg., due to the higher production response. This finding lends credence to arguments that lower prices from technology response may ultimately decrease returns to the technology, unless markets can be developed to utilize the surplus. Low prices in the short run will lead to an equilibrium in the intermediate run of lower fertilizer use, lower production and higher commodity prices. In the long run, however, growth of population and income, growth of livestock feed demand with rising income, and export demand from exchange rate adjustment may increase cereals demand. Evaluation of these effects are currently beyond the model's capabilities.

Technology Scenario VIII: Removing restrictions on animal traction resources increases the utilization of donkey traction units nationwide from 31.9 to 155.6 thousand units, a five-fold increase. Oxen traction units increase from 26.2 to 366.7 thousand units, a 14-fold increase over 'base' period utilization. The greatest increase in animal traction utilization is in the north and central areas. The number of donkey traction units increases from 9.9 to 24.6 thousand units in the north and 16.3 to 86.4 thousand units in the central region. The number of oxen teams increases from 7.8 to 156.3 thousand units in the north and 3.3 to 120.7 thousand units in the central zone. As in the case of fertilizer, the higher utilization of animal traction in these zones is due to the greater number of farms on the Central Plateau and the strong latent demand for animal traction

resources in the region. If the farming population density would increase in the east, west and southwest regions to the same level as on the Central Plateau, similar increases would be observed.

By relaxing animal traction constraints, households have the choice of buying donkey or oxen traction services (or both), whichever offers the highest returns. Even though oxen cultivation is assumed to be technically superior to donkey cultivation, some donkey units are used on the margin due to their cheaper annualized investment cost. Several technical factors that may restrict adoption of animal traction services, however, have not been incorporated into the analysis. Inadequate forage during the dry season, for example, may limit oxen traction on the Central Plateau. Heavy soils in the west and southwest zones may curtail use of donkey cultivation. Nevertheless, the results suggest there is considerable scope for the government to expand its supply of animal traction inputs.

Animal traction affects cropping patterns in three ways. The labor time saved from using traction units can be used to: (1) expand production on bush land, favoring cultivation of millets and sorghums; (2) cultivate more time intensive crops, such as groundnuts and maize; and, (3) yield increases associated with using animal traction encourage the production of high yielding crops such as maize. However, labor saving effects predominate.

Taking the north region as an example, millet production expands from 151.1 to 236.1 thousand tons, maize from 7. to 21.7 thousand tons and groundnuts from 18.9 to 61.6 thousand tons. Similar results are experienced in other zones, with the exception of the central

region. There, cotton production, increasing from 2.3 to 78.8 thousand tons, substitutes for millet. This result is implausible, but exemplifies the substitutions which are occurring in the model for labor. It also illustrates the model's sensitivity to labor costs.

Solution results for area harvested verify the extensification effects. Total area harvested increases from 641.6 to 964.2 thousand hectares in the north, 891.7 to 1,167.8 thousand hectares in the central region, 183.1 to 242.6 thousand hectares in the east, 299.5 to 354.7 thousand hectares in the west and 443.5 to 546.5 thousand hectares in the southwest.

Given the high population densities that exist on the Central Plateau, the possibilities for area expansion of the magnitude reported in this analysis would seem unlikely. If land supply were perfectly inelastic, land extensification would be restricted, largely eliminating the benefits of animal traction, given current technical assumptions. Animal traction might be used to intensify production per unit of area by shifting cropping patterns towards cultivation of higher yielding crops like maize and groundnuts. However, yield assumptions reflecting these intensification possibilities have not been built into the model. Historically, animal traction has emphasized extensification, hence coefficients (taken from on-farm studies) do not reflect the technological possibilities of intensification. Evaluation of these alternatives are perhaps better conducted with micro studies that enable greater flexibility in studying technological options.

Technology Scenario IX: National constraints were placed on the supply of modern inputs and the government was allowed to allocate inputs among regions based on economic efficiency. In the west and southwest regions, fertilizer is applied due to the relatively high agronomic response to fertilizer in the region, even though crop prices are low. In the north and central regions, high commodity prices provide an incentive to use fertilizer, even though the production response to fertilizer is relatively low. Thus, fertilizer is used in all zones. Donkey and oxen units are also distributed fairly evenly across regions, with the exception of the central zone. Due to discontinuities in the production functions to animal traction units, donkey traction in the central region is eliminated in favor of oxen traction.

The aggregate production function for fertilizer in a region, as with an individual crop, faces diminishing returns. In the optimization problem, marginal costs of an input are equated with marginal returns. Since marginal returns decline with greater fertilizer use while marginal costs are assumed to be constant, fertilizer is allocated across zones.

The effect of trade on technology use is also important. Decreasing fertilizer use in grain surplus regions of the west and southwest, for example, would lead to lower production, higher prices and less exports from the zone. This in turn would lead to [illegible] imports and higher prices in the grain deficit regions (north [illegible] central), increasing the profitability and use of modern inputs. Conversely, increasing fertilizer use in the west and southwest [illegible]

lead to higher production, lower prices and more trade. Lower prices of import substitutes in turn lead to higher imports and lower prices in deficit regions, decreasing the profitability and use of modern inputs. An equilibrium solution in prices and quantities would represent the balance between these opposing forces.

This effect cannot be evaluated with the model, since expected prices, used to solve the LPs, only change with dynamic simulations (for which model results are weak). However, the trade effect lends support to the finding that modern inputs are allocated to all regions in the model solution.

Summary: Technology Scenarios

Several important results come from the technology analysis. First, the country has a strong latent demand for fertilizer and animal traction inputs. The government will have to expand considerably its input distribution and marketing network if it is to meet this large potential demand in agriculture. Meeting this demand will require investments to improve the marketing infrastructure and export oriented strategies to provide foreign exchange for imports of intermediate inputs. Greater participation of private entrepreneurs might be considered to exploit existing infrastructure in the private market.

Second, the results suggest that experiment station and FSR research on fertilizer and animal traction technologies should continue nationwide. Input rations should be set to maximize returns across zones. This model proved to be a useful analytical tool for

evaluating the costs and benefits associated with fixed rations and for determining the optimal allocation of resources under alternative fixed-resource regimes.

CHAPTER X

SUMMARY AND CONCLUSIONS

Background and Objectives

Low and declining agricultural productivity has plagued Africa for more than a decade. Drought, the subsistence orientation of agriculture, rapid population growth, increased land-use pressures, decline of traditional methods of soil conservation, fragility of African soils, poor management practices and low modern input use are interrelated factors that have contributed to the deterioration of land and labor productivity.

There is growing awareness that agricultural policies of African countries are partially to blame. Marketing boards or parastatal agencies are used by governments to regulate markets. Pressures exist to maintain cheap food prices to satisfy urban consumers. But the necessity to maintain profitable operating margins leads to low producer prices, creating price disincentives for producers. Input subsidies are offered to producers as compensation, but modern input use is often low, benefiting only a narrow segment of the farmer population. Input supply is restricted by infrastructural and capacity constraints and budgetary difficulties of the government. New technological packages have been slow to be adopted because price incentives are poor and input supply is regulated.

Burkina Faso is a West African country beset with many of the same problems facing the entire continent. Agricultural productivity is low and stagnant. Population is expanding rapidly. Food imports, a large fraction of which is food aid, are required to meet food deficits. Food self-sufficiency is the country's number one objective, yet there is growing dependence on international donors for food aid assistance. Export growth has lagged imports, creating balance of payments and foreign exchange problems. In the late 1970s, the government experienced budget deficits; high costs of input subsidies to producers plus consumer subsidies raised government expenditures at the same time that export revenues were falling.

The State intervenes extensively in Burkina agriculture. Government programs regulate public investment in irrigation schemes. The AVV has responsibility for reclaiming lands along river valleys that have been freed of disease by WHO spraying programs. Cotton marketing and exports are controlled by SOFITEX. The CSPPA has an export monopoly in groundnuts, sesame and shea-nuts. Modern inputs, including agricultural chemicals, are distributed by SOFITEX and the ORDs. Recurrent inputs are subsidized by 50 percent.

OFNACER, the government's cereals marketing board, is involved in cereals marketing. OFNACER buys grain from producers at fixed 'producer' prices. However, low prices, physical restrictions on marketing activities and budgetary constraints impede domestic procurements. Domestic procurements plus food aid imports are sold to consumers, mainly in cities and extreme food deficit areas, at official 'consumer' prices. Input subsidies create income transfers to

producers; low 'consumer' prices provide income transfers to consumers. Costs are borne by the government, supported in part by foreign development assistance and export taxes.

Growing budget deficits and balance of payments problems in the 1970s prompted intervention by the IMF and the World Bank to correct the structural imbalance in agriculture. Three related policies were proposed: a) raise producer prices of sorghum and cotton; b) remove fertilizer subsidies; and c) eliminate food aid imports that depress prices. The policy emphasized a free market approach towards commodity and input pricing.

Proponents for the elimination of subsidies argue: 1) benefits accrue primarily to better farmers using modern inputs; 2) subsidies are inferior to higher commodity prices as a means for attaining higher agricultural output; and 3) the cost of subsidies becomes increasingly difficult to pay with the technological evolution of agriculture. Opponents argue higher fertilizer prices would lead to diminished fertilizer use and would have profound negative impacts on agricultural output. Also, the policy runs counter to the country's number one priority -- food self-sufficiency -- and stifles efforts to transform the productivity of the sector.

This study investigates four components of Burkina Faso's agricultural policy reform. The study's objectives are:

1) to evaluate the economic consequences of removing fertilizer subsidies;

2) to examine the effect of removing food aid imports on prices and incentives for domestically produced cereals;

3) to evaluate the economic impact of raising official 'producer' prices;

4) to evaluate the impacts of price policy on technology adoption and the allocation of commercial inputs in agriculture.

Separate and joint effects of the fertilizer and price policy reform are evaluated with the model. The study evaluates policy impacts on production, consumption, prices, trade, resource utilization, and the distributional effects among producer, consumer, urban and rural groups.

Methodology

A spatial, recursive and dynamic model of Burkina's agricultural sector is constructed for policy evaluation. Spatial dimensions of the model are represented by the determination of quantities and prices in private regional markets, connected by interregional trade. Recursive and dynamic dimensions refer to the manner in which supply, international trade and demand components are solved in arriving at a market solution.

The model contains 9 commodities, 5 supply regions, 7 demand regions and 2 types of markets. Supply is estimated via Linear Programming (LP) based on profit maximizing behavior of producers. Demand is estimated via a Linear Expenditure System (LES), in which parameters are derived from limited data using the Frisch procedure. Domestic production and consumption are linked with foreign markets through trade. The sector model links LP models of supply, LES models of demand and import-export equations for trade, solving for a competitive market equilibrium in prices and quantities. The framework permits representation of market behavior of producers and consumers

in two types of markets: a private unrestricted market where prices are set by competitive market forces of supply and demand and an official government controlled market, where both prices and quantities are restricted.

In the official market, the government has monopoly control over input supply and distribution. Inputs are sold at fixed, government regulated prices. Commodities are bought from producers at fixed 'producer' prices, through OFNACER's marketing operations. Input distribution and commodity procurements are restricted to reflect capacity, institutional and budgetary constraints. Grain procurements and food aid imports are sold to consumers at fixed 'consumer' prices, but in rationed quantities because supplies are limited. The official market equilibrium determines commodity procurement from producers and market rations to consumers.

The private market equilibrium determines prices, quantity supplied, quantity demanded and trade in the private sector of the economy. In regional LPs, producers make their planting decisions based on their expectations of prices on the private market and administered output and input prices on the official market. Output may be sold to the government through private or official markets, wherever returns are greatest. Consumers allocate their income to purchasing goods on the private or official market. Profit from agricultural operations affects rural consumption through income and the income elasticity of demand.

The complete model is solved sequentially:

1) Output is estimated via LP models of crop production based on producers' expectations of prices in the private market and present government administered prices in the official market.

2) Sales of output to the private or official markets in regional LPs constitute marketing activities of producers.

3) Commodity procurements by the government in the LPs plus food aid imports are used to set consumer rations in the official market.

4) With official market rations set, consumption, prices and trade are determined in the private market. The model is solved as a Linear Complementarity Problem (LCP). Output, food aid imports, income and market margins are constants for the LCP. Linearized parameters from regional LES systems, foreign trade equations and price linkages are nested in the LCP. Quantity demanded, prices and trade are solved endogenously in the LCP as a competitive private market equilibrium.

5) Producers' price expectations are revised given updated prices from the LCP, then steps (1) to (4) are repeated. Price expectations of producers are revised based on a distributed lag model of long term expected prices and previous period prices forecast by the LCP model. Steps (1) to (5) can be solved recursively for 'n' iterations.

Steps (1) through (4) represent an annual short term model. Revising price expectations via step (5) and repeating the model enable long term evaluations of dynamic adjustments to policy change.

This methodology makes several unique contributions. The sector model explicitly incorporates official markets for input supply and commodity marketing into the analysis. LPs estimating supply are linked with an LCP for estimating prices, demand and trade. The model is solved sequentially, permitting both short and long term analyses of policy impacts. The model's sequential nature also permits solution of large supply models, without excessively slowing calculation of the market equilibrium. Supply models, estimated with producers'

price expectations rather than market equilibrium prices, more accurately reflect producer decision making. The LES, for estimating demand, satisfies the general restrictions of demand theory. Supply models have detailed specifications, enabling evaluation of a wide mix of technological options. The models are estimated from experiment station and Farming Systems Research (FSR) data, exploiting areas where information is relatively abundant. Thus, the model links FSR research with national policy making at the macro level. All data for the analysis comes from secondary sources making the approach applicable to other regions of Africa where data are perceived to be equally limiting. The model is a flexible analytical tool, suitable for evaluating a broad range of policy issues.

Summary of Policy Simulations

The annual model proved to be a robust and flexible policy analysis tool. It provided useful economic information on production and consumption response, trade in domestic and foreign markets, income distributional impacts, balance of payments, government costs, resource utilization and shadow prices of scarce factors in the economy. The dynamic model provided disappointing results for reasons discussed later. Policy results then are for the annual model unless otherwise stated.

Fertilizer Policy: Two aspects of fertilizer policy were evaluated: a) the effect of removing fertilizer price subsidies; and, b) the effect of relaxing fertilizer rations (constraints on fertilizer supply) on the official market. With existing fertilizer

rations, model results suggest that removing input subsidies would have minimal effect on commodity prices, output, consumption or international trade. The quantity demanded of fertilizer showed no perceptible decline in response to higher fertilizer prices, due to low levels of fertilizer use in Burkina agriculture and the stepped supply function characteristics of LP.

Maintaining subsidies, but removing restrictions on fertilizer availability, increases national fertilizer utilization from 12.4 to 214.0 thousand tons. Fertilizer use shows the greatest gain in the north and central regions. Although yield response there is low, the high concentration of farms plus high commodity prices create a strong latent demand for fertilizer. Total production of cereals increases 15 percent nationwide. Cotton production more than doubles. Producers benefit from the fertilizer subsidies while consumers benefit from lower commodity prices. The cost of fertilizer subsidies increases from 0.7 to 11.1 billion FCFA, substantially increasing government outlays for the subsidy program. Fertilizer imports exceed earnings from cotton exports, causing the balance of payments to decline by 7.2 billion FCFA. These forcasts lend credence to worries of international authorities concerning the government's ability to meet subsidy payments under current price policy. Since subsidy payments rise with greater use of agricultural inputs, the government's goal of technologically transforming agriculture will meet with growing budget restrictions.

When both fertilizer subsidies and restrictions on the supply of fertilizer in the official market are removed, fertilizer utilization

drops from 214.0 to 129.7 thousand tons, showing a strong price response. Even with higher fertilizer prices, fertilizer utilization is 10.5 times 'base' period levels, indicating there is considerable scope for expanding the government's fertilizer marketing activities. Cereals production is 17 percent above 'base' period levels. Even though fertilizer prices increase, cereals production rises due to the substitution of grains for cotton. These results point out the difficulties of evaluating the 'pure' supply response of a crop to price policy when using a multi-commodity framework.

Cereals prices fall due to greater supply. The national price of white sorghum, which shows the greatest production response to fertilizer, falls from 68 to 27 FCFA/kg. in the Ouagadougou market. Prices of maize and groundnuts increase due to expansion of white sorghum area.

Fertilizer imports increase from 0.9 billion FCFA (base case) to 9.6 billion FCFA. Imports of maize also increase in response to higher domestic prices. The value of cotton exports, however, rises from 6.5 to 8.2 billion FCFA. Since cotton is exported only through official market channels at low 'producer' prices, higher expected prices for grains make cereals production more profitable. While cereal production increases, high transport costs to the international market at Abidjan inhibit cereals exports at current exchange rates. Exports to neighboring countries increase, but the effect is small due to the inelastic nature of regional import demand.

Overall, the trade balance worsens by 7.2 billion FCFA. Also, higher payments for fertilizer imports increase demands on scarce

foreign exchange. Thus, fertilizer policy leads to higher output, lower food prices and the elimination of government outlays for input subsidies. But, the import bill exceeds export earnings, creating problems in maintaining fertilizer imports over the long run. The second component of the World Bank policy--elimination of food aid imports (that depress private market prices) and higher commodity prices in the official market--is aimed at raising producer returns and at improving the balance of payments situation.

Elimination of Food Aid: Eliminating food aid imports, amounting to 15.4 thousand tons of white sorghum, 16.4 thousand tons of maize and 9.0 thousand tons of wheat and rice, has three main economic effects. First, commodity prices increase in the private market. National prices in Ouagadougou increase 5 percent for white sorghum, 18 percent for maize, 2 percent for wheat and 6 percent for rice. The result of higher prices is improved producer incentives for domestically produced cereals. Conversely, if food aid were to be increased, price disincentives would be created.

Second, the elimination of food aid increases imports on the private market. Wheat imports through Abidjan increase from 16.3 to 18.3 thousand tons. Rice imports increase from 15.7 to 19.7 thousand tons. The country becomes an importer of coarse grains; sorghum imports increase from 0 to 1.2 thousand tons while maize imports increase from 0 to 5.0 thousand tons. Imports increase, due to higher domestic prices and highly elastic import supply equations assumed in the model. The overall result is a 0.9 billion FCFA deterioration in the balance of payments.

Third, consumer subsidies drop nationwide from 0.7 to 0.2 billion FCFA. The decline is especially sharp in the north and in Ouagadougou, which receive the highest rations of food aid. Since food aid is the largest component of official market rations, eliminating food aid has major implications for government strategies intended to transfer income to consumer groups.

Higher Commodity Prices: Two aspects of the government's price policy are evaluated: a) increasing commodity prices in the official market and relaxing procurement constraints; and b) removing subsidies, eliminating food aid imports and raising official market commodity prices, corresponding to the complete World Bank policy. Official 'producer' prices for cereals and cotton were increased 20 percent to bring them in line with international prices. 'Consumer' prices were also raised to maintain fixed margins in the official market. 'Base' period procurement constraints were partially relaxed; a ceiling on grain procurements of 50,000 tons was retained, reflecting maximum storage capacity. No production, processing or marketing constraints were imposed on cotton.

Raising commodity prices in the official market, increases cotton production from 63.8 to 194.9 thousand tons. Production of sorghum falls from 561.1 to 454.5 thousand tons, due to area displacement by cotton. Even though the government increases official 'producer' prices of cereals, the capacity constraint of 50,000 tons effectively limits the quantity of cereals the government can procure from producers at those prices. Higher cotton prices and unconstrained cotton marketing activities stimulate the production response for

cotton. Cotton exports rise from 23.6 to 72.1 thousand tons. Since fertilizer imports are constrained at 'base' period levels, the trade balance improves by 12.7 billion FCFA. Production and consumption of cereals fall, however, exacerbating the country's food problem.

Raising commodity prices, removing input subsidies, relaxing fertilizer rations and eliminating food aid resembles a free market scenario. Fertilizer utilization in the model solution is 151.9 thousand tons, an increase of 22.1 thousand tons over the price policy scenario alone. Sorghum production increases from 561.1 to 670.1 thousand tons due mainly to fertilizer policy. Cotton production increases from 63.8 to 245.5 thousand tons mainly in response to higher prices. White sorghum prices in the Ouagadougou market fall from 68.0 to 43.9 FCFA/kg. Maize prices increase from 66.5 to 101.6 FCFA/kg., due to substitution of white sorghum for maize in the southwest. Maize imports through Abidjan increase, from 0 to 25.4 thousand tons, due to sharply higher domestic prices. Wheat imports increase from 16.3 to 18.6 thousand tons and rice imports increase from 15.7 to 19.5 thousand tons due to the elimination of food aid. Fertilizer imports rise from 0.9 to 11.2 billion FCFA. Cotton exports increase from 6.5 to 25.0 billion FCFA, however, more than compensating for the higher import bill. Overall, the trade balance improves by 6.3 billion FCFA.

Policy Implications

In summary, fertilizer policy alone increased agricultural output, lowered prices for consumers and reduced costs of government

input and commodity subsidy programs. However, higher fertilizer imports were not accompanied by growth in exports, leading to balance of payments and foreign exchange problems. Without capital inflows from abroad, the country would probably be unable to achieve its objectives of expanding use of modern technology and transforming agriculture over the long run. With fertilizer and price policy combined, cereal production and consumption increase. Improved profitability of new agricultural technologies leads to expanded use of modern inputs. Moreover, the policy has a favorable effect on the external trade balance. Thus, the World Bank policy appears to accomplish its intended objectives.

The policy, however, places heavy emphasis on cotton cultivation and export, creating a dilemma for policymakers. Higher cotton production generates foreign exchange needed for purchase of intermediate inputs. However, it creates dependence on cotton cultivation which is incompatible with national objectives of food self-sufficiency. Also, the viability of the policy crucially depends on the production response of cotton. Solution results are very sensitive to changes in relative prices (for reasons discussed below) as indicated by the increase in cotton production in the central region, from 2.3 to 111.3 thousand tons, in response to the new fertilizer and price policy. This region is an insignificant cotton producer at present, suggesting that supply is probably more inelastic than model results suggest, due to technical and processing constraints. Further analysis may consider constraining cotton production in the model. However, this procedure warrants caution because it creates model

rigidity and ignores investment decisions that might be made to relax current constraints.

The government will have to considerably expand its input distribution and marketing network if it is to meet the potential input demand that exists in agriculture. This will require either a substantial investment in government marketing infrastructure or greater participation of private entrepreneurs in input markets. Commodity marketing faces the same problem. The policy of higher prices, which is often proposed for Africa, was shown to be ineffective due to market constraints which impede cereals procurements, storage and handling. If government input and commodity programs are to be effective, greater investment in marketing infrastructure and improved marketing strategies will be required.

Model Performance

The annual model proved to be a robust and flexible analytical tool for short term policy analyses. The dynamic model, for evaluating the long term impacts of policy change, provided disappointing results. Prices and quantities oscillate in the model with simulations over time. Since the LPs are solved with expected prices of producers, policies which sharply lower private market prices only affect production via lower expected prices in the long run. Since agricultural income is based on expected prices of producers, reduced income from lower prices only affects consumption through dynamic

simulations with the model. Hence, for policies which greatly influence the outcome of prices and income, longer term policy impacts are important considerations.

The oscillation of the model in dynamic simulations is characterized by the following problem. Updating producers' price expectations with previous period prices from the LCP leads to adjustments in production. Due to own-price flexibilities on the order of 2 in the LES demand systems, quantity adjustments result in magnified price changes in the LCP. These prices in turn alter producers' price expectations which lead to larger quantity adjustments, then larger price adjustments and so on. The extent of model instability depends on the dampening factor used to update producers' price expectations.

The causes of model oscillation are several-fold. One, large cross-price effects in the LPs lead to high substitution among crops and technologies with small changes in expected relative prices. Second, demand is driven by own-price and income effects. Cross-price effects that might soften the degree of price adjustments in the LCP are small. Third, the procedure used to model producers' price expectations in the model (i.e. distributed lag model) does not adequately capture producers' actual behavior.

There are several explanations for the high cross-price effects in the LPs. The assumptions of constant labor supply, during the agricultural season, but labor flows which vary, result in positive shadow prices for only 2 to 3 periods of the agricultural season. These shadow prices are high, compared with zero costs in off-peak periods of labor demand and with annual average wage rates. Considerable substitution occurs in the LPs to minimize these peak

season labor costs, as relative output prices shift. Also, the stepped supply function characteristics of LP creates discontinuities in price-quantity adjustments.

The influence of these factors was apparent in the results for cotton. With small changes in relative prices, the model forecasted large changes in crop production and considerable crop substitution. The severity of this problem might be reduced in several ways. Large quantity adjustments to changes in prices suggests there are insufficient activites in the model, creating discontinuity in the production possibility surface. Hence, expanding activities would be a solution, but at higher costs in terms of expanded model size and additional effort for generating model parameters.

Second, the LP farm models are presently formulated as a linear process. By formulating the model as a non-linear problem, increasing costs could be imposed on higher activity levels, thereby decreasing the extent of substitution in the model. This procedure requires the availability of a mathematical programming package which is suitable for handling non-linear problems (e.g. MINOS). Third, the sensitivity of the model to labor costs could be lessened by raising labor costs in off-peak periods of labor demand (by reducing labor supply). This would lessen the significance of peak season shadow prices, but may underestimate the severity of peak period labor constraints that producers actually face.

The stability problems experienced with supply in dynamic simulations with the sector model are not unique to the LPs in this analysis. LP models of household producer and consumer behavior are

rarely submitted to the extremes of price changes experienced with macro policy evaluations in the process of model validation. Sectoral modelling approaches that nest LPs with demand in a large mathematical programming framework exhibit stability because the solution depicts a long term equilibrium between supply and demand. As will be explained shortly, eliminating the recursive structure of the sector model represents an alternative solution for dealing with stability problems in the LPs.

Estimating the LES with the Frisch procedure enabled estimation of a demand system, using limited data, with properties consistent with demand theory. The small cross-price effects inherent to the LES are a liability, however. There are three directions that might be taken to improve on demand: a) draw on a better base of income elasticies for the Frisch procedure; b) draw on a better base of own-price, cross-price and income elasticities and alternative functional forms for estimating demand systems; or c) estimate demand systems directly. All require more empirical research than now exists. Direct estimation of demand and elasticities is difficult given the problems of multi-collinearity and, in Africa, acute data shortages. Current research efforts by IFPRI should help rectify these problems, although even in the U.S., weak elasticity estimates remain a troublesome area in policy research.

To solve the oscillation problems, the sectoral modelling approach can take two directions. Both directions have their advantages and disadvantages. The first approach is referred to as the 'Expanded LCP.' The second is referred to as the 'Fixed Point and Pseudo Data'

approach. Both involve expanding frontiers in solving computable equilibrium models.

The 'Expanded LCP' approach would involve nesting LP models of supply, LES models of demand, trade and market problems into one, large LCP. By so doing, quantities, prices, and income would be solved endogeneously, in a rational expectations framework. This would avoid some of the problems inherent to the recursive structure of the current model. The 'Expanded LCP' would eliminate difficulties of accounting for and transferring prices and quantity information among sub-models that are inherent to the current approach. However, the equilibrium would constitute a long term model solution; short term and intermediate term analyses of policy impacts would not be possible, representing an important loss of information on market dynamics. The 'Expanded LCP' would also preclude using producers' expected prices to forecast supply. Expected prices, not long-term equilibrium prices, are more appropriate for forecasting producers' planting decisions. The analysis would require solving LCP problems of uncommonly large size It also requires the generation of large data (MPS) files, creating additional problems for debugging and manipulation.

In the 'Fixed Point and Pseudo Data' approach, pseudo data procedures would be used to estimate continuous supply equations from the stepped supply functions implicit in the LPs. Details on this procedure are explained in Preckel and Hertel (1986). Equations representing supply and demand could then be linked in a market equilibrium framework and solved via a fixed point algorithm. State of

the art fixed point methods are slow, relative to Newton methods, but they guarantee finding a solution if one exists. Estimating continuous supply, via the pseudo data approach, would considerably ease computational requirments for obtaining a solution, thereby lessening computer time requirements. The pseudo data approach, however, does not correct underlying structural deficiencies of the LPs. The approach is computationally costly and requires further research to determine the extent of information loss between the LP and Psuedo data supply systems.

Further Considerations

There are three further considerations, concerning model development and performance, that merit mentioning: a) individual versus aggregate supply response in the model solution; b) data requirements for empirical model development; and c) computational and computer requirments needed for solving the model.

Individual Versus Aggregate Elasticity Response: While the production responses of individual crops in the LPs are price elastic, the aggregate production response is relatively price inelastic. Price changes in scenarios where fertilizer was held constant resulted in considerable substitution among crops, while total agricultural output remained relatively constant. This phenomenon is due to fixed resource endowments assumed in the LPs and is common to agricultural sectoral models. In African economies, where modern input use is low, output response depends on the supply elasticities of land and labor in agriculture. If the supply of land and labor are fixed, total

output is constrained by endowments of these resources. Crops may still substitute for scarce factors, however, exhibiting elastic responses.

Many of the critical research issues in Africa involve the intensity of resource use in agriculture. Urban-rural migration, emmigration from the country and availability of land in agriculture are issues which require a more flexible treatment of input markets. To adequately address these issues, the fixed resource assumptions need to be relaxed. Non-linear programming approaches can be used to endogenize resource supply as a function of prices or returns in agriculture The effect of price and income adjustments (from policy change) on resource utilization can then be evaluated with dynamic model simulations.

Data: Considerable effort was taken to document data sources used for model estimation. After perusing these sources, the reader may believe that data high in quality and consistent in nature exists. This would be an erroneous conclusion. The major portion of time for model development was spent filling data voids, reconciling data inconsistencies and integrating data from diverse sources in arriving at a plausible set of coefficients. The difficulties involved in this process can only be appreciated by researchers faced with similar data problems. Time and data limitations should be carefully kept in mind when attempting to replicate this approach elsewhere. Also, the empirical development of the model requires considerable subjective judgement. On the other hand, relying on existing research helped identify critical areas where empirical research is needed, provided a

framework for prioritizing data collection efforts, integrated diverse data sources, and aided in understanding complex data relationships. The fact that this analysis was done, attests to the feasibility and benefits of conducting similiar analyses elsewhere in Africa.

Computational Requirements: The entire model was run on a PRIME mini computer. Supply sub-models were solved with MINOS, starting with advanced bases whenever possible. The LCP was solved with an LCP algorithm, also starting with advanced bases. Still, the model requires about 2 hours of CPU processing time to run dynamically for 5 complete iterations. These time requirements would be formidable in African environments, where technical problems like power shortages are commonplace. Adapting the model to micro computer applications, while possible, would face serious time constraints.

Several of the approaches mentioned above may help rectify this problem. Pseudo data approaches which reduce the computational time required to solve supply would greatly reduce time requirments. Reducing the number of commodities, activities or regions and simplifying the constraint set would also ease computational requirements.

Ending Comments

Overall, this analysis offers much insight into the agricultural policy issues facing the government of Burkina Faso. The sector model provided an effective framework for defining and understanding policy related problems, for integrating data and for evaluating a broad range of policy issues. The analysis was constrained by the model's

capacity to handle only short term analyses. However, research directions were identified--the 'Pseudo data approach' and the 'Expanded LCP'--which extend the model's usefulness to an even broader set of applications, including the dynamics of policy and long term issues dealing with resource allocation in agriculture. In spite of this limitation, this study provides concrete analyses of the policy reform package suggested by the World Bank for Burkina Faso and will be useful for improving agricultural policies in the country and elsewhere in sub-Saharan Africa.

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APPENDICES

Appendix 1

Agricultural Statistics, Burkina Faso

Table A1.1. Aggregate Economic Accounts, Measured at Market Prices, Burkina Faso, 1970-1979.

Aggregates	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
	(million FCFA)									
Gross Domestic Product (at market prices)	98,749	101,609	109,434	109,739	131,040	145,493	158,397	192,131	213,213	252,775
Government Purchases of Goods and Services	7,948	8,501	9,533	10,916	13,425	23,542	21,243	24,708	30,068	36,015
Personal Consumption Expenditure	92,076	94,591	99,195	96,932	106,899	126,935	133,654	180,564	196,977	240,270
Gross Domestic Investment	7,500	12,200	15,471	20,050	28,826	29,500	34,029	35,872	39,219	41,119
Inventory Adjustment	2,250	2,685	3,549	3,300	6,009	5,600	6,200	5,120	6,800	4,941
Exports of Goods and Services	8,615	9,091	11,585	11,785	18,691	18,441	23,902	27,393	29,086	34,040
Imports of Goods and Services	-13,640	-25,459	-29,899	-33,244	-42,810	-58,525	-60,631	-81,526	-88,937	-103,610
Indirect Taxes Net of Subsidies	7,224	7,467	7,572	8,771	10,444	12,023	16,015	20,510	22,547	19,539
Gross Domestic Product (at Cost of Production)	91,525	94,142	101,826	100,968	120,596	133,470	142,382	171,621	190,666	233,236

Sources: Banque Centrale des Etats de L'Afrique de L'Ouest, Statistiques, Economiques et Monetaries: Haute-Volta, 1983, p. 13 and Ministere de L'Economie et du Plan, Institut National de la Statistiques et de la Demographie, Comptes Nationaux et Indicateurs Economiques de la Haute-Volta de 1970 a 1979, 1981, pp. 9-11.

Table A1.2. Aggregate Economic Accounts, Measured at Cost of Production, Burkina Faso, 1970 to 1979.

Aggregates	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
	(million francs, FCFA)									
Gross Domestic Product(Cost of Production)	91,525	94,142	101,826	100,968	120,596	133,470	142,382	171,621	190,666	233,236
Agriculture, Forestry & Fisheries	46,667	46,868	50,833	46,408	56,644	59,524	59,184	72,333	74,501	95,589
Mining	55	61	74	80	97	110	150	196	250	290
Manufacturing and Cottage Industries	10,363	11,329	13,146	14,019	16,441	17,923	20,238	22,422	24,702	29,044
Electricity, Gas and Water	610	705	847	938	952	1,049	1,411	1,745	2,098	2,105
Construction and Public Works	3,600	4,046	3,567	4,790	4,216	6,802	8,381	6,352	8,680	8,357
Commerce, Restaurants and Hotels	11,800	11,933	12,417	12,164	14,776	15,231	16,752	25,738	32,607	39,824
Transport, Warehousing and Communications	5,956	6,076	6,841	6,562	8,920	9,386	10,460	12,685	12,820	16,090
Other Market Services	5,667	5,883	6,111	6,364	6,693	7,140	6,935	7,270	8,099	9,860
Non-Market Services	6,807	7,241	8,026	9,643	11,857	16,305	18,871	22,880	26,909	32,077
Indirect Taxes Net of Subsidies	7,224	7,467	7,572	8,771	10,444	12,023	16,015	20,510	22,547	19,539
Gross Domestic Product (at Market Prices)	98,749	101,609	109,434	109,739	131,040	145,493	158,397	192,131	213,213	252,775

Sources: Banque Centrale des Etats de L'Afrique de L'Ouest, Statistiques, Economiques et Monetaires: Haute Volta, 1983, p. 13 and Ministere de L'Economie et du Plan, Institut National de la Statistiques et de la Demographie, Comptes Nationaux et Indicateurs Economiques de la Haute-Volta de 1970 a 1979, 1981. pp. 9-11.

Table A1.3. Significance of Agriculture in the National Accounts.

Year	GDP (at cost of factors)	Crops		Livestock		Fishing and Forestry		All Agriculture
		mil. FCFA	%	mil. FCFA	%	mil. FCFA	%	%
1970	91,525	26,243	28.7	14,685	16.0	5,739	6.3	51.0
1971	94,142	26,233	27.9	14,815	15.7	5,820	6.2	49.8
1972	101,826	28,600	28.1	16,007	15.7	6,226	6.1	49.9
1973	100,968	24,132	23.9	15,994	15.8	6,282	6.2	46.0
1974	120,596	31,981	26.5	17,254	14.3	7,409	6.1	46.9
1975	133,470	33,997	25.5	18,302	13.7	7,225	5.4	44.6
1976	142,382	31,906	22.4	19,791	13.9	7,487	5.3	41.6
1977	171,621	43,770	25.5	20,543	12.0	8,020	4.7	42.1
1978	190,666	46,065	24.2	18,850	9.9	9,586	5.0	39.1
1979	233,236	63,262	27.1	22,523	9.7	9,804	4.2	41.0

Source: Ministere de L'Economie et du Plan, Institut National de la Statistique et de la Demographie, Comptes Nationaux et Indicateurs Economiques de la Haute-Volta de 1970 a 1979, 1981, p. 9.

Table A1.4. Government Revenues and Expenditures, Burkina Faso, 1976 to 1979.

	1976	1977	1978	1979
	(million francs FCFA)			
Revenues:				
Direct taxes	3,071	3,813	4,328	4,872
Taxes and Duties on Exports:	1,032	935	1,040	1,098
Agriculture and Livestock	1,003	916	1,022	1,079
Other	29	19	18	19
Indirect Taxes	14,389	19,747	21,792	21,921
Non-Tax Revenues	2,473	4,180	2,704	3,300
Total	20,965	28,675	29,864	31,191
Expenditures:				
Public Debt	932	1,032	1,140	1,931
Operating Expenditures:	14,799	17,728	20,972	26,297
Personnel	11,867	14,370	17,024	19,787
Material	2,933	3,358	3,948	6,510
Public Interventions	1,778	2,506	3,659	4,578
Equipment and Investment	3,460	4,611	3,845	6,513
Total	20,969	25,877	29,616	39,319
Budget Surplus (negative implies deficit)	-4	2,798	248	-8,128

Sources: Budget de l'Etat, Exercises 1976 and 1977, Second edition; Exercises 1978, 1979, 1980, first edition; Treasury Accounts 1976-79. In World Bank, "Upper Volta Agricultural Issues Study," 1981, p. 233.

Table A1.5. Area Cultivated and Yields of Principal Crops, Burkina Faso, 1972/73 to 1981/82.

	1972/ 73	1973/ 74	1974/ 75	1975/ 76	1976/ 77	1977/ 78	1978/ 79	1979/ 80	1980/ 81	1981/ 82
Area Harvested ('000 ha.):										
Millet	711.4	[1,757.0]	[1,581.0]	[2,193.0]	828.4	841.9	767.6	767.9	719.9	900.0
Sorghum	1,050.7				1,023.4	1,089.1	1,098.4	1,106.3	956.7	1,084.1
Maize	80.9	89.2			93.1	103.1	115.7	109.7	115.7	142.9
Fonio	n.a.	n.a.	n.a.	21.1	10.7	13.4	13.1	11.7	10.1	9.0
Rice: Traditional	38.6	38.9	n.a.	41.3	37.4	17.2	31.3	28.2	33.1	35.1
Modern	1.9		n.a.		4.0	14.7	3.0	3.1	3.5	4.1
Groundnuts	104.7	166.8	n.a.	163.6	144.4	118.4	152.3	154.0	105.7	128.1
Cotton[a]	79.4	66.6	60.7	77.2	93.8	76.6	75.7	84.2	76.8	65.8
Sesame	25.8	n.a.	n.a.	n.a.	38.2	35.9	29.4	38.5	22.4	23.0
Other	15.0	n.a.	n.a.	242.7	n.a.	45.2	n.a.	n.a.	n.a.	n.a.
Total	2,108.4	2,118.5	1,790.1	2,738.9	2,273.4	2,355.5	2,286.5	2,303.6	2,043.9	2,392.1
Yields (kg./ha.):										
Millet	373	-	-	-	419	421	492	492	487	492
Sorghum	490	-	-	-	526	583	578	590	572	608
Maize	725	656	-	-	645	715	931	907	903	830
Fonio	n.a.	n.a.	n.a.	578	355	403	733	299	564	522
Groundnuts	576	377	666	558	503	482	485	505	510	607
Cotton	461	401	303	751	632	584	818	952	836	904
Sesame	380	n.a.	n.a.	n.a.	453	262	224	226	268	348

a/ Cotton figures are official ORD estimates, not those of CFDT or SOFITEX.

Source: Republique de Haute-Volta, Ministere du Developpement Rural, Annuaire de Statistiques Agricoles, 1972, (various pages); Annuaire de Statistiques Agricoles, 1976, (various pages), Annuaire de Statistiques Agricoles, 1977, (various pages); and Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81, and 1981/82, (various pages).

Table A1.6. Cereals Production and Gross Food Balance, Burkina Faso, 1972/73-1981/82.

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
Cereals Production ('000 m.t.)										
Millet	265.6	[734.1]	[1,045.8]	[1,205.3]	347.3	354.7	377.9	377.7	350.7	442.8
Sorghum	512.4				534.0	634.8	635.0	653.2	546.9	658.8
Maize	58.7	58.5			60.0	73.7	107.7	99.5	104.5	118.6
Fonio	n.a.	n.a.	n.a.	12.2	3.8	5.4	9.6	3.5	5.7	4.7
Rice (paddy x 0.65)	21.8	20.7	22.9	25.9	29.5	24.4	25.6	30.5	26.1	29.4
Total	858.5	813.3	1,068.7	1,243.4	974.6	1093.0	1156.0	1164.4	1033.9	1254.3
Imports ('000 m.t.)										
Millet, Sorghum & Maize	15.3	28.9	54.0	2.8	0.8	8.3	29.2	20.4	19.8	8.7
Rice	0.0	0.0	3.1	9.7	12.3	17.9	10.2	25.5	30.3	15.0
Wheat	24.8	10.4	17.0	13.4	15.5	28.2	23.8	34.9	26.9	24.4
Total	40.1	39.3	74.1	25.9	28.6	54.4	63.2	80.8	77.0	48.1
Exports ('000 m.t.)										
Millet, Sorghum, Maize, Rice and Wheat	-	-	-	4.7	5.0	0.2	0.1	0.4	0.2	0.1
Total Cereals Available[a/]	-	897.8	887.4	1,089.9	1,267.0	1,028.8	1,156.1	1,236.4	1,241.2	1,081.9
Resident Population ('000)	5,355	5,448	5,542	5,638	5736	5836	5938	6040	6145	6251
Cereals Available (kg/person)	-	165	160	193	221	176	195	205	202	173

a/ Total cereals available is calculated as previous year production (Oct.-Nov. harvests) plus current year trade (imports-exports). Imports leave out maize flour equivalents due to incomplete data (Appendix 1, Table A1.8). Stocks are assumed to remain constant or be completely exhausted at year's end. No deductions are made for post-harvest losses or seed requirements. Hence, the figures estimate gross availability of grain for current year utilization.

Sources: Production figures were taken from Republique de Haute-Volta, Ministere du Developpement Rural, Annuaire de Statistiques Agricoles, 1972, 1976, and 1977, (various pages), and Bulletin de Statistics Agricoles, Campagnes 1978/79, 1979/80, 1980/81 and 1981/82, (various pages). Imports and exports are from Appendix 1, Table A1.8 and resident population is from Republique de Haute-Volta, Ministere de Plan et de la Cooperation, INSD, Principaux Resultats du Recensement de 1975, (1979, p. 26).

Table A1.7. Production of Non-Cereal Agricultural Commodities, Burkina Faso, 1972 to 1981.

	Starches[a/]	Groundnuts	Cotton	Sesame	Shea-nuts	Sugar Cane
	('000 metric tons)					
1972/73	39.0	60.4	36.6	5.7	44.5	-
1973/74	40.0	62.9	26.7	n.a.	10.4	-
1974/75	40.5	98.9	18.4	n.a.	50.2	-
1975/76	41.1	91.3	58.0	n.a.	48.6	190
1976/77	39.8	72.7	59.3	17.3	32.4	211
1977/78	41.0	57.1	44.7	9.4	56.7	287
1978/79	42.3	73.9	61.9	6.6	42.4	301
1979/80	43.0	77.8	80.2	8.7	27.3	283
1980/81	43.7	53.9	64.2	6.0	60.0	290
1981/82	n.a.	77.7	59.5	8.0	n.a.	n.a.

a/ Includes yams, sweet potatoes and cassava.

Sources: Production of starches, shea-nuts and sugar cane are from Republique de Haute-Volta, Minsitere de L'Economie et du Plan, INSD, Comptes Nationaux et Indicateurs Economiques de la Haute-Volta de 1970 a 1979, 1981, p. 38. Production of groundnuts, cotton and sesame were taken from Republic de Haute-Volta, Ministere du Development Rural, Annuaire de Statistics Agricoles, 1972, 1976 and 1977 (various pages) and Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81 and 1981/82, (various pages).

Table A1.8. Imports and Exports of Cereals, Burkina Faso, 1972-1982.

Year	Imports				Exports			
	Millet & Sorghum	Maize[a/]	Rice	Wheat[a/]	Millet & Sorghum	Maize	Rice	Wheat[a/]
	metric tons							
1982	30,000	8,500	25,000	34,500	-	-	-	-
1981	7,931	740	15,001	24,436	131	-	-	-
1980	19,579	259	30,322	26,908	214	-	-	-
1979	18,549	1,809	25,476	34,912	332	1	-	111
1978	29,[illegible]	-	10,237	23,827	114	1	-	-
1977	8,204	70	17,939	28,173	232	-	-	-
1976	308	501	12,308	15,478	5,006	-	30	-
1975	2,615	164	9,706	13,415	4,654	-	-	-
1974	30,000	24,000	3,055	17,019	-	-	-	-
1973	22,000	6,850	-	10,353	-	-	-	-
1972	15,000	273	041	24,806	-	-	-	-

a/ Includes wheat and wheat flour equivalents. Maize includes grain only, excluding imports of maize flour.

Source: Food and Agriculture Organization of the United Nations, FAO Trade Yearbook, Vols. 29-35 (various issues).

Table A1.9. Total Cereals Imports Including Food Aid, Burkina Faso, 1974 to 1979.

	1974	1975	1976	1977	1978	1979
	thousands of metric tons					
Sorghum[a/]	38.0	2.6	0.3	8.2	29.2	18.7
Maize[b/]	45.2	7.5	7.3	6.2	24.7	18.4
Rice	3.1	9.7	12.4	18.4	10.3	25.5
Wheat[c/]	19.2	13.5	15.5	28.3	26.0	36.4
Other (Non-Specified)	2.3	0.8	-	1.5	2.0	2.8
Total Imports[d/]	107.7	34.1	35.5	62.5	92.2	101.8
Food Aid Received	85.5	12.7	14.4	21.3	75.6	47.4
Percent Food Aid	(79.7)	(37.2)	(40.6)	(34.1)	(82.0)	(46.5)

a/ Includes some millet or sorghum flour converted to grain at 70 percent milling rate.
b/ More than half is maize flour converted to grain at 70 percent milling rate.
c/ Includes wheat flour and semolina converted to grain at 70 percent milling rate.
d/ Total imports are nearly the same as those of FAO in Appendix 1, Table A1.8 except maize flour is excluded from FAO data.

Sources: Total imports of cereals are taken from Republique de Haute-Volta, Ministere de L'Economie et du Plan, INSD, Comptes Nationaux et Indicateurs Economiques de la Haute-Volta de 1970 a 1979, 1981, p. 69. Information on food aid was estimated by World Bank from government data in "Upper Volta Agricultural Issues Study," 1981, p. 227.

Table A1.10. Physical Exports by Commodity, Burkina Faso, 1972-1981.

Exports	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
	metric tons									
Live animals	31,354	29,004	31,117	28,224	7,226	19,636	24,933	34,236	25,040	17,737
Fruit and legumes	5,328	3,383	7,079	9,728	13,192	14,119	3,480	n.a.	n.a.	n.a.
Groundnuts (shelled)	7,564	11,293	16,824	17,769	11,114	4,739	24	1,308	831	133
Cotton seed	9,584	7,065	1,346	-	21	-	-	-	-	-
Sesame seed	3,425	4,067	4,131	4,885	1,708	3,024	1,522	9,338	3,891	2,841
Shea nuts	10,648	3,821	8,763	11,597	40,489	30,613	21,516	23,694	34,700	43,622
Shea nut oil	2,104	16	1,631	2,104	2,357	1,172	1,626	1,331	352	52
Animal feed (cake)	6,702	4,256	4,790	7,599	8,986	7,575	2,324	8,509	11,160	9,013
Hides & leather products	801	903	6,864	771	634	821	902	1,406	855	1,689
Ginned cotton	8,910	10,473	8,271	9,540	20,671	15,305	10,633	21,427	27,890	22,151
Other products	4,957	7,941	5,374	5,172	12,718	3,104	643	22,561	22,896	23,132

Sources: Exports for 1972 through 1976 are from Republique de Haute-Volta, Ministere du Plan et la Cooperation, INSD, Bulletin Mensuel D'Information Statistiques et Economie, 1976 (p. 27) and 1979 (p. 27). Information for 1977 to 1981 are taken from BCEAO, Statistique, Economique et Monetaires: Haute-Volta, 1983, p. 25.

Table A1.11. Value of Exports by Principal Commodities, Burkina Faso, 1972-1981.

Aggregate Exports	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
	---million francs, FCFA---									
Live animals	2,100	2,287	3,061	3,381	1,479	3,949	3,536	4,282	4,512	3,509
Fruit and legumes	191	153	268	329	419	424	160	247	n.a.	n.a.
Groundnuts (shelled)	373	655	1,698	1,440	666	381	3	160	90	18
Cotton seed	94	55	46	-	-	-	-	-	-	-
Sesame seed	255	230	318	534	131	257	148	711	438	292
Shea nuts	132	73	358	638	2,089	1,305	908	1,102	1,535	2,984
Shea nut oil	62	36	141	374	438	226	317	349	103	9
Animal feed (cake)	68	79	141	170	209	214	56	227	268	291
Hides & leather products	213	254	210	257	394	528	580	850	738	1,012
Ginned cotton	1,021	1,206	1,546	1,525	5,785	5,400	3,002	5,341	8,369	8,174
Other exports	632	570	915	721	1,080	930	890	3,216	3,013	3,630
Total exports	5,141	5,598	8,702	9,369	12,690	13,614	9,600	16,238	19,066	19,919

Sources: Value of exports for 1972 through 1976 are from Republique de Haute Volta, Ministere du Plan et de la Cooperation, INSD, Bulletin Mensuel D'Information Statistique et Economie, 1976 (p. 26) and 1979 (p. 26). Information from 1977 to 1981 are taken from BCEAO, Statistique, Economique et Monetaires: Haute-Volta, 1983, p. 25.

Table A1.12. Value of Imports by Principal Categories, Burkina Faso, 1972-1981.

Aggregate	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981
	million francs FCFA									
Food:	3353	3648	10,854	5861	5353	8700	12,348	10,890		
Milk and egg products	288	313	2708	712	1958	2510	4270	2319	2888	4764
Cereals and cereal products	741	1355	4707	2407	2389	4504	6537	6285		
Fruits and vegetables	613	385	775	803	396	579	653	838		
Sugar	898	761	1259	1040	92	127	62	188	111	838
Other	813	834	1405	899	518	980	826	1260		
Tobacco and alcohol	468	489	660	723	836	1043	1088	1570		
Crude materials (non-combustible)	526	855	776	930	1054	1273	1016	1615		
Gas and petrol products	1311	1233	2247	2864	2700	4358	4358	7245	9973	14,206
Animal and vegetable oil	125	86	379	225	312	708	1090	1500		
Chemicals:	1269	1732	2959	4232	3431	4761	4460			
Manufactured fertilizer	176	342	513	963	296	826	963	1525	1314	1702
Manufactured goods	3951	4602	7366	7180	8822	11,049	8999	12,818		
Machinery and transport equipment	3537	4002	8207	8661	10,103	17,035	15,538	18,221		
Other	772	785	1216	1710	1812	2430	2186			
Total Imports	15,312	17,432	34,664	32,386	32,611	51,357	51,083	63,916	75,614	91,443

Source: Value of imports for 1972 through 1979 are from Republique de Haute Volta, Ministere du Plan et de la Cooperation, INSD, Bulletin Menseul D'Information Statistique et Economie, 1976 (pp. 22,23) and 1979 (pp. 22,23) and Comptes Nationaux et Indicateurs Economiques de la Haute-Volta de 1970 a 1979, 1981, pp. 65-67. Information for 1980 and 1981 are taken from BCEAO, Statistique, Economique et Monetaires: Haute Volta, 1983, p. 28.

Table A1.13. Balance of Payments in International Trade, Burkina Faso, 1972-1979.

	1972	1973	1974	1975	1976	1977	1978	1979
	million francs FCFA							
Current Accounts:								
Merchandise Trade Balance	-12,974	-16,826	-19,642	-24,449	-20,091	-30,831	-33,155	-37,923
Travel and Transport	-1789	-2345	-8151	-12,190	-13,326	-18,054	-20,280	-25,537
Net Investment Income	- 392	- 233	- 125	-585	-750	-1,501	- 2,281	-1,750
Government Transactions	-1993	- 967	-1489	-277	-717	-329	-252	1,295
Other Services Net	-1284	-1107	- 851	-2353	-1921	-4,256	- 4,987	-5,425
Balance of Private Goods & Services	-18,432	-21,478	-30,258	-39,854	-36,805	-54,981	-60,955	-69,340
Private Transfers from Abroad:	9044	10,264	9590	10,096	11,550	13,258	17,432	23,559
Worker Remittances	6433	6834	5669	5500	7,607	8,313	10,075	15,243
Non-Concessionary Gov't. Assistance	8326	11,769	19,727	20,809	17,450	21,249	29,988	33,650
Balance on the Current Account	-1062	555	-941	-8949	-7,305	-20,474	-13,535	-12,131
Capital Accounts:								
Capital from Non-Monetary Sectors:	1526	4013	1600	6939	4,169	13,248	5,875	13,061
Direct Investment	-85	913	622	-81	490	1,131	89	241
Private Short and Long Term Loans	996	1075	-2316	2670	130	6,371	2,210	2.117
Central Government	615	2025	3294	4350	3,549	5,746	3,576	10,703
Errors and Omissions	-301	-570	281	550	402	433	180	1,650
Official Settlements:								
Monetary Flows:	607	-1721	3254	54	3,643	2,346	1,913	1,826
Commercial Banks	591	-1663	2765	-578	2,017	4,566	-289	702
Central Bank	16	- 58	489	632	1,626	-2,220	2,202	1,124
IMF Special Drawing Rights	383	-	-	-93	50	88	-24	443
Changes in Reserve Assets	-1153	-2277	-4194	1499	-459	4,359	5,591	-4,849

Source: BCEAO, Statistiques, Economiques et Monetaires, 1983, p. 34.

Table A1.14. Size of Urban and Rural Resident Population by Region, 1975 Population Census, Burkina Faso.

ORD (Region) - Capital City	Resident Population (1975)	Rurala/ Population (1975)	Estimatedb/ Agricultural Work Force
Centre Nord	632,285	613,680	287,682
- Kaya	19,293		
Yatenga	530,192	493,405	223,696
- Ouahigouya	25,690		
Sahel	354,079	354,079	172,008
- Dori	6,599		
Sub-Total (North)	1,516,556	1,461,164	683,386
Centre	944,706	770,050	381,675
- Ouagadougou	172,661		
Centre-Ouest	788,962	726,880	331,401
- Koudougou	36,838		
Centre-Est	404,602	386,273	174,020
- Tenkodogo	18,224		
Sub-Total (Central)	2,138,270	1,883,203	887,096
Est (East)	407,215	393,928	179,159
- Fada N'Gourma	13,067		
Volta-Noire (West)	635,760	623,229	278,562
- Dedougou, Houna, Tougan	31,381		
Hauts Bassins	582,810	443,103	203,887
- Bobo-Dioulasso	115,063		
- Sanfora	12,358		
Bougouriba	357,592	357,592	163,591
- Gaoua	6,658		
Sub-Total (Southwest)	940,402	800,695	367,478
Burkina Faso	5,638,203	5,162,219	2,395,681

a/ No regional breakdown of rural population is available in published census data. These figures were estimated from resident population per region and a ratio of rural population (semi-urban plus rural) to present population. The latter was taken from unofficial census data published in Agra-Und Hydrotechnik GMBH (1979, Annex 5, p. 2).

b/ From Table A1.15.

Sources: République de Haute-Volta, Ministere du Plan et de la Cooperation, INSD, Recensement General de la Population, Decembre 1975; resultats definitifs: les donnees departementales, Vol. 2, 1978 (various pages).

Table A1.15. Estimates of Agricultural Work Force by Region, 1975 Population Census, Burkina Faso.

ORD	Total Residents	Estimated c/ Agricultural Work Force	Male Actives Adults +15	Male Actives Children b/ 10-14	Female Actives a/ Adults +15	Female Actives a/ Children b/ 10-14
Centre-Nord	632,285	287,682	142,810	2,205	140,464	2,203
Yatenga	530,192	223,695	108,434	2,320	110,526	2,416
Sahel	354,079	172,008	87,416	1,770	81,145	1,677
Sub-Total	1,516,556	683,386	338,660	6,295	332,135	6,296
Centre	944,706	381,675	189,337	4,462	183,448	4,428
Centre Ouest	788,962	331,401	160,896	3,469	163,435	3,601
Centre Est	404,602	174,020	85,272	1,368	86,000	1,380
Sub-Total	2,138,270	887,096	435,505	9,299	432,883	9,409
Est	407,215	179,159	90,197	2,375	84,307	2,280
Volta-Noire	635,760	278,562	135,917	2,590	137,386	2,669
Hauts Bassins (Includes Comoe)	582,810	203,887	98,254	1,760	101,633	2,240
Bougouriba	357,592	163,591	78,844	1,815	81,023	1,909
Sub-Total	940,402	367,478	177,098	3,575	182,656	4,149
Burkina Faso	5,638,203	2,395,681	1,177,377	24,134	1,169,367	24,803

a/ Total female active workers were estimated by applying the ratio of MW/TM to total female population in a region; where, MW equals total male workers in the primary agricultural sector and TM equals the region's total male population (see footnote d, Appendix 1, Table A1.16. This estimate assumes that the proportion of females employed in agriculture is equivalent to that of men.

b/ The number of male children, ages 10-14, who were actively employed on the farm were taken from census data. The ratio of female children actives to female adult actives is assumed to be the same as that of males.

c/ Total agricultural workforce consists of total male actives employed in crop farming (as reported in the census) and estimates of female actives which were adapted from census data.

Source: Republique de Haute-Volta, Ministere du Plan et de la Cooperation, INSD, Recensement General de la Population, Decembre 1975; resultats definitifs: les donnees departmentales, Vol. 2, 1978 and Principaux Resultats du Recensement de 1975, 1979.

Table A1.16. Size of Resident Population and Workforce Engaged in Agricultural and Non-Agricultural Activities, 1975 Population Census, Burkina Faso.

ORD	Total[a] Residents	Males: Primary Ag. Sector	Males: Other[b] Ag. Sector	Males: Sec. and Tertiary Sectors	Males: Inactives[c]	Females: Primary Ag. Sector	Females: Other Ag. Sector	Females: Sec. and Tertiary Sectors	Females: Domestic[d] Work	Females: Inactives[c]	Indeterminant
Centre Nord	632,285	145,015	7,116	4,092	159,496	5,496	149	351	166,733	140,099	3,738
Yatenga	530,192	110,754	4,555	5,628	138,567	5,654	85	433	127,861	132,940	3,715
Sahel	354,079	89,186	8,807	3,894	80,049	1,570	159	497	98,538	69,340	2,039
Centre	944,706	193,799	3,921	31,803	242,793	7,635	109	3,433	237,953	213,861	9,399
Centre-Ouest	788,962	164,365	4,591	10,363	207,505	5,020	137	684	199,653	190,986	5,658
Centre-Est	404,602	86,640	2,993	4,617	106,570	2,489	41	359	104,737	93,298	2,858
Est	407,215	92,572	7,404	3,936	104,255	3,868	113	397	102,006	89,516	3,148
Volta-Noire	635,760	138,507	6,713	8,584	158,626	2,377	152	602	162,687	152,350	5,162
Hauts Bassins	582,810	100,014	4,976	29,484	147,898	2,247	84	2,530	150,437	141,060	4,080
Bougouriba	357,592	80,659	927	3,803	88,992	1,449	52	255	95,712	83,241	2,492
Burkina Faso	5,638,203	1,201,511	52,003	105,204	1,431,751	37,805	1,081	9,551	1,446,317	1,306,691	42,289

a/ Total residents include those persons, present or absent at the time of census, who normally reside there more than 6 months of the year. Total resident population excludes persons living outside the country (334,715) and visitors and passerbys (174,590). All categories included, total population was estimated at 6,147,508 in 1975.

b/ Other agricultural sectors includes persons listing vegetable gardening, livestock husbandry and forestry as their primary occupation.

c/ Inactives include the retired, unemployed, students, those who are sick and disabled and the young. Children ages 0-9 years make up the largest proportion.

d/ Most women listed domestic work as their principal occupation. No information was sought for secondary activities. As most women in rural areas perform fieldwork, the census greatly underestimates the size of agricultural work force.

Sources: Republique de Haute-Volta, Ministere du Plan et de la Cooperation, INSD, Recensement General de la Population, Decembre 1975; resultats defintifs: les donnees departmentales, vol. 2, 1978 and Principaux Resultats du Recensement de 1975, 1979.

Table A1.17. Quantity of Fertilizer Used by Region, Burkina Faso, 1979-81 Average.

Region	ORD	N.P.K. (Cotton Fertilizer)	Urea	Super Phosphate Plus Simple	Natural Phosphate
		metric tons			
North	Centre Nord	394.5	29.0	0.7 b/	6,762.5 b/
	Yatenga	1,135.0 a/	0.0	1.4 a/	1,150.0 a/
	Sahel	0.0	0.0	0.0	0.0
	Sub-Total	1,529.5	29.0	2.1	7,912.5
Central	Centre	426.7	18.1	9.7	250.0 a/
	Centre-Ouest	904.9	4.3	3.4	12,083.3
	Centre-Est	24.8 b/	23.5 a/	6.9 b/	2,940.0 a/
	Sub-Total	1,356.4	45.9	20.0	15,273.3
East	Est	143.6	40.1	17.7	29,325.0
West	Volta Noire	3,562.7	126.9	14.3 b/	3,800.0 a/
Southwest	Hauts Bassins	4,504.8	237.3	0.0	0.0
	Dougouriba	511.8	18.6	24.2	355.0 b/
	Comoe	698.0 c/	108.9 c/	4.3 c/	0.0
	Sub-Total	5,814.6	364.8	28.5	355.0
Nation	Total	12,406.8	606.7	82.6	56,655.8

a/ One year observation.
b/ Two year average.
c/ Information is unavailable for 1979-1981. Fertilizer data is for 1978.

Source: Ministere du Developpement Rurale, Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81, and 1981/82, (1984), pp. 46, 47.

Table A1.18. Animal Traction Teams Available by Region, Burkina Faso, 1978/79.[a/]

Region	ORD	Pairs of Oxen	Single Oxen	Horse	Donkey
		(Number of Animals Potentially Available)[b/]			
North	Centre Nord[a/]	1,700	174	103	5,250
	Yatenga	4,728	n.a.	1,141	1,851
	Sahel	n.a.	n.a.	n.a.	n.a.
	Sub-Total	6,428	174	1,244	7,101
Central	Centre	1,244	654	895	9,391
	Centre Ouest	866	-	284	3,090
	Centre Est	n.a.	n.a.	n.a.	n.a.
	Sub-Total	2,110	654	1,179	12,481
East	Est[a/]	727	n.a.	n.a.	1.739
West	Volta Noire	7,248	n.a.	349	2,080
Southwest	Hauts Bassins	4,276	n.a.	n.a.	481
	Bougouriba	226	n.a.	n.a.	121
	Comoe	221	n.a.	n.a.	n.a.
	Sub-Total	4,723	n.a.	-	602
National	Total	21,236	828	2,772	24,003

a/ Information for the "Est" and "Centre Nord" regions are for 1979/80 and 1980/81, respectively. The year 1978/79 represented the most common period of data availability across regions.

b/ These are census estimates by each ORD of the number of traction animals available. The number of animal traction teams actually working in agriculture would be less due to animal sickness, use of teams for other purposes, etc. Actual animals working are estimated to be around 90% of those potentially available.

Source: Regional Developpement Organizations (Organismes Regional de Developpement), Annual Reports (Rapport Annuel), Various issues, 1978/79-1980/81.

Table A1.19. Stock of Agricultural Equipment Reported by Region, Burkina Faso, 1978/79.[a]

Region	ORD	Plows[b] and Multi-cultivators	Weeders[c] and Ridgers	Line/Row Tracers	Carts	Chemical Sprayers
		(Number of Units)				
North	Centre Nord[a]	5,687	4,145	2,448	4,094	342
	Yatenga	3,327	2,119	1,087	2,072	28
	Sahel	n.a.	n.a.	n.a.	n.a.	n.a.
	Sub-Total	9,014	6,264	3,535	6,166	370
Central	Centre	607	13,229	n.a.	n.a.	n.a.
	Centre Ouest	540	2,394	24	1,871	492
	Centre Est	n.a.	n.a.	n.a.	n.a.	n.a.
	Sub-Total	1,147	15,623	24	1,871	492
East	Est	1,720	98	747	n.a.	n.a.
West	Volta Noire	7,433	2,356	n.a.	6,443	6,074
Southwest	Hauts Bassins	3,867	n.a.	165	1,690	n.a.
	Bougouriba	398	529	n.a.	308	n.a.
	Comoe	n.a.	n.a.	n.a.	n.a.	n.a.
	Sub-Total	4,265	529	165	1,998	
National	Total	23,579	24,870	4,471	16,478	6,936

a/ Information for the "Centre Nord" ORD are for 1980/81. The year 1978/79 was chosen because it represents the most common year of data availability across regions.

b/ Includes the HV1B, a 9" plow with a 3-tined weeder and a ridger as accessories; HV2B, a multi-cultivator based on a 9" ox plow with chisel points, 5-tined weeder and scarifying and weeding shares as attachments; BM2M, a 9" plow with a 3-tined weeder and ridger for oxen; TOM and HV1A, a 6" donkey plow plus weeding attachments; and a HV2A, a multi-cultivator for a donkey based on a 6" moldboard plow and a 3-tined weeder but no ridger.

c/ Weeders include the "Houe Sine", "Houe Manga", "Triangle HV2", "Cult. HV1" and "Houe Fada".

Source: Regional Developpement Organizations (Organismes Regional de Developpement), Annual Reports (Rapport Annuel), Various issues, 1979/80-1981/82.

Table A1.20. Crop Yield Response to Chemical Fertilizer, On-Farm Trials, Selected Studies, Burkina Faso.

a) Sorghum

Region/Village	Technology	Details	Yield (kg./ha.) Traditional Management	Post Technology	Increase	Reference
North/Djibo	100 kg. (14-23-15)[b]	Local variety	109	249	140	ICRISAT (1982, p. G26)
North/Bangasse	100 kg. (14-25-15)[b] 50 kg. Urea	Manual tillage	406	705	299	SAFGRAD-FSU (1984, p. 13)
Central/Nedogo	100 kg. (14-25-15)[b] 50 kg. Urea	Manual tillage Donkey tillage	430 444	547 604	117 160	SAFGRAD-FSU (1984, p. 13)
Central/Yako Ziniare	100 kg. (14-23-15)[b]	Yako Ziniare	303 245	467 798	164 553	ICRISAT (1982, p. G26)
North, Central, East	100 kg. (14-25-15)[a] 50 kg. Urea	4 villages combined	385	759	374	SAFGRAD-FSU (1983, p. 63)
Central--Ouagadougou, Koudougou	100 kg. (18-35)[b]	Manual tillage Donkey Tillage	830 800	1100 1120	270 320	L'Operation Terroir (1972) Ministere des Affaires Etrangeres (?, p. 34)
Central--Nabitenga, Nakomtenga	100 kg. (15-23-14)[b] *Avg. of 3 Varieties	Local variety New variety*	607 515	1143 1178	536 663	ICRISAT (1981, p. H41)
East/ Diapangou	100 kg. (14-25-15)[b] 50 kg. Urea	Manual tillage Donkey tillage Oxen tillage	363 481 526	719 837 857	356 356 331	SAFGRAD-FSU (1983, p. 13)
West Dissankuy	100 kg. (14-25-15)[a] 50 kg. Urea	Variety-local	1402	1624	222	SAFGRAD-FSU (1984, p. 32)
West Boromo	100 kg. (15-23-14)[b]	Variety-local	443	752	309	ICRISAT (1982, p. G26)

Table A1.20. (Continued)

a) Sorghum

Region/Village	Technology	Details	Yield (kg./ha.) Traditional Management	Post Technology	Increase	Reference
Not Specified	Assume: 100 kg (15-25)c/	3-6 kg. of grain per kg of N plus P_2O_5	-	-	120 to 240	IFDC (1977, p. 21)
Central Saria	100 kg. (14-25-15)b/ 50 kg. Urea	Shallow soils	355	634	279	IRAT (1983, p. 127)
		Deep soils	889	1289	400	
Central Nabitenga Nakomtenga	100 kg. (14-25-15)b/	Local: Bush	532*	936	404	ICRISAT (1980, p. 129)
		Village	606*	1298	692	
		Compound	710*	1155	445	
	*implies local varieties grown on contiguous fields	E35-1: Bush	532*	1106	574	
		Village	606*	1241	635	
		Compound	710*	1421	711	
Central Nabitenga Nakomtenga	100 kg. (15-23-14)b/	Local: Plateau	189	273	84	ICRISAT (1981, p. H43)
		Upper Slope	605	1102	497	
	*Avg. yields of E35-1, 38-3 and CSH5.	Mid Slope	626	1197	571	
		Lower Slope	606	1150	544	
		New Variety* Plateau	231	499	268	
		Upper Slope	449	1090	641	
		Mid Slope	511	1229	718	
		Lower Slope	643	1232	589	

a/ Researcher managed trials on farmers' fields.
b/ Farmer run trials on farmers' fields
c/ Summary of several on-farm trials.

Table A1.20. (Continued)

b) Millet

Region/ Village	Technology	Details	Yield (kilograms) Traditional Management	Post Technology	Increase	Reference
North/Djibo	100 kg. (14-23-15)[b/]	Varieties: Local	184	238	54	ICRISAT (1982, p. G37)
		Souna 3	70	209	139	
North Bangasse	100 kg. Volta phosphate[b/] 50 kg. Urea	Local variety	435	435	0	SAFGRAD-FSU (1983, p. 72)
North Bangasse	100 kg. Volta Phosphate[b/] 50 kg. Urea	Local variety	218	202	-16	SAFGRAD-FSU (1984, p. 9)
North Ouahigouya	100 kg (14-23-15)[b/] 50 kg. Urea	Millet/millet rotation 1981	410	665	255	IRAT(1983, p. 149)
		1982	502	769	267	
Central Nedogo	100 kg. Volta Phosphate[b/] 50 kg. Urea	Local	345	420	75	SAFGRAD-FSU (1982, p. 72)
Central Nedogo	100 kg. Volta Phosphate[b/] 50 kg. Urea	Manual tillage	346	338	-8	SAFGRAD-FSU (1983, p. 9)
		Donkey tillage	354	370	+16	
Central Nakomtenga Nabitenga	100 kg. (15-23-14)[b/]	Local variety	388	456	68	ICRISAT (1981, p. H51)
East Diapangou	100 kg. Volta Phosphate[b/] 50 kg. Urea	Local variety	484	494	10	SAFGRAD-FSU (1982, p. 72)

a/ Researcher managed on-farm trials.
b/ Farmer managed on-farm trials.

Table A1.20. (Continued)

c) Maize

Region/ Village	Technology	Details	Traditional Management	Post Technology	Increase	References
Central Nedogo	100 kg./ha. (14-25-15)[a/] + 50 kg./ha. Urea	Variety Pool 16	926	1266	340	SAFGRAD/FSU (1983, p. 68)
		UST 42	545	549	4	
		Local	1076	823	-253	
Central Nedogo	200 kg. (14-25-15)[a/] + 50 kg. Urea	Variety: Local	600	625	25	SAFGRAD/FSU (1984, p. 24)
		SAFITA 2	337	471	134	
Central/East Nedogo Diapangou	100 kg. (14-25-15)[a/] 50 kg. Urea	Severe drought Aggregate Results for 2 villages	1506	2091	585	SAFGRAD/FSU (1983, p. 61)
North/East Bangasse Diapangou	100 kg. (14-25-15)[a/] 50 kg. Urea	Variety: SAFITA 104	2486	2017	-469	SAFGRAD/FSU (1983, p. 69)
		SAFITA 2	2459	2237	-222	
		Local	2396	2572	176	
East Diapangou	100 kg. (14-25-15)[a/] 50 kg. Urea	Village fields	-	-	600	SAFGRAD/FSU (1983, p. 60)
West Dissankuy	200 kg. (14-25-15)[a/] 50 kg. Urea	Variety: Local	615	739	124	SAFGRAD/FSU (1984, p. 26)
		SAFITA 2	672	920	248	
West Dissankuy	100 kg. (14-25-15)[a/] 50 kg. Urea	Variety: Local	615	748	133	SAFGRAD/FSU (1984, p. 30).

a/ Researcher managed on-farm trials.
b/ Farmer managed on-farm trials.

Table A1.20. (Continued)

d) Groundnuts, Rice and Cotton

Region/ Village	Technology	Details		Traditional Management	Post Technology	Increase	References
Groundnuts							
North Ouahigouya	100 kg. (14-23-15)[b/]	Groundnuts in Millet/Groundnuts rotation	1981:	1262	1366	104	IRAT (1983, p. 149)
			1982:	402	518	116	
East	150 kg. phosphate	Manual tillage		582	648	66	Barrett, et al. (1982, p. 62)
		Animal plowing		582	738	156	
Rice							
Central Kongmassa	50 kg. Urea	Traditional rice on "bas fond"		924	1405	481	L'Operation Terroir, Ministere des Affaires Etrangeres(?, p. 35)
Sigle-Bakan				1870	2720	850	
Yargo							
Cotton							
Central	100 kg. (18-35)[b/]	Manual tillage		490	700	210	L'Operation Terroir (1972) Ministere des Affaires Etrangeres (? , p. 35).
		Animal traction		310	400	90	

a/ Researcher managed on-farm trials.
b/ Farmer managed on-farm trials.

Table A1.21. Area, Production and Yields of Irrigated Paddy, Burkina Faso, 1979-1981 Averages.

	Bottomlands			Perimeter Irrigation		
	Area (ha.)	Production (tons)	Yields[a] (kg./ha.)	Area (ha.)	Production (tons)	Yields (kg./ha.)
North						
Centre Nord	1,666	2,233	1,340	220	982	4,464
Yatenga	269	247	918	58	195	3,362
Sahel	128	45	352	-	-	-
Central						
Centre	2,048	2,413	1,178	268	1,014	3,784
Centre Ouest	3,509	2,481	707	-	-	-
Centre Est	8,179	8,516	1,041	90	270	3,000
East						
Est	262	131	500	133	363	2,729
West						
Volta Noire	4,585	4,738	1,033	-	-	-
Southwest						
Hautes Bassins	4,251	3,499	823	30(1228)[a]	31(9982)[a]	1,042(8129)[a]
Bougouriba	3,063	2,419	790	-	-	-
Comoe	4,293	4,956	1,154	353	1,115	3,159
National	32,253	31,678	982	1,152(1228)	3,970(9982)	3,446(8129)

[a] Figures in parentheses are statistics for double cropped rice in the Vallee du Kou and Plaine de Banzon. Area is total hectares planted in 1st and 2nd crops divided by two to show average size of irrigated area.

Source: Ministere du Developpement Rural, Service de Statistiques Agricoles, "Bulletin de Statistiques Agricoles, Campagnes 1978/79, 1979/80, 1980/81, 1981/82, pp. 58-103.

Table A1.22. Yields of Principal Crops Reported for AVV Villages, Burkina Faso, 1977-79.[a]

AVV Cluster of Villages	Crop Season	Cotton	White Sorghum	Red Sorghum	Maize	Cowpeas
		(kg/ha)				
Linoghin	1977	-	-	-	-	-
	1978	-	-	340	-	710
	1979	940-1000	540	390	590	550
Mogtedo B mbore	1977	-	-	-	800	870
	1978	-	-	-	520	570
	1979	640-1190	900	500	660	780
Bane	1977	-	-	1130	-	380
	1978	-	-	1130	-	780
	1979	1100	700	910	-	730
Kaibo Nord	1977	-	-	540	-	-
	1978	-	-	-	-	-
	1979	-	-	740	1010	450
Kaibo Sud	1977	-	-	1150	730	660
	1978	-	-	590	900	930
	1979	1010	210	650	560	490

a/ The authors report yield information for farms by stage of development (first year, second year and full size farm) and tillage technology (plowed versus non-plowed). The figures reported here represent only the range of yields obtained on fully developed farms with plowing.

Source: J. Murphy and L. H. Sprey, 1980, "The Volta Valley Authority: Socio-Economic Evaluation of a Resettlement Project in Upper Volta," pp. 52-55.

Appendix 2

Yield and Labor Assumptions

Documenting Supply Models in Four Regions

Table A2.1. Crop Activities and Yields Associated with Manual and Animal Traction Technologies, Regional Supply Models.[1/]

a) Northern Region

Type of Land l_ℓ	No.	Crop Mixture x_j^m, x_j^d, x_j^o	Yield-Manual Technologies (kg./ha.) Hand Tillage Y_j^m	Percentage Increase Over Manual Technologies: Donkey Tillage r^d	Oxen Tillage r^o
Swampy lowlands	1	Paddy	800	8	16
Compound land; other highly manured soils	2	Maize	450	8	16
	3	Red Sorghum	520	6	12
	4	White Sorghum	500	6	12
	5	Millet	475	6	12
High quality village and bush fields	6	Maize	250	7	14
	7	R. Sorghum/Cowpeas	410-55	5-7	10-14
	8	White Sorghum	420	5	10
	9	W. Sorghum/Cowpeas	420-55	5-7	10-14
	10	Millet/Cowpeas	400-55	5-7	10-14
	11	W.Sorghum(.50)/Millet(.50)/ Cowpeas	216-206-55	5-5-7	10-10-14
Lower quality village fields	12	White Sorghum	340	5	10
	13	W. Sorghum/Cowpeas	340-40	5-7	10-14
	14	Millet	355	5	10
	15	Millet/Cowpeas	355-40	5-7	10-14
	16	Millet(.75)/W.Sorghum(.25)/ Cowpeas	274-88-40	5-5-7	10-10-14
	17	Fonio	310	-	-
	18	Cotton	365	5	10
	19	Bambara Nuts	315	7	14
	20	Peanuts	390	7	14
Bush Fields	21	Cult.Fallow-Sorghum/Cowpeas	350-42	-	-
	22	Cult.Fallow-Millet/Cowpeas	365-42	-	-
	23	W. Sorghum/Cowpeas	285-25	3-5	6-10
	24	Early Millet/Cowpeas	325-25	3-5	6-10
	25	Early Millet	325	3	6
	26	Late Millet/Cowpeas	295-25	3-5	6-10
	27	Fonio	250	-	-
	28	Cotton	285	3	6
	29	Bambara Nuts	265	5	10
	30	Peanuts	300	5	10

Table A2.1. (Continued)

b) Eastern Region

Type of Land T_ℓ	No.	Crop Mixtures X_j^m, X_j^d, X_j^o	Yield-Manual Technologies (kg./ha.) Hand Tillage y_j^m	Percentage Increase Over Manual Technologies: Donkey Tillage r^d	Percentage Increase Over Manual Technologies: Oxen Tillage r^o
Swampy lowlands	1	Paddy	975	8	16
Compound land; other highly manured soils	2	Maize	1100	8	16
	3	Red Sorghum	925	6	12
	4	White Sorghum	875	6	12
	5	Maize(.80)/W.Sorghum(.20)	906-180	8-6	16-12
High quality village and bush fields	6	Maize	750	7	14
	7	R.Sorghum/Cowpeas	710-85	5-7	10-14
	8	White Sorghum	670	5	10
	9	W.Sorghum/Cowpeas	670-85	5-7	10-14
	10	W.Sorghum(.75)/Millet(.25)	518-162	5-5	10-10
	11	W.Sorghum(.75)/Millet(.25)/ Cowpeas	518-162-85	5-5-7	10-10-14
	12	Millet(.50)/W.Sorghum(.50)/ Cowpeas	324-345-85	5-5-7	10-10-14
Lower quality village fields	13	W.Sorghum(.75)/Millet(.25)	441-131	5-5	10-10
	14	W.Sorghum(.75)/Millet(.25)/ Cowpeas	441-131-65	5-5-7	10-10-14
	15	Millet(.50)/W.Sorghum(.50)/ Cowpeas	263-288-65	5-5-7	10-10-14
	16	Millet/Cowpeas	510-65	5-7	10-14
	17	Soybeans	400	7	14
	18	Cotton	365	5	10
	19	Bambara Nuts	350	7	14
	20	Peanuts	530	7	14
Bush Fields	21	Cult.Fallow-W.Sorghum/ Cowpeas	600-70	-	-
	22	Cult.Fallow-Peanuts	575	-	-
	23	Millet	410	3	6
	24	Millet/Cowpeas	410-45	3-5	6-10
	25	Millet/W. Sorghum	317-98	3-3	6-6
	26	Millet/W.Sorghum/Cowpeas	317-98-45	3-3-5	6-6-10
	27	Soybeans	375	5	10
	28	Cotton	325	3	6
	29	Bambara Nuts	300	5	10
	30	Peanuts	465	5	10

Table A2.1. (Continued)

c) Western Region

Type of Land T_ℓ	No.	Crop Mixture x_j^m, x_j^d, x_j^o	Yield-Manual Technologies (kg./ha.) Hand Tillage y_j^m	Percentage Increase Over Manual Technologies: Donkey Tillage r^d	Oxen Tillage r^o
Swampy lowlands	1	Paddy	990	8	16
Compound land; other highly manured soils	2	Maize	1080	8	16
	3	Red Sorghum	950	6	12
	4	White Sorghum	900	6	12
	5	Maize(.80)/R.Sorghum(.20)	890-196	7-6	14-12
High Quality village and bush fields	6	Maize	850	7	14
	7	Red Sorghum	820	5	10
	8	R.Sorghum/Cowpeas	820/90	5-7	10-14
	9	W. Sorghum	790	5	10
	10	W. Sorghum/Cowpeas	790-90	5-7	10-14
	11	R.Sorghum(.80)/Maize(.20)	675-175	5-7	10-14
Lower quality village fields	12	Red Sorghum	725	5	10
	13	R.Sorghum/Cowpeas	725-70	5-7	10-14
	14	R.Sorghum(.80)/Maize(.20)	597-129	5-7	10-14
	15	White Sorghum	690	5	10
	16	W.Sorghum/Cowpeas	690-70	5-7	10-14
	17	Millet/Cowpeas	650-70	5-7	10-14
	18	W.Sorghum/Millet/Cowpeas	345-325-70	5-5-7	10-10-14
	19	Cotton	745	5	10
	20	Groundnuts	730	7	14
Bush fields	21	Cult.Fallow-W.Sorghum/Cowpeas	700-75	-	-
	22	Cult.Fallow-Groundnuts	665	-	-
	23	White Sorghum	540	3	6
	24	W.Sorghum/Cowpeas	540-50	3-5	6-10
	25	Fonio	400	-	-
	26	Millet	510	3	6
	27	Cotton	550	3	6
	28	Bambara Nuts	510	5	10
	29	Grounduts	625	5	10

Table A2.1. (Continued)

d) Southwest Region (Continued)

Type of Land T_ℓ	No.	Crop Mixture X_j^m, X_j^d, X_j^o	Yield-Manual Technologies (kg./ha.) Hand Tillage Y_j^m	Percentage Increase Over Manual Technologies: Donkey Tillage r^d	Oxen Tillage r^o
Swampy lowlands	1	Paddy	975	8	16
	2	Starchy Root Crops	5500	-	-
Compound land; other highly manured soils	3	Maize	1265	8	16
	4	Red Sorghum	1010	6	12
	5	White Sorghum	960	6	12
	6	Maize(.80)/R.Sorghum(.20)	1042-208	8-6	16-12
High quality village and bush fields	7	Maize	1035	7	14
	8	Maize(.80)/R.Sorghum(.20)	853-176-100	7-5	14-10
	9	Maize(.80)/W.Sorghum(.20)	853-172-100	7-5	14-10
	10	Red Sorghum	855	5	10
	11	R.Sorghum/Cowpeas	855-100	5-7	10-14
	12	White Sorghum	835	5	10
	13	W.Sorghum/Cowpeas	835-100	5-7	10-14
Lower quality village fields	14	R.Sorghum(.80)/Maize(.20)	643-150	5-7	10-14
	15	R. Sorghum	780	5	10
	16	R. Sorghum/Cowpeas	780-80	5-7	10-14
	17	W. Sorghum	765	5	10
	18	W. Sorghum/Cowpeas	765-80	5-7	10-14
	19	Cotton	800	5	10
	20	Groundnuts	780	7	14

Table A2.1. (Continued)

d) Southwest Region

Type of Land T_x	No.	Crop Mixture x_j^m, x_j^d, x_j^o	Yield-Manual Technologies (kg./ha.) Hand Tillage	Percentage Increase Over Manual Technologies Donkey Tillage r^d	Oxen Tillage r^o
Bush fields	21	Cult.Fallow-W.Sorghum/Cowpeas	785-85	-	-
	22	Cult.Fallow-Groundnuts	690	-	-
	23	White Sorghum	625	3	6
	24	W.Sorghum/Cowpeas	625-60	3-5	6-10
	25	Millet	595	3	6
	26	Millet/Cowpeas	595-60	3-5	6-10
	27	Fonio	450	-	-
	28	Cotton	610	3	6
	29	Bambara Nuts	500	5	10
	30	Groundnuts	650	5	10

1/ Source: Information on crop mixtures were adapted from R. Ford, "Subsistence Farming Systems in Semi-Arid Northern Yatenga," 1982 (North); P. D. Kabore, Y. Lebene and P. J. Matlon, "Modeles de Culture dans Trois Zones Agro-Climatiques de Haute Volta," Mars 1983, pp. 30-32 (North, Central, West): R. Singh, E. Kehrberg, and W. H. M. Morris, Small Farm Production Systems in Upper Volta: Descriptive and Production Function Analysis, 1983, p. 21 (North, Central); G. Lassiter, "Cropping Enterprises in Eastern Upper Volta," 1981, pp. 27-40 (East): and J. McIntire, "Sondages de Reconnaisance au Nord et a L'Ouest de la Haute Volta," 1982, p. 17 (West and Southwest). Yield levels were derived from on-farm yield measurements reported in various agro-economic studies (see Appendix 1, Tables A1.20 and A1.21 for a synthesis of these data) and macro-level production statistics (Table 2.3 in Chapter II and Appendix 1, Table A1.5).

Table A2.2. Total Labor Requirements for Principal Crop Mixtures, Traditional Technologies, Regional Supply Models.

a) Northern Region

No.	Crop Mixture	Bush Fields $\ell=1$	Lower Quality Village Fields $\ell=2$	Higher Quality Village & Bush Fields $\ell=3$	Swampy Low-lands and Compound Soils $\ell=4,5$
		(Total Hours/Hectare, $\sum_{i=1}^{10} A^{m}_{ij\ell}$)[a/]			
1	Paddy				1150
2	Maize			630	725
3	Red Sorghum				600
4	R.Sorghum/Cowpeas			525	
5	White Sorghum		399	467	600
6	W.Sorghum/Cowpeas	395	450	525	
7	W.Sorghum/Millet/Cowpeas			525	
8	Cult.Fallow-W. Sorghum	380			
9	Cult.Fallow-Millet	380			
10	Millet	349	399		600
11	Early Planted Millet/Cowpeas	395	450	525	
12	Late Planted Millet/Cowpeas	375			
13	Millet/W.Sorghum/Cowpeas		450		
14	Fonio	325	350		
15	Cotton	490	540		
16	Groundnuts	540	580		
17	Bambara Nuts	560	600		

a/ Total labor includes unweighted time worked by family members on land preparation through second weeding activities. It excludes time spent manuring and clearing of fields in the off-season and harvesting.

Source: This information was adapted from various agro-economic studies of labor flows on cropping operations in Burkina-Faso. See Table 5.6, in Chapter V, for a synthesis of these supporting data.

Table A2.2. (Continued)

b) Eastern Region

No.	Crop Mixture	Bush Fields $\ell=1$	Lower Quality Village Fields $\ell=2$	Higher Quality Village and Bush Fields $\ell=3$	Low Lying Areas and Compound Soils $\ell=4$
		(Total Hours/Hectare, $\sum_{i=1}^{10} A^{m}_{i,\ell}$)[a/]			
1	Paddy				1280
2	Maize			700	800
3	Red Sorghum				750
4	Red Sorghum/Cowpeas			675	
5	White Sorghum			605	750
6	White Sorghum/Cowpeas			675	
7	Maize/White Sorghum				
8	White Sorghum/Millet		505	605	
9	White Sorghum/Millet/Cowpeas		560	675	
10	Cult.Fallow-W. Sorghum	435			
11	Cult.Fallow-Groundnuts	530			
12	Millet	400			
13	Millet/Cowpeas	450	560		
14	Millet/W. Sorghum	400			
15	Millet/W.Sorghum/Cowpeas	450	560	675	
16	Soybeans	760	870		
17	Cotton	550	625		
18	Bambara Nuts	580	660		
19	Groundnuts	565	645		

a/ Total labor includes unweighted time worked by family members on land preparation through second weeding activities. It excludes time spent manuring and clearing of fields in the off-season and harvesting.

Source: This information was adapted from various agro-economic studies of labor flows on cropping operations in Burkina Faso. See Table 5.6, in Chapter V, for a synthesis of these supporting data.

Table A2.2. (Continued)

c) Western Region

No.	Crop Mixture	Bush Fields $\ell=1$	Lower Quality Village Fields $\ell=2$	Higher Quality Village and Bush Fields $\ell=3$	Low Lying Areas and Compound Soils $\ell=4$
		(Total Hours/Hectare, $\sum_{i=1}^{10} A^{m}_{ij\ell}$)[a/]			
1	Paddy				1280
2	Maize			710	725
3	Maize/R. Sorghum				830
4	Red Sorghum		505	610	750
5	R.Sorghum/Cowpeas		585	680	
6	R.Sorghum/Maize		550	660	
7	White Sorghum	425	505	610	750
8	W.Sorghum/Cowpeas		585	680	
9	W.Sorghum/Millet/Cowpeas		615		
10	Millet/Cowpeas		585		
11	Cult.Fallow-W.Sorghum/Cowpeas	430			
12	Cult.Fallow-Groundnuts	525			
13	Early W. Sorghum/Cowpeas	480			
14	Late W. Sorghum/Cowpeas	450			
15	Fonio	410			
16	Millet	425			
17	Cotton	555	640		
18	Bambara Nuts	595			
19	Groundnuts	580	635		

a/ Total labor includes unweighted time worked by family members on land preparation through second weeding activities. It excludes time spent manuring and clearing of fields in the off-season and harvesting.

Source: This information was adapted from various agro-economic studies of labor flows on cropping operations in Burkina Faso. See Table 5.6, in Chapter V, for a synthesis of these supporting data.

Table A2.2. (Continued)

d) Southwest Region

No.	Crop Mixture	Bush Fields $\ell=1$	Lower Quality Village Fields $\ell=2$	Higher Quality Village and Bush Fields $\ell=3$	Low Lying Areas and Compound Soils $\ell=4$
		(Total Hours/Hectare, $\sum_{i=1}^{10} A^{m}_{ij\ell}$)[a/]			
1	Paddy				1280
2	Maize			680	750
3	Maize/R.Sorghum			705	799
4	Maize/W.Sorghum			705	
5	Starchy Root Crops				800
6	Red Sorghum		530	630	775
7	R.Sorghum/Cowpeas		600	700	
8	R.Sorghum/Maize		565		
9	White Sorghum	435	530	630	775
10	W.Sorghum/Cowpeas	500	600	700	
11	Cult.Fallow-W.Sorghum/Cowpeas	470			
12	Cult.Fallow-Groundnuts	550			
13	Millet	435			
14	Millet/Cowpeas	500			
15	Fonio	430			
16	Cotton	585	655		
17	Bambara Nuts	550			
18	Groundnuts	600	650		

a/ Total labor includes unweighted time worked by family members on land preparation through second weeding activities. It excludes time spent manuring and clearing of fields in the off-season and harvesting.

Source: This information was adapted from various agro economic studies of labor flows on cropping operations in Burkina Faso. See Table 5.6, Chapter V, for a synthesis of these supporting data.

Table A2.3. Agricultural Labor Calendars of Field Crop Operations, Regional Supply Models.

a) Northern Region[1/] [3/]

Constraint Number	Time Period	Millet[b/]	White Sorghum[a/]	Paddy	Maize	Ground-nuts	Bambara Nuts	Cotton	Fonio
		(Percent of Total Agricultural Labor)[2/]							
1	May 3-June 6	11.6	14.7	47.0	-	-	-	-	-
2	June 7-20	4.0	23.4	19.8	-	-	-	-	20.0
3	June 21-27	10.7	6.9		17.1	-	16.6	-	12.0
4	June 28-July 4	1.6	5.3	1.2	31.5	17.5	37.1	5.6	4.0
5	July 5-11	5.3	10.0	-	2.8	30.0	9.6	5.6	4.0
6	July 12-18	18.9	8.4	4.3	1.3	1.5	2.0	8.2	20.0
7	July 19-25	3.9	1.3	5.8	11.0	0.3	2.6	8.2	20.0
8	July 26-Aug. 1	10.6	3.0	-	24.6	7.4	-	18.2	10.0
9	Aug. 2-22	18.9	20.9	13.2	6.9	24.8	13.7	30.6	10.0
10	Aug. 23-Sept. 12	14.5	6.1	8.7	4.8	18.5	18.4	23.6	-

a/ The calendar for white sorghum is used to schedule labor activities for all sorghum and millet mixtures on compound land and high quality village and bush fields.

b/ The calendar for millet is used for all millet and sorghum mixtures on lower quality village and bush fields.

Table A2.3. (Continued)

a) Northern Region (Continued) 3/

Constraint Number	Time Period	Observations
1	May 3-June 6	Planting of millet and white sorghum commence with the onset of rains, gathering intensity towards the period's end. Land preparation and planting of rice are performed.
2	June 7-13	Planting of millet and white sorghum continue while first weeding of earlier planted sorghum begins. Land preparation and planting of rice near completion.
3	June 14-20	Emphasis is given to first weeding of white sorghum. Some sowing of millet and white sorghum is done.
4	June 21-27	A concerted effort is made to till and plant maize and bambara nut fields. Late planting of millet and white sorghum continue. First weeding of millet begins while weeding continues on sorghum fields.
5	June 28-July 4	Land preparation and planting activities are intense for maize and bambara nuts, but just begin for groundnuts. Planting of millet and white sorghum terminate while some first weeding continues.
6	July 5-11	Emphasis is given to first weeding of millet and white sorghum. Land preparation and planting slows for bambara nuts but gains intensity for groundnuts.
7	July 12-18	Late plantings of groundnuts and bambara nuts are performed. First weeding of rice begins while continuing on principal cereal fields. Second weeding of white sorghum begins.
8	July 19-Aug. 1	First weeding of maize receives heavy emphasis. Some first weeding of millet and rice and second weeding of white sorghum is performed. Second weeding of millet starts.
9	Aug. 2-22	Some first weeding of millet and maize is done though major emphasis is placed on second weeding of principal cereals. First weeding of groundnuts, rice and bambara nut fields continue.
10	Aug. 23-Sept. 12	First weeding of groundnuts, bambara nuts and rice and second weedings of millet, white sorghum and maize terminate.

Table A2.3. (Continued)

b) Eastern Region[1/] [4/]

Constraint	Time Period	White[a/] Sorghum	Millet/[b/] White Sorghum	Millet[c/]	Maize	Pea-nuts	Bambara Nuts	Soy-beans	Cotton	Trad. Rice
		(Percent of Total Seasonal Labor per Hectare)[2/]								
1	May 1-June 6	12.9	12.8	11.1	-	-	-	-	-	19.2
2	June 7-13	9.9	7.4	10.4	-	-	-	-	-	22.7
3	June 14-20	2.5	11.9	10.7	2.0	-	-	-	-	6.8
4	June 21-27	7.9	7.5	8.7	19.3	-	13.1	-	3.0	9.9
5	June 28-July 4	8.1	6.3	1.1	22.4	6.8	16.8	9.8	8.2	5.6
6	July 5-11	10.6	9.4	2.9	8.3	9.5	4.7	7.4	8.2	0.4
7	July 12-18	3.6	5.9	16.4	11.3	21.0	7.9	12.4	8.2	1.4
8	July 19-Aug. 1	9.8	10.3	20.0	16.0	20.1	25.6	21.3	18.2	8.4
9	Aug. 2-22	20.8	18.1	12.0	12.8	25.6	19.5	31.8	30.6	14.5
10	Aug.23-Sept. 20	13.9	10.4	6.7	7.9	17.0	12.5	17.3	23.6	11.1

a/ The calendar for white sorghum is used to schedule labor activities for all millet and sorghum mixtures on compound and higher quality village and bush fields.

b/ The calendar for millet/white sorghum is used for all millet and sorghum mixtures on lower quality village and bush fields.

c/ The calendar for millet is used strictly for millet cultivated in sole stands on the poorest fields.

Table A2.3. (Continued)

b) Eastern Region (Continued)[4/]

Constraint Number	Time Period	Observations
1	May 1-June 6	Planting begins on millet, sorghum and especially millet/sorghum "association" fields. Planting activities become particularly intense towards the period's end. Land preparation and planting of rice are also performed.
2	June 7-13	Planting continues of sorghum, millet, "associations" and rice fields. First weeding begins on early planted crops.
3	June 14-20	Some planting of major cereals and rice continue to occur. Emphasis is given to first weeding of "association" fields though some weeding of sole cropped millet, sorghum and rice is also done.
4	June 21-27	The emphasis continues on first weeding of association fields; planting of sorghum resumes with intensity. Planting of millet ends. First weeding of earlier planted millet, sorghum and rice progresses (with some planting of rice) while the work begins on preparing land and planting of maize and bambara nuts.
5	June 28-July 4	Planting of sorghum and rice continue along with some first weeding of all cereals. A concerted effort is made to get maize planted; less attention is given to planting of soybeans, groundnuts and bambara nuts.
6	July 5-11	Some planting of sorghum still occurs. First weeding of major cereals continue. Weeding of maize commences while planting of groundnuts, soybeans and bambara nuts proceed.
7	July 12-18	First weeding is performed on millet, sorghum, "associations", rice and maize. Emphasis is given to planting of groundnuts and soybeans and to a lesser degree, bambara nuts. Second weeding begins of earlier planted cereals.
8	July 19-Aug. 1	The principle cereals, maize and rice continue to be weeded. Planting of groundnuts, soybeans and bambara nuts still take place while first weeding of earlier plantings begin.
9	Aug. 2-22	First weeding of cereals is finished with the exception of rice. Second weeding is continued. The last of the groundnuts and soybeans are planted; first weeding (including that on bambara nuts) continues.
10	Aug. 23-Sept. 20	First and second weedings of all cereals, groundnuts, soybeans and bambara nuts are finished. Some third weedings of earlier planted "association" fields are done.

Table A2.3. (Continued)

c) Western Region[5/]

Constraint No.	Estimated Time Period	R.[a/] Sorghum	W.[b/] Sorghum	W. Sorghum & Millet[c/]	Maize (Compound)	Maize[d/] (Outlying Soils)	Peanuts	Bambara Nuts	Cotton	Trad. Rice	Fonio
		(Percent of Total Agricultural Labor)[2/]									
1	May 1-June 6	20.0	18.4	18.4	-	-	6.9	-	-	19.2	-
2	June 7-20	9.2	3.4	3.8	-	-	7.4	-	-	22.7	19.0
3	June 21-27	7.1	10.3	5.5	19.3	2.0	9.0	16.6	-	6.8	11.5
4	June 28-July 4	8.8	6.7	5.7	14.9	19.3	10.6	37.1	5.5	9.9	6.1
5	July 5-11	4.3	11.5	8.3	12.1	22.4	21.7	9.6	5.6	5.6	6.1
6	July 12-18	3.5	1.1	12.7	1.4	8.3	-	2.0	8.2	0.4	18.3
7	July 19-25	3.4	0.8	10.8	12.1	11.3	2.0	2.6	8.2	1.4	19.3
8	July 26-Aug. 1	16.1	8.8	7.5	27.2	16.0	11.3	-	18.2	8.4	9.8
9	Aug. 2-22	18.6	30.9	17.5	7.6	12.8	26.9	13.7	30.6	14.5	9.8
10	Aug. 23-Sept. 12	9.0	8.1	10.1	5.2	7.9	3.8	18.4	23.6	11.1	-

a/ The calendar for red sorghum is used to schedule labor activities for all sorghum mixtures on compound land and higher quality village and bush fields.

b/ The calendar for white sorghum is used for all sorghum and millet mixtures on lower quality village fields.

c/ The calendar for white sorghum and millet is used to schedule labor activities on all sorghum and millet mixtures on bush fields.

d/ The calendar for early planted maize incorporates harvesting labor.

Table A2.3. (Continued)

d) Southwest Region[5/]

Constraint	Estimated Time Period	R.[a/] Sorghum	W.[b/] Sorghum	W. Sorghum & Millet[c/]	Maize (Compound)	Maize[d/] (Outlying Soils)	Peanuts	Cotton	Bambara Nuts	Starchy Root Crops	Fonio	Trad. Rice
		(Percent of Total Agricultural Labor)[2/]										
1	April 1-May 16	20.0	18.4	18.4	-	42.3	6.9	-	-	2.7	-	19.2
2	May 17-25	9.2	3.4	3.8	-	13.1	7.4	-	-	0.6	19.0	22.7
3	May 26-June 3	7.1	10.3	5.5	2.0	13.1	9.0	-	16.6	0.6	11.5	6.8
4	June 4-12	8.8	6.7	5.7	19.3	8.7	10.6	5.6	37.1	3.3	6.1	9.9
5	June 13-21	4.3	11.5	8.3	22.4	8.7	21.7	5.6	9.6	3.3	6.1	5.6
6	June 22-30	3.5	1.1	12.7	8.3	4.5	-	8.2	2.0	9.4	18.3	0.4
7	July 1-9	3.4	0.8	10.7	11.3	4.5	2.0	8.2	2.6	9.4	19.3	1.4
8	July 10-27	16.1	8.8	7.5	16.0	1.7	11.3	18.2	-	18.6	9.8	8.4
9	July 28-Aug. 22	18.6	30.9	17.5	12.8	3.3	26.9	30.6	13.7	7.8	9.8	14.5
10	Aug.23-Sept. 27	9.0	8.1	10.1	7.9	-	3.8	23.6	18.4	44.4	-	11.1

a/ The calendar for red sorghum is used to schedule labor activities for all sorghum mixtures on compound land and higher quality village and bush fields.

b/ The calendar for white sorghum is used for all sorghum and millet mixtures on lower quality village fields.

c/ The calendar for white sorghum and millet is used to schedule labor activities on all sorghum and millet mixtures on bush fields.

d/ The calendar for early planted maize incorporates harvesting labor.

Table A2.3. (Continued)

1/ The labor calendar (Table 2.3) combined with seasonal labor estimates (Table 2.2) were used to compute labor flows for traditional technologies (manual tillage, no modern inputs) in respective supply models. The calendars were derived from farm level data which reflect weather anamolies and gross aggregation across soil types and management practices. In the actual formulation of labor constraints, adjustments had to be made to labor-output coefficients in disaggregating labor flows across land types and technologies. Hence, the calendars provided here represent only an aggregate overview of timing of operations by crop. Comparisons with crop budgets developed by Delgado (1978), Ford (1982), Lassiter (1981), ICRISAT (1980) and Singh (1983) facilitated the generalization of farm level labor budgets to the sectoral level.

2/ Total hours implicit in the agricultural calendar includes only time spent from land preparation at planting through field cultivation and weeding. Time spent performing off-season fieldwork (i.e., land clearing and manuring) and harvesting lay outside the calendar's time frame.

3/ The agricultural labor calendar for all crops except cotton, fonio, and irrigated rice was taken from data collected by SAFGRAD-FSU for the village of Bangasse, near Kaya, 1982. The calendar for fonio is constructed based on the assumptions of a 55-65 day growing cycle, low labor inputs and planting times coincident with millets and sorghums (Ford, 1982, p. 506). The figures for cotton are adapted from a calendar reported by Delgado (1978b, p. 19) for the Tenkodogo region.

4/ The agricultural labor calendar for all crops except cotton and irrigated rice were taken from data collected by SAFGRAD-FSU for the village of Diapangou, near Fada N'Gourma, 1982. The figures for cotton and scheme irrigated rice were interpolated from data collected in the eastern ORD (see Lassiter, 1981, p. 23).

5/ No labor calendars of field crop operations, based on actual on-farm data, could be located by the author for the west and southwest regions of the country. Labor calendars for these regions were adaopted from those empirically estimated for the north, central and east regions of the country, above.

Table A2.4. Crop Activities and Yields Associated with Fertilizer Technologies, Regional Supply Models.[a]

a) Northern Region

Land Type	Crop:	Fertilizer-Tillage (kilograms)	Kg. Cereals[b] per Kg. $N + P_2O_5$	Yield Y_j^f	Abs. Increase[c] Over Base Yields, y_j^f
			(Fertilizer Yield Response Functions)		
Compound Land	Maize:	50 - Hand	3.5	514	64
		100 - Hand	3.3	572	122
		150 - Hand	3.2	625	175
		100 - Donkey	3.3	608	122
		100 - Oxen	3.3	644	122
	White Sorghum:	50 - Hand	4.5	583	83
		100 - Hand	4.3	658	158
		150 - Hand	4.1	725	225
		100 - Donkey	4.3	688	158
		100 - Oxen	4.3	718	158
High Quality Village and Bush Fields	W.Sorghum/ Cowpeas:	50 - Hand	5.2	517-64	97-9
		100 - Hand	5.0	605-72	185-17
		150 - Hand	4.8	685-80	265-25
		100 - Donkey	5.0	626-76	185-17
		100 - Oxen	5.0	647-80	185-17
	Millet/ Cowpeas:	50 - Hand	4.3	479-64	79-9
		100 - Hand	4.1	550-72	150-17
		150 - Hand	3.9	615-80	215-25
		100 - Donkey	4.1	570-76	150-17
		100 - Oxen	4.1	590-80	150-17

Table A2.4. (Continued)

a) Northern Region (Continued)

Land Type	Crop:	Fertilizer-Tillage (kilograms)	Kg. Cereals[b] per Kg. $N + P_2O_5$	Yield Y_j^f	Abs. Increase[c] Over Base Yields, y_j^f
		(Fertilizer Yield Response Function)			
Lower Quality Village Fields	Cotton:	50 - Hand	4.6	451	86
		100 - Hand	4.4	529	164
		150 - Hand	4.2	600	235
		100 - Donkey	4.4	547	164
		100 - Oxen	4.4	566	164
	Peanuts:	50 - Hand	3.0	446	56
		100 - Hand	2.8	493	103
		150 - Hand	2.5	530	140
		100 - Donkey	2.8	520	103
		100 - Oxen	2.8	548	103
	W.Sorghum/ Cowpeas	50 - Hand	3.9	412-46	72-6
		100 - Hand	3.5	470-52	120-12
	Millet/ Cowpeas	50 - Hand	3.6	421-46	66-6
		100 - Hand	3.2	475-52	120-12
Bush Fields	Millet/ Cowpeas	50 - Hand	1.7	356-28	31-3
		100 - Hand	1.6	385-31	60-6
Improved Lowlands	Rice	50 - Hand	10.7	1148	-
		100 - Hand	10.3	1330	-
		150 - Hand	9.9	1500	-
Scheme Irrigation	Rice[d]	100 - Hand	16.0	3410	-
		150 - Hand	15.5	3845	-
		200 - Hand	15.0	4250	-

Table A2.4. (Continued)

b) Eastern Region

Land Type	Crop:	Fertilizer-Tillage (kilograms)	(Fertilizer Yield Response Function) Kg. Cereals[b] per Kg. $N + P_2O_5$	Yield Y_j^f	Abs. Increase[c] Over Base Yield, y_j^f
Compound Land	Maize:	50 - Hand	7.6	1240	140
		100 - Hand	7.2	1365	265
		150 - Hand	6.8	1475	375
		100 - Donkey	7.2	1453	265
		100 - Oxen	7.2	1541	265
	White Sorghum:	50 - Hand	6.1	987	112
		100 - Hand	5.7	1087	212
		150 - Hand	5.4	1175	300
		100 - Donkey	5.7	1140	212
		100 - Oxen	5.7	1192	212
High Quality Village and Bush Fields	Maize:	50 - Hand	9.6	927	177
		100 - Hand	9.1	1086	336
		150 - Hand	8.6	1225	475
		100 - Donkey	9.1	1139	336
		100 - Oxen	9.1	1191	336
	W.Sorghum/ Cowpeas:	50 - Hand	7.4	806	136-17
		100 - Hand	7.0	928	258-32
		150 - Hand	6.6	1035	365-45
		100 - Donkey	7.0	962	258-32
		100 - Oxen	7.0	995	258-32
Lower Quality Village Fields	W.Sorghum/ Millet/ Cowpeas:	50 - Hand	5.8	518-161-78	77-30-13
		100 - Hand	5.5	586-188-90	145-57-25
		150 - Hand	5.1	646-211-100	205-80-35
		100 - Donkey	5.5	608-195-95	145-57-25
		100 - Oxen	5.5	630-201-99	145-57-25
	Soybeans:	50 - Hand	4.5	484	84
		100 - Hand	4.3	559	159
		150 - Hand	4.1	625	225
		100 - Donkey	4.3	587	159
		100 - Oxen	4.3	615	159

Table A2.4. (Continued)

b) Eastern Region (Continued)

Land Type	Crop:	Fertilizer-Tillage (kilograms)	Kg. Cereals[b] Per Kg. $N + P_2O_5$	Yield Y_j^f	Abs. Increase[c] Over Base Yields, Y_j^f
		(Fertilizer Yield Response Functions)			
Lower Quality Village Fields	Cotton:	50- Hand	6.4	483	118
		100- Hand	6.0	588	223
		150- Hand	5.7	680	315
		100- Donkey	6.0	606	223
		100- Oxen	6.0	625	223
	Peanuts:	50- Hand	3.5	595	65
		100- Hand	3.4	654	124
		150- Hand	3.2	705	175
		100- Donkey	3.4	691	124
		100- Oxen	3.4	728	124
	Millet/ Cowpeas:	50- Hand	4.7	597	87-13
		100 Hand	4.5	675	165-25
Bush Fields	Millet/ Cowpeas:	50- Hand	3.1	468	58-6
		100- Hand	3.0	520	110-12
	Millet/ W.Sorghum/ Cowpeas:	50- Hand	3.3	357-119-52	40-21-7
		100- Hand	3.1	392-138-57	75-40-12
Improved Lowland	Rice:	50- Hand	11.6	1190	-
		100- Hand	11.2	1390	-
		150- Hand	10.8	1575	-
Scheme Irrigation	Rice:[d]	100- Hand	15.5	2430	-
		150- Hand	15.0	2650	-
		200- Hand	14.5	3250	-

Table A2.4. (Continued)

c) Western Region

Land Type	Crop:	Fertilizer-Tillage (kilograms)	Kg. Cereals[b] per Kg. $N + P_2O_5$	Yield Y_i^f	Abs. Increase[c] Over Base Yields, y_j^f
		(Fertilizer Yield Response Functions)			
Compound Land	Maize:	50 - Hand	7.1	1212	132
		100 - Hand	6.8	1333	253
		150 - Hand	6.5	1441	361
		100 - Donkey	6.8	1419	253
		100 - Oxen	6.8	1506	253
	Red Sorghum:	50 - Hand	6.6	1072	122
		100 - Hand	6.3	1183	233
		150 - Hand	6.0	1283	333
		100 - Donkey	6.3	1240	233
		100 - Oxen	6.3	1297	233
	White Sorghum:	50 - Hand	6.4	1018	118
		100 - Hand	6.1	1125	225
		150 - Hand	5.8	1222	322
		100 - Donkey	6.1	1179	225
		100 - Oxen	6.1	1233	225
High Quality Village and Bush Fields	Maize:	50 - Hand	7.1	982	132
		100 - Hand	6.8	1103	253
		150 - Hand	6.5	1211	361
		100 - Donkey	6.8	1163	253
		100 - Oxen	6.8	1222	253
	R.Sorghum/ Cowpeas:	50 - Hand	7.5	958	138-15
		100 - Hand	7.1	1084	264-28
		150 - Hand	6.8	1197	377-40
		100 - Donkey	7.1	1125	264-28
		100 - Oxen	7.1	1166	264-28
	W.Sorghum/ Cowpeas:	50 - Hand	7.4	926	136-15
		100 - Hand	7.0	1050	260-28
		150 - Hand	6.7	1162	372-40
		100 - Donkey	7.0	1090	260-28
		100 - Oxen	7.0	1129	260-28

Table A2.4. (Continued)

c) Western Region (Continued)

Land Type	Crop:	Fertilizer-Tillage (kilograms)	(Fertilizer Yield Response Functions) Kg. Cereals[b] per Kg. $N + P_2O_5$	Yields Y_j^f	Abs. Increase[c] Over Base Yields, y_j^f
Lower Quality Village Fields	Cotton:	50 - Hand	8.3	898	153
		100 - Hand	7.9	1036	291
		150 - Hand	7.5	1161	416
		100 - Donkey	7.9	1073	291
		100 - Oxen	7.9	1111	291
	Peanuts:	50 - Hand	4.3	809	79
		100 - Hand	4.0	879	149
		150 - Hand	3.8	941	211
		100 - Donkey	4.0	930	149
		100 - Oxen	4.0	981	149
	W.Sorghum/ Cowpeas:	50 - Hand	6.1	802-81	112-11
		100 - Hand	5.8	903-91	213-21
		150 - Hand	5.5	995-100	305-30
		100 - Donkey	5.8	938-96	213-21
		100 - Oxen	5.8	972-101	213-21
Bush Fields	Cotton:	50 - Hand	7.7	693	143
		100 - Hand	7.4	822	272
		150 - Hand	7.0	939	389
		100 - Donkey	7.4	839	272
		100 - Oxen	7.4	855	272
	W. Sorghum:	50 - Hand	5.3	637	97
		100 - Hand	5.0	725	185
Improved Lowlands	Rice:	50 - Hand	11.6	1205	-
		100 - Hand	11.2	1405	-
		150 - Hand	10.8	1590	-

Table A2.4. (Continued)

d) Southwest Region

Land Type	Crop:	Fertilizer-Tillage (kilograms)	Kg. Cereals[b] per Kg. $N + P_2O_5$	Yield Y_j^f	Abs. Increase[c] Over Base Yields, y_j^f
		(Fertilizer Yield Response Functions)			
Compound Land	Maize:	50 - Hand	8.6	1425	160
		100 - Hand	8.3	1573	308
		150 - Hand	8.0	1709	444
		100 - Donkey	8.3	1674	308
		100 - Oxen	8.0	1775	308
	Red Sorghum:	50 - Hand	6.7	1134	124
		100 - Hand	6.5	1249	239
		150 - Hand	6.2	1354	344
		100 - Donkey	6.5	1310	239
		100 - Oxen	6.5	1370	239
	White Sorghum:	50 - Hand	6.5	1080	120
		100 - Hand	6.2	1191	231
		150 - Hand	6.0	1293	333
		100 - Donkey	6.2	1249	231
		100 - Oxen	6.2	1306	231
High Quality Village and Bush Fields	Maize:	50 - Hand	9.7	1215	180
		100 - Hand	9.4	1382	347
		150 - Hand	9.0	1535	500
		100 - Donkey	9.4	1454	347
		100 - Oxen	9.4	1527	347
	Maize/ R.Sorghum:	50 - Hand	9.3	997-208	144-28
		100 - Hand	9.0	1131-234	278-54
		150 - Hand	8.7	1253-258	400-78
		100 - Donkey	9.0	1191-243	278-54
		100 - Oxen	9.0	1250-252	278-54
	R.Sorghum/ Cowpeas:	50 - Hand	7.6	1015	140-16
		100 - Hand	7.3	1145	270-31
		150 - Hand	7.0	1264	389-45
		100 - Donkey	7.3	1189	270-31
		100 - Oxen	7.3	1233	270-31
	W.Sorghum/ Cowpeas:	50 - Hand	7.5	973-116	138-16
		100 - Hand	7.2	1101-131	266-31
		150 - Hand	6.9	1218-145	383-45
		100 - Donkey	7.2	1143-138	266-31
		100 - Oxen	7.2	1185-145	266-31

Table A2.4. (Continued)

d) Southwest Region (Continued)

Land Type	Crop:	Fertilizer-Tillage (kilograms)	Kg. Cereals[b] per Kg. $N + P_2O_5$	Yield Y_j^f	Abs. Increase[c] Over Base Yields, y_j^f
		(Fertilizer Yield Response Functions)			
Lower Quality Village Fields	Cotton:	50 - Hand	8.3	954	154
		100 - Hand	8.0	1096	296
		150 - Hand	7.7	1227	427
		100 - Donkey	8.0	1136	296
		100 - Oxen	8.0	1176	296
	Peanuts:	50 - Hand	4.3	860	80
		100 - Hand	4.2	934	154
		150 - Hand	4.0	1002	222
		100 - Donkey	4.2	898	154
		100 - Oxen	4.2	1043	154
	W.Sorghum/ Cowpeas:	50 - Hand	6.2	879-93	114-13
		100 - Hand	5.9	984-104	219-24
		150 - Hand	5.7	1081-115	316-35
		100 - Donkey	5.9	1022-110	219-24
		100 - Oxen	5.9	1061-115	219-24
Bush Fields	Cotton:	50 - Hand	7.8	754	144
		100 - Hand	7.5	887	277
		150 - Hand	7.2	1010	400
		100 - Donkey	7.5	905	277
		100 - Oxen	7.5	924	277
	W.Sorghum:	50 - Hand	5.4	725	100
		100 - Hand	5.2	817	192
Improved Lowlands	Rice:	50 - Hand	11.6	1205	-
		100 - Hand	11.3	1410	-
		150 - Hand	11.0	1600	-
Scheme Irrigation	Single Crop Rice:[d]	100 - Hand	15.8	2148	-
		150 - Hand	15.4	2586	-
		200 - Hand	15.0	3000	-
	Double Crop Rice:[d]	200 - Hand	15.8	2*(3198)	
		300 - Hand	15.4	2*(3636)	
		400 - Hand	15.0	2*(4050)	

Table A2.4. (Continued)

a/ Yield response figures for fertilizer activities were derived from on-farm fertilizer trials. A synthesis of farm level fertilizer research is reported in Appendix 1, Table A1.20 and World Bank (1981, p. 78). Yield information for rice irrigation was taken from official government statistics (see Appendix 1, Table A1.21). The yield response functions to fertilizer are assumed to exhibit diminishing returns.

b/ These response rates show yields of cereals per kilogram of Nitrogen plus P_2O_5 applied per hectare for sake of comparison with World Bank (1981, p. 78) and IFDC (1977, pp. 20-24) reporting methods.

c/ Yield response rates are based on the application of a mixed N.P.K. fertilizer (14-23-14) adapted for cotton. It also contains small quantities of sulphur and baracine. The label "Maize: 50-hand" implies that 50 kilograms of cotton fertilizer are applied per hectare of maize which is cultivated manually.

d/ Irrigated rice under scheme management receives an application of Urea (46-0-0) in addition to the cotton mixed fertilizer. It is applied at half the rate of cotton fertilizer. Yield response figures calculated per kilogram of N plus P_2O_5 are adjusted for the additional nitrogen application.

Appendix 3

Formulas for Estimating Labor Requirements of Traction Animals in Chapter V

Labor requirements for donkey and oxen teams are required in the model because, unlike mechanization with tractors, animals have limited endurance. Data are required on labor requirements by the animal traction team, exclusive of human labor. These data are not easily or directly obtained from the literature. Labor requirements must be estimated indirectly from technical data on animal traction performance.

Methodology

A donkey traction unit is generally operated by 1 male adult and 1 child helping to guide the animal. An oxen unit generally employs 1 male adult with 1 to 2 children serving as guides. Children are assumed to be equally as effective as adults in guiding the animals, but have less endurance when performing manual tillage. Hence, the labor intensity of children, increases when working with traction teams.

Suppose the total active work force of the household is comprised of MW male workers, FW female workers, and CW child workers. Let MHR_{gj}, FHR_{gj}, CHR_{gj}, DHR_{gj}, and OHR_{gj} be hours worked per day on activity 'g' and crop enterprise 'j' by a male adult worker, female adult worker, child worker, a donkey and oxen, respectively. Moreover, let DYS^{m}_{gj}, DYS^{d}_{gj}, and DYS^{o}_{gj} represent the number of days required to complete activity 'g' on a hectare of crop enterprise 'j' using manual labor donkey and oxen traction, respectively.

Thus, the total amount of time required for activity 'g' using strictly manual labor is:

$$(1) \quad DYS^{m}_{gj} \; [MHR_{gj}(MW) + FHR_{gj}(FW) + CHR_{gj}(CW)] = Z^{m}_{gj}$$

where the term, Z^{m}_{gj}, is equivalent to the coefficient A^{m}_{ij}, defined in Chapter IV, summed over all 'i' periods to complete activity 'g'. Similarly, the total time required for activity 'g' by humans with donkey and oxen traction, Z^{d}_{gj} and Z^{o}_{gj}, respectively, on enterprise 'j' are:

$$(2) \quad DYS^{d}_{gj}[MHR_{gj}(MW - 1) + FHR_{gj}(FW) + CHR_{gj}(CW - 1)] + DYS^{d}_{gj}[MHR^{d}_{gj}(1) + (MHR^{m}_{gj} - MHR^{d}_{gj}) + CHR_{gj}(1)] = Z^{d}_{gj}$$

$$(3) \quad DYS^{o}_{gj} \; [MHR_{gj}(MW - 1) + FHR_{gj}(FW) + CHR_{gj}(CW - 1.5)] + DYS^{o}_{gj}[MHR^{o}_{gj} \; (1) + (MHR^{m}_{gj} - MHR^{o}_{gj}) + CHR_{gj} \; (1.5)] = Z^{o}_{gj}$$

The first half of equations 2 and 3 represent time spent on manual tillage by workers accompanying donkey and oxen traction in the field. Even with animal traction, manual tillage is required for weeding and ridging within the row and follow up cleaning. The second half of these equations defines human labor time spent driving the traction team. Because time worked by animals is less than humans, the extra components $(MHR^{m}_{gj} - MHR^{d}_{gj})$ and $(MHR^{m}_{gj} - MHR^{o}_{gj})$ are allocated to manual tillage.

The percentage savings of human labor associated with donkey and oxen traction, S^{d}_{gj} and S^{o}_{gj}, can be calculated as:

$$(4) \quad S^{d}_{gj} = \frac{Z^{d}_{gj} - Z^{m}_{gj}}{Z^{m}_{gj}} * 100$$

$$(5) \quad S^o_{gj} = \frac{Z^o_{gj} - Z^m_{gj}}{Z^m_{gj}} * 100$$

for activity 'g' on enterprise 'j'. Since time worked with animal traction is normally less than time requirements with manual tillage, S^d_{gj} and S^o_{gj} are generally negative. Labor savings, S^d_{gj} and S^o_{gj}, should not be confused with those defined in Chapter V. As will be shown shortly, they are derived from technical performance parameters while in Chapter V they are estimated from actual labor savings observed in on-farm use.

The total number of animal hours spent on activity 'g' per hectare are obtained from the expressions, $THR^d_{gj} = DYS^d_{gj}\ DHR_{gj}$ for donkey and $THR^o_{gj} = DYS^o_{gj}\ OHR_{gj}$ for oxen. The relationship between time spent on various tillage systems then can be expressed as:

$$(6) \quad Z^d_{gj} + \phi^d_{gj}\ (THR^d_{gj}) = Z^m_{gj}$$

$$(7) \quad Z^o_{gj} + \phi^o_{gj}\ (THR^o_{gj}) = Z^m_{gj}$$

where, ϕ^d_{gj} and ϕ^o_{gj} are technical efficiency parameters relating time worked by a donkey or oxen team, respectively, to savings of human labor (e.g., $Z^m_{gj} - Z^d_{gj}$ and $Z^m_{gj} - Z^o_{gj}$).

Given information on total hours worked on manual tillage, Z^m_{gj}, labor saving effects associated with animal mechanization, S^d_{gj} for donkey and S^o_{gj} for oxen, and parameters relating productivity of traction teams to humans working manually, ϕ^d_{gj} and ϕ^o_{gj}, time spent on traction teams can be estimated by:

$$(8) \quad THR^{d}_{gj} = \frac{Z^{m}_{gj} - (1+S^{d}_{gj})\, Z^{m}_{gj}}{\phi^{d}_{gj}}$$

$$(9) \quad THR^{o}_{gj} = \frac{Z^{m}_{gj} - (1+S^{o}_{gj})\, Z^{m}_{gj}}{\phi^{o}_{gj}}$$

The derivation of $A^{m}_{ij} \approx Z^{m}_{gj}$, $S^{d}_{ij} \approx S^{d}_{gj}$ and $S^{o}_{ij} \approx S^{o}_{gj}$ are explained in Chapter V. The rest of this section deals with derivation of technical efficiency parameters ϕ^{d}_{gj} and ϕ^{o}_{gj}.

What are needed to estimate these parameters are information on household demographics, time worked per day by various age/sex groups and information which compare technical performance of manual, donkey and oxen tillage. These information need to be further disaggregated by activity 'g' and technology 'j'.

Data

The amount of time workers spend per day varies from 4 to 5 hours at planting (Swanson, 1981) to as many as 8 to 11 hours during the critical first weeding of principal cereals (Swanson, 1981; Delgado, 1978b; Ford, 1982). Ancey (1974, p. 77) reports that on average, for the agricultural season (months of June, July, and August), workers spend 4.4 to 4.7 hours per day doing fieldwork on the Central Plateau and 3.4 to 4.8 hours in western areas of the country.

These estimates represent an average labor intensity across age/sex strata. In practice, women generally work fewer hours per day on fieldwork than males because of other work obligations (housework, marketing, fetching wood and water, etc.). Bleiberg, et al. (1980, p.

76) and Brun, et al. (1981, p. 71) estimate that, for the entire agricultural season, men work on average 4.7 hours and women 3.0 hours per day on hoeing of crops. Children work less than adults because they are not as physically strong and tire more quickly.

As for technical parameters relating performance of manual, donkey and oxen tillage, data are limited. Perhaps the best source is Jaeger's 1982 farm management survey. That survey elicited farmers' subjective responses on animal traction performance and the amount of time animals can work per day (Table A3.1). Four problems are apparent in the data, however: a) field size is indeterminant, complicating comparisons between activities and regions; b) data are influenced by farmers' subjective biases and their desire to please interviewers with positive responses; c) information is unavailable on relative time requirements for manual plowing; d) no control is given to the type of soil on which traction systems are used. Donkey traction use is correlated with cultivation of lighter sandier soils and oxen traction with heavier soils. Jaeger's study is ambiguous regarding whether performance parameters are based on the same or different soil types among tillage systems. Hence, the data should be interpreted as only crude measures of technical performance.

Results

The technical efficiency parameters, ϕ^d and ϕ^o, for weeding activities are derived in Table A3.2. Data on household demographics (MW, FW, and CW) are adapted from SAFGRAD-FSU (1983, p. 51); measures of work intensities of family members (MHR, FHR, and CHR) are work rates used in regional supply models; work intensities of animal

Table A3.1. Farmers' Subjective Estimates of the Performance of Animal Traction.

Regions: Survey Villages	North Djibo	Central Nedogo	East Diapangou	West & Southwest Boromo
Days required using draft animals to accomplish the weeding that could be done in 10 days by hand:				
Donkey	4.5	4.7	4.9	4.6
Oxen Team	5.1	3.7	2.8	3.7
Days required with donkey to plow an area that an ox can plow in 5 days:	-	7.2	10.2	8.8
Hours per day that draft animals can weed:				
Donkey	7.5	8.7	3.7	4.5
Oxen Team	6.4	6.5	4.6	5.4
Hours per day that draft animals can plow:				
Donkey	6.0	5.1	3.5	4.0
Oxen Team	5.7	6.7	4.3	5.8

Source: William K. Jaeger, "Agricultural Mechanization: The Economics of Animal Traction in Upper Volta," (1984).

Table A3.2. Derivation of Technical Efficiency Parameters, ϕ^d and ϕ^o for Donkey and Oxen Technologies.

Variable	North	Central	East	West & Southwest
Active Workers/Household[a/]				
MW = male adults	2.1	2.0	2.1	1.8
FW = female adults	2.2	2.8	2.6	1.8
CW = children	1.5	1.5	2.5	1.5
Inactive Workers[a/]	3.3	4.4	2.3	2.9
Total Residents[a/]	9.1	10.7	9.5	8.0
Hours Worked/Day During the Critical Weeding Period:				
MHR[b/]	7.3	7.2	7.3	7.5
FHR[b/]	5.1	5.0	5.2	5.2
CHR[b/]	3.4	3.4	3.5	3.5
DHR[c/]	5.7	5.7	4.2	4.7
OHR[c/]	6.5	6.5	5.0	5.5
Days to Weed a Field:				
DYS^m	10.0	10.0	10.0	10.0
DYS^d	6.6	6.6	6.6	6.6
DYS^o	5.4	5.4	5.4	5.4
Total Hours Worked (Labor Savings):[d/]				
Z^m	317	335	380	281
$Z^d(S^d_{gj})$[e/]	224(-29)	236(-29)	256(-33)	193(-31)
$Z^o(S^o_{gj})$[e/]	196(-38)	206(-39)	217(-43)	168(-40)
Total Animal Team Hours:				
$THR^d = DYS^d_{gj}\ DHR_{gj}$	38	38	38	31
$THR^o = DYS^o_{gj}\ OHR_{gj}$	35	35	27	30
Efficiency Parameters:[f/]				
ϕ^d	2.4	2.6	4.4	2.8
ϕ^o	3.5	3.7	6.0	3.8

Sources: a/ SAFGRAD-FSU, 1983, p. 51; b/ Model assumptions from Table 5.16, in Chapter V; c/ adapted from Jaeger's (1984) data on farmers' subjective opinion on animal traction performance in Table A3.1; d/ computed from equations (1) to (3); e/ coefficients S^d_{gj} and S^o_{gj} are computed from equations (4) and (5); f/ computed from equations (6) and (7).

teams, (DHR and OHR), and relative weeding requirements (DYS^m, DYS^d, and DYS^o) are adapted from Jaeger's (1984) findings in Table A3.1. Estimates of DYS^d and DYS^o are conservatively set to compensate for farmers' subjective biases.

The efficiency parameters estimated in Table A3.2 are similar across regions (with the exception of the east), ranging from 2.4 to 2.8 for donkeys (ϕ^d) and 3.5 to 3.8 for oxen (ϕ^o). For the model, $\phi^d = 2.5$ and $\phi^o = 3.6$ were assumed for all regions. These say that one hour worked by a donkey team displaces 2.5 hours, and an oxen team 3.6 hours, of human labor on average. The fact that proportional labor savings, S^d_{gj} and S^o_{gj}, are similar to S^d_{ij} and S^o_{ij} assumed for first weeding in Chapter V (Tables 5.12 and 5.13) suggests that parameters are consistent with performance rates observed in on-farm use.

Lack of data preclude estimation of technical parameters for plowing and land preparation of minor crops. Moreover, information is unavailable concerning how ϕ^d and ϕ^o vary with land type and crop. Hence, estimates of ϕ^d and ϕ^o in Table A3.2 are assumed to remain constant for all 'g' activities and all 'j' crop enterprises.

Appendix 4

Studies Documenting the Use and Benefits of Animal Traction in Chapter V

Study A4.1. Percentage of Fields Cultivated with Animal Traction.

Singh, et al., (1983, p. 33) report the percentage of fields cultivated with animal traction in two different survey villages as:

	Nedogo (Central)	
	Land Prep.	Weeding
Millet	0	24
Sorghum	0	46
Maize	38	0
Peanuts	17	5

	Aorema (North)	
	Land Prep.	Weeding
Millet	25	5
Sorghum	27	0
Maize	39	0
Peanuts	50	0

Study A4.2. Alleviation of Labor Constraints with Animal Traction.

Jaeger (1983, p. 7) asked animal traction adopters which activities were most constraining before and after adoption. Responses were (percent responding yes):

	Diapangou	
	Before	After
Preplant plowing	43	6
Planting	11	38
1st weeding	66	49
2nd weeding	19	21
Labor not constraining	0	9

	Nedogo	
	Before	After
Preplant plowing		
Planting	36	14
1st weeding	81	25
2nd weeding	0	0
Labor not constraining	3	67

In the case of Diapango where plows are more common, animal traction alleviated preplant plowing constraints. In the case of Nedogo where plowing is not performed, animal mechanization alleviated weeding constraints.

Study A4.3. Labor Saving Effects Associated with Animal Traction, On-Station Research, Mali.

In on-station research trials by IRAT in Mali (in Sargent, et al., 1981, p. 25) use of fully equipped oxen teams reduced human labor requirements.

	Peanuts	Sorghum/Millet
	percent	
Land preparation	-	17/24
Planting	80	3
1st weeding		50
Ridging		68
2nd weeding	58	50
3rd weeding	68	
Transport	52	43/36
Total	43	42/43

Oxen teams were equipped with a multi-cultivator, planter, cultivator (for peanuts) and cart.

Study A4.4. Allocation of Manure by Crop and Field, Central Plateau.

Bonkian (1980, p. 14) studied the allocation of manure among hand tillage and animal traction households in two villages on the Central Plateau. The following figures are kg. of manure as a mean of all fields whether manure was received or not.

	Hand		
	House	Village	Bush
White sorghum	160	0	0
Red sorghum	652	272	433
Millet	40	51	77
Maize	3756	0	0
Groundnuts	190	0	0

	Animal Traction		
	House	Village	Bush
White sorghum	542	265	0
Red sorghum	1326	550	0
Millet	13	197	92
Maize	3063	2101	0
Groundnuts	633	0	0

Appendix 5

Derivation of Costs for Animal Traction and Land Reclamation (AVV)

Table A5.1. Derivation of Annualized Cost of Fully Equipped Animal Traction Teams, All Regions, Burkina Faso.

a) Donkey Traction

Variable	Estimated 1980 Price (FCFA)	Estimated Working Life (Years)	Salvage Value (FCFA)	Annualized Costs a/ (FCFA)
Donkey Purchase Price b/	25,000	7	4,000	5,650
Donkey Drawn Implements: d/				
Plow	14,500	10	1,500	2,815
Weeder	22,000	8	2,000	4,755
Accessories	6,600	5	300	1,925
Equipment Repair (10%) f/				4,310
Grain, Forage, Salt, Medicine g/				2,500
Expected Loss of: h/				
Animals (3%)				750
Equipment (5%)				1,295
Annual Cost of a Donkey Team, Ψ^d				24,000

Table A5.1. (Continued)

b) Oxen Traction

Variable	Estimated 1980 Price (FCFA)	Estimated Working Life (Years)	Salvage Value (FCFA)	Annualized Costs a/ (FCFA)
Oxen (2) Purchase Price: c/	45,000 * 2	4	90,000 * 2	(4525)
Oxen Drawn Implements: e/				
Plow	25,000	10	2,500	4,860
Weeder	26,000	8	2,750	5,595
Ridger	8,500	5	425	2,475
Accessories	9,500	5	475	2,765
Equipment Repair (10%) f/				6,900
Grain, Forage, Salt, Medicine g/ (2 oxen)				9,000
Expected Loss of: h/				
Animals (3%)				4,500
Equipment (5%)				3,450
Annual Cost of an Oxen Team, Ψ^{o}				35,020

Table A5.1. (Continued)

a/ Annualized costs of animals and equipment are computed with the Capital Recovery Factor:

$$A = PV \left(\frac{r}{1 - \frac{1}{(1+r)^t}} \right)$$

where A = annualized cost of the capital item,

PV = present value of capital item defined as purchase price, PP, minus present worth of its future salvage value, SV. That is, $PV = PP - SV \left(\frac{1}{(1+r)^t} \right)$

r = 0.15 discount rate,

t = estimated working life.

b/ The purchase price of a donkey was reported as 30,000 FCFA by the Centre Ouest ORD (1980/81 Annual Report) and 35,000 FCFA by the Centre Nord ORD (1980/81 Annual Report). For the eastern region of the country, estimates range from 18,000 FCFA by Barrett, et al. (1982) in their 1978 eastern ORD study to 20,000 FCFA by Swanson (1981 SAFGRAD-FSU Annual Report) in the village of Diapangou near Fada N'Gourma.

c/ The cost of a pair of oxen in 1980 was reported as 35,000 FCFA by the Centre Ouest ORD (1980 Annual Report) and 45,000 FCFA by the Centre Nord ORD (1980 Annual Report). These costs were the average price of an ox purchased with CNCA credit. Cohen (1982) reports that an ox can be bought for 40,000 FCFA and resold after four years for 55,000 FCFA. The fact that an oxen's resale price is higher than its purchase price has been documented as well by Jaeger (1983) (50,000 FCFA purchase price versus 100,000 FCFA resale value) and by Barrett, et al. (1982) (35,000 FCFA purchase price versus 75,000 FCFA resale value).

d/ The HV2A is a 6" moldboard plow suited for donkeys. It comes complete with a three-tined cultivator but no ridger. Its cost was reported as 27,650 FCFA by the Centre Ouest ORD (1979/80 Annual Report) and 35,500 FCFA by Swanson (1981) in the eastern region. Barrett, et al., placed just the cost of a plow at 11,320 FCFA in 1978. Estimates of the price of a houe Manga--flexible tined weeder with scarifying equipment (3 tines)--varies from 20,100 FCFA by the Centre Ouest ORD (1980 Annual Report) to 26,050 and 28,500 by Swanson (1981) for the Centre Est and the Est ORD's, respectively. Barrett, et al., report the cost of a weeder as 17,200 FCFA in 1978 with an additional 5,185 FCFA required for accessories.

Table A5.1. (Continued)

d/ An HV2B is a multi-cultivator for oxen. It is based on a nine-inch plow with a steel beam. Additional attachments include a chisel point to help break hardened soils, a cultivator with 5 flexible tines plus scarifying and weeding shares. The Centre Ouest ORD (1979 Annual Report) listed the price of an HV2B in 1979/80 as 41,815 FCFA. They also give the price of BM2M plow for oxen as 27,000 FCFA. Barrett, et al., (1982) list the price of a plow as 18,250 FCFA in 1978 and the price of a ridger as 6,470 FCFA. With regards to just weeding equipment, the Centre Nord ORD lists the price of an oxen weeder as 27,960 FCFA. Barrett, et al., report the price of a 5 chisel weeder as 19,635 FCFA and accessories as 7,225 FCFA.

f/ Sargent, et al. (1981, p. 39) estimate repair and maintenance of equipment at 10 percent of purchase price per year. Barrett, et al. (1982, p. 51) observed farmers spending 1264 FCFA for repairs while oxen farmers spent 1,380 FCFA per year on average. These latter estimates are probably low, since a large proportion of farmers recently purchased equipment, hence repair costs were lower. Also, farmers were not fully equipped.

g/ Barrett, et al. (1982, p. 38) report the average annual cash expense of maintaining a donkey (ox) as 938 or 1,900 FCFA, respectively in 1978. Jaeger (1983) reports expenses of 4,310 FCFA to cover feed grain, salt, etc. for donkeys and 4,138 for oxen. Since oxen require higher levels of feed supplements than donkeys, higher costs are assumed.

h/ Barrett, et al. (1982) in their eastern region farm management study, observed a 1.2 and 5 percent mortality rate per annum of donkey and oxen. The rates 3 percent (750 FCFA per annum) and 5 percent (2250 FCFA) for donkeys and oxen assumed in the analysis are similar to insurance rates charged by the Eastern ORD to insure animals in credit schemes (Barrett, et al., 1982, p. 43). For equipment, a figure of 5 percent of purchase price is assumed to cover thefts and irrepairable damage. Labor costs to care for animals are captured through labor demands and opportunity costs of labor calculated within regional supply models. Labor costs during the off-season are assumed to be zero for lack of alternative sources of employment.

	Initial 1978 Cost (FCFA)	Estimated Life Span	Annualized Costs (FCFA)
Preliminary Studies	75,800	20	12,110
Settling Farmers[a/]	133,325	20[b/]	21,300
Infrastructure:			
Roads[c/]	742,600	20	118,639
Housing[d/]	210,600	8	46,932
Wells	81,600	10	16,259
Land Preparation[e/]	368,700	20	58,904
General:			
Equipment and Supplies	40,700	5	12,141
Field Personnel for 3 Years	138,000	20	22,047
Cars and Furniture	34,200	5	10,202
General Expenses AVV	491,700	20	78,555
Technical Assistance (3 Years)	297,000	20	47,449
Total Cost (FCFA)	2,614,225		444,538
Cost per Hectare,[f/] AVV			65,857

Table A5.2. (Continued)

Source: These results were taken from a report prepared in 1978 for donor countries estimating the cost of settling one family in disease freed areas. In Murphy and Sprey, "The Volta Valley Authority: Socio-Economic Evaluation of a Resettlement Project in Upper Volta," 1980; p. 86.

a/ Includes 50,600 FCFA for recruiting and moving, 19,900 FCFA for transportation and food and 63,425 FCFA for preparing the master plan, village, and field sites.

b/ Assumes family will remain settled for 20 years.

c/ Includes 557,000 FCFA for roads, 139,900 FCFA for equipment and personnel and 45,700 FCFA for technical assistance.

d/ Includes housing of 187,600 FCFA and equipment and personnel of 23,000 FCFA.

e/ Includes land clearing for 53,000 FCFA, deep plowing for 212,100 FCFA and harrowing for 103,600 FCFA.

f/ The cost per hectare is total costs of settling a family divided by 6.75, the total farm size expected once farmers are settled.

g/ Investment costs are annualized based on the capital recovery factor in footnote 'a', Appendix 1, Table A5.1, 15 percent discount rate, zero salvage value, and 20 year time horizon.

Appendix 6

Results of Food Consumption Surveys, Selected Studies

Study A6.1

Burkina Faso, Ouagadougou, Bobo-Dioulasso and Rural Households: This was a nutrition study conducted in four regions of Burkina Faso: the city of Ouagadougou, city of Bobo-Dioulasso, rural areas around Ouagadougou and rural areas around Bobo-Dioulasso. A total of 9,310 households encompassing 63,640 consumers were included in the study. Measurements on food intake were collected over the course of a year. Average food consumption was estimated as:

Food Group	Ouagadougou	Bobo Dioulasso	Mossi Region	Southwest Region
		(grams/day)		
Cereals	377.2	484.6	445.0	445.8
Fruits & Vegetables	63.0	104.0	49.0	51.0
Tubers	12.0	24.0	3.0	3.0
Meat	76.0	69.0	14.0	10.0
Fish	4.0	12.0	2.0	6.0
Oils	25.9	34.7	5.0	11.0

Source: Republique de Haute-Volta, Minstere du Developpement et du Tourisme, Direction de la Statistique et de la Mecanographie. "Enquete Budget Consommation 1963-64, Results Provisoires," June 1966. (In RHV/MDR/DSA, "Rapport sur l'Atelier National sur l'Economie Alimentaire et les Politiques Alimentaire et Nutritionnelles," Janvier 1981).

Study A6.2

Burkina Faso, Ouagadougou. A consumer panel survey covering 73 households was conducted in the city of Ouagadougou from September 1982 to August 1983. Data were collected on weekly expenditures of 63 food and non-food items and socio-economic characteristics of sample households. Monthly expenditure data are summarized for three income stratum: low income (0 to 35,000 FCFA), middle income (35,000 to 75,000 FCFA) and high income (75,000+ FCFA). Data below are estimates of annual consumption per capita adapted from household expenditure data and average prices. Consumption estimates are biased downward because of incomplete reporting.

Food Group	Low Income HHLD's	Middle Income HHLD's (kg./annum)	High Income HHLD's	Price
Household size	8.16	8.93	8.82	
Sorghum	41.9	46.6	22.4	81.1
Millet	8.6	6.7	2.6	87.2
Maize	1.7	8.8	5.4	80.4
Rice	34.5	38.8	32.7	141.7
Wheat Bread	2.9	6.2	15.5	80.0
Meat and Fish	6.2	7.4	12.0	647.1
Vegetables	8.4	8.8	11.2	686.6
Oils	8.2	12.1	15.1	477.8

Source: Savadogo, K. "An Analysis of Determinants of Household Food Consumption in Ouagadougou, Burkina Faso" (1986).

Study A6.3

Burkina Faso, Rural Households, Northern Region. Nutrition studies were undertaken in three villages of the Centre-Nord (Kaya) ORD: Noaka (7/5/78 to 13/5/78), Guilla (14/5/78 to 20/5/78) and Goungla (20/5/78 to 27/5/78). Six households were surveyed in each village covering 149 prepared meals during a three week period in May. Food consumption per day averaged:

Food Item	Noaka	Guilla	Goungla
		(grams/day)	
White Sorghum	165	408	332
Red Sorghum	36	30	27
Millet	73	-	6
Maize	-	-	65
Rice	1	-	-
Beans and Peas	9	9	92
Vegetables	27	36	29
Meat and Fish	-	12	2

Source: Republique de Haute-Volta, Ministere du Developpement Rural, Direction des Service Agricoles, Rapport Sur l' Execution de la Seconde Phase du Projet "Strategie Pour l'Alimentation, TF-INT-210 (SWE), Composante Haute Volta," Avril 1979.

Study A6 4

Burkina Faso, Rural Households, Central and Southwest Regions. Three farmers in each of 6 villages in the central and southwest regions were surveyed from September 1978 to February 1979. The villages were Sokorny, Sienana and Kimini in the vicinity of Banfora and Arbolle (adjacent to Yako), Kombissirri and Koupela. The purpose of the survey was to examine the importance of tubers in agriculture, hence results are biased towards households which normally cultivate tubers. Consumption of cereals were estimated as:

	(Southwest)			(Central)		
	Sokorny	Sienana	Kimini	Arbolle	Kombissirri	Koupela
			(grams/day)			
W.Sorghum	33		51	402	78	
R.Sorghum				59	129	
Millet	288		109	84	229	
Maize	209	515	596	86	5	
Rice	131	168	67	3	75	
Fonio	30					
Tubers	169	20	248	168	13	
Tot.Cereals	691	683	823	634	516	490

Data are average cereal consumption per consumer averaged over three households per village.

Source: R. Dumont, Enquetes Socio-Economiques Concernant le Problem des Tubercules en Haute-Volta, Mai 1979.

Study A6.5

Burkina Faso, Rural Households, Southwest Region. Average cereals consumption per inhabitant per day were computed by this author from consumption data reported for three villages near Bobo-Doulasso. Inhabitants of the villages were of similar ethnic heritage and largely free of urban influences affecting food habits. Measurements were taken of food consumed per day by household members over a 4 day period, three times during the year. Food consumption per day was estimated from the 4 day total divided by total consumers, undifferentiated by age or sex:

	March to June	July to October	November to February
		(grams/day)	
(Number surveyed)	(135)	(243)	(219)
W. Sorghum	42.0	4.8	30.0
R. Sorghum	31.8	1.7	37.0
Millet	779.0	655.0	665.0
Maize	1.2	11.6	59.0
Fonio	7.0	10.9	86.4
Rice	-	2.0	7.0
Starchy Tubers	11.7	8.7	5.6
Total Cereals	861.0	686.0	884.4

Source: Organisme de Recherches sur l'Alimentation et la Nutrition Africaines, "Enquete Nutrition--Niveau de Vie en Pays Bobo-Fing," 1955.

Study A6.6

Senegal, Rural Versus Urban Households. The following data are reported second-hand without explanation of methodology.

	Senegal	Rural	Urban
		(kg./person/yr.)	
Milled Rice	54.2	37.2	91.0
Millet/Sorghum (flour)	72.7	96.7	20.7
Other Flours	22.2	19.3	28.6

Source: In Thenevin, P., "l'Aide Alimentaire en Cereales dans les Pays Saheliens," Septembre 1980.

Study A6.7

Mali, Rural Versus Urban Households. A nutritional study was conducted in three diverse ecological zones of Mali, encompassing 8 villages and 56 concessions (1,522 persons). Further, 14 concessions (316 persons) were interviewed in the city of Bamoko and 7 (293 persons) in Segou. The survey was conducted in 2 phases: the wet season, July and August 1977, and dry season, from January to April, 1978. The following data on cereals consumption were computed from sample averages by this author.

	Rural (Wet Season)	Rural (Dry Season)	Urban (Dry Season)
		(kg./person/year)	
(Nbr. of Concessions)	(28)		
Rice	17	49	92
Millet and sorghum	102	114	82
Maize	72	39	1
Fonio		2	1
Total Cereals	191	204	174

Source: Mondot-Bernard, J. Satisfaction du Besoin Alimentaire et Developpement Agricole au Mali; Tome 1, Resultats d'Enquetes de Consommation Alimentaire, 1980.

Appendix 7

Market Prices Reported in

Study A7.1. Marketing Prices Observed by a World Bank Mission to Burkina Faso, March 1980.

(FCFA/kg.)

	Central		East		Southwest	
	Rural 1/	Ouagadougou 2/	Rural 1/	Fada 2/	Rural 1/	Bobo-Dioulasso 2/
Sorghum	58	70	46	58	46	58
Millet	59	71	47	59	-	71
Maize	55	67	55	67	55	67
Rice Paddy	74	-	66	-	72	-
Rice Milled	123	135	111	123	120	132
Yams	60	78	45	60	45	60
Cassava	40	-	40	-	40	-
Cowpeas	65	-	53	-	53	-
Ground- (unshelled)	83	-	76	-	76	-
nuts (shelled)	131	150	119	138	119	138
Soybeans	-	-	50	-	-	-
Cotton	53	-	53	-	53	-

1/ Figures are financial prices received by producers in rural areas collected by a World Bank mission mainly during March 1980.

2/ Ouagadougou was chosen as the main center of consumption in the central region, Fada N'Gourma in the east and Bobo-Dioulasso in the southwest. Producer prices are market prices in rural areas within a 100 km. proximity of the urban centers. Urban prices are calculated from rural prices plus 5 FCFA/kg. for transport, 1 FCFA/kg. for handling and 6 FCFA/kg. gross margin (returns to risk and capital, storage costs, losses and returns to entrepreneurship).

Source: World Bank, "Upper Volta, Agricultural Issues Study," 1981b, p. 209 and "Haute-Volta: Etude des Questions Agricole, Annex II," p. 316, 317.

Study A7.2. Regional Prices Observed by OFNACER, Unpublished Data, 1982/83.

(FCFA/100 kg. sack)

Region	White Sorghum	Millet
Ouagadougou	10,767	10,767
7 regional towns	9,233	10,300
Bobo-Dioulasso	9,533	9,933
4 regional towns	7,250	7,350
Dedougou (west)	9,200	8,633
6 regional towns	9,167	9,683
Fada N'Gourma (east)	10,000	10,000
4 regional towns	10,000	10,000
Kaya (north)	10,500	12,000
4 regional towns	11,833	11,833
Dori (north)	11,167	11,833
4 regional towns	10,750	12,433

Prices are simple averages of market prices colleced by OFNACER for the months September through November, 1982.

Source: OFNACER, "Unpublished Data," 1982.

Study A7.3. Regional Prices Observed by OFNACER, Unpublished Data, 1983/84.

(FCFA/kg.)

Region		White Sorghum	Millet	Rice
Ouagadougou	(Mar-Apr)	93	87	88
Bobo-Dioulasso	(Dec-Feb)	68	64	
	(Mar-Apr)	69	65	65
Dedougou	(Dec-Feb)	61	57	
Fada	(Mar-Apr)	73	75	

Figures are average prices reported by OFNACER centers in respective CDG's. Price series were selected based on matching observations across regions.

Study A7.4. Market Prices for White Sorghum and Millet Observed in Various Regional Markets, 1982, 1983.

(FCFA/kg.)

Region		White Sorghum	Millet
Ouagadougou	(Sept.82-Dec.82)	75	
	(Sept.82-Feb.83)	75	85
	(Sept.82-Apr.83)	77	85
	(Mar.83-Aug.83)	85	
	(Apr.83-Sept.83)	88	
(North): Kaya (Sept.82-Dec.82)		56	
(Central): Yako (Apr.83-Sept.83)[1/]		55	56
(Central): Pabre (Sept.82-Feb.83)		65	68
(East): Diapangou (Mar.-Aug.83)		56	
(West): Boromo (Apr.-Sept.83)[2/]		43	54
(West): Dissankuy (Apr.-Sept.83)		69	

1/ Average prices for 4 markets including the Yako market.
2/ Average prices in Boromo market plus 2 village prices.

Source: Prices are averages adapted from monthly price data in Bukowski (1986).

Study A7.5. Market Prices Observed in Two Villages Near Ouagadougou, Central Region, 1980 and 1981.

	Ouagadougou 1/	Ziniare 2/	Nabitenga 2/
		(Oct.-Dec., 1980)	
White Sorghum	83	60	68
Red Sorghum		70	57
Millet	83	70	67
Groundnuts (in shell)		90	62
Cowpeas		105	96
		(Jan.-Mar., 1981)	
White Sorghum	80	60	51
Red Sorghum		55	55
Millet	78	73	69
Groundnuts		103	112
Cowpeas		169	153

Sources: 1/ Prices were collected in the Zogona marche, Ouagadougou. Prices for 1980 are based on small purchases (boh) while purchases in 1981 are based on a larger (tinne) measure. From unpublished data by D. A. Smith (USAID, Ouagadougou).

2/ Ziniare is the capital and principal town in the Ziniare 'sous-prefecture'. It is located about 35 kilometers to the northeast of Ouagadougou on the main Ouaga-Koya route. Nabitenga is a bush market 7 km. north of Ziniare. Figures are simple averages adapted from fortnightly observations (missing values excluded) reported in the original study. From Bonkian, Les Structures de Marche et le Prix des Cereals dans Deux Villages du Centre de la Haute-Volta, 1982, p. 20-24.

Study A7.6. Market Prices Observed in Three Villages in the Central and East Regions, 1981 and 1982.

Commodity	Ouagadougou 1/	(Central) 2/ Pabre'	(Central/East) 2/ Zorgho, Puitenga	(East) 2/ Fada, Diapangou
	(Prices (FCFA/kg.):		Nov. 81 - Jan. 82)	
White Sorghum	63	59	62	55
Red Sorghum		49	48	
Millet	62	58	62	59
Millet-Sorghum Mix				52
Maize	62		57	42
Peanuts		92	93	87
Soybeans				135
Cowpeas		117	109	66

Sources: 1/ Prices are adapted from unpublished data collected by D. A. Smith (USAID, Ouagadougou) in the Zagona marche, Ouagadougou. Prices are based on a 'tinne' measure.

2/ Pabre' is a small village market about 17 km. from Ouagadougou. Fada N'Gourma is about 220 km. east of Ouagadougou, connected by paved road. The village of Diapangou lies 20 km. west of Fada on the main Ouaga-Fada route. Zorgho is about 117 km. east of Ouagadougou on the main Ouaga-Fada route. Puitenga is a major regional market, 20 km. east and 8 km. north of Zorgho. From Swanson, "FSR Research in Upper Volta," 1981, p. 156.

Study A7.7. Weighted Average Prices Received by Producers in 25 Villages, Eastern ORD, 1978-79.

Crop	Prices[1/] (FCFA/kg.)	Crop	Prices[1/] (FCFA/kg.)
Sorghum	45.5	Cowpeas	73.2
Millet	45.5	Soybeans	72.4
Niadi	45.5	Sesame	57.6
Maize	30.6	Cotton	67.4
Groundnuts	68.9	Rice	90.2
Bambara nuts	59.0		

1/ Prices represent the weighted average selling price realized by a sample of 355 'traditional' and 125 'animal traction' households in 25 villages during the 1978-79 survey period. Commodities are threshed, shelled or hulled crop equivalents.

Source: Lassiter, G., "Cropping Enterprises in Eastern Upper Volta," 1981.

Study A7.8. Weighted Price Observed in Large and Small Markets in AVV Villages, Central Region.[1/]

Markets		White Sorghum	Red Sorghum	Rice Paddy	Rice Milled
(Jan.-Mar, 1979)	Large	61	56	72	136
	Small	61	57	71	162
(Apr.-June, 1979)	Large	64	62	78	143
	Small	61	62	76	146
(July-Sept., 1979)	Large	66	62	78	152
	Small	65	60	74	157
(Oct.-Dec., 1980)	Large	51	47	63	132
	Small	47	45	60	126

1/ AVV cluster villages lie to the south of the main Ouaga-Fada route. The villages are Linoghin, roughly 35 km. from Ouagadougou bordering the main Ouaga-Fada route; Mogtedo and Bombore, about 80 km. east of Ouagadougou, several km. off the main route; Kaibo Nord and Kaibo Sud, roughly 10 km. east of Manga. Manga lies off the main Ouaga-Po route, around 100 km. southeast of Ouagadougou; and Bane, about 30 km. south of Tenkodogo.

Source: Murphy and Sprey, "Farmers' Response to an Intensive Extension Program in Upper Volta," 1980, p. 47.

Appendix 8

Derivation of Economic (Tariff Free) Prices

Table A8.1. Economic (Tariff Free) Prices Estimated at Point of Major Urban Markets.

(1980 Price per Ton)

Items		Sorghum	Maize	Rice	Wheat	Groundnuts
		(1980 Price per Ton)				
Commodity	Type:	No. 2 Yellow FOB	No. 2 Yellow FOB	Thai 5% Broken	No. 2 H.W. FOB	Var.Origin, Shelled
	Origin	Gulf Port	Gulf Port	Bangkok	Gulf Port	CAF Rotterdam
Cost per ton (1980):		U.S.$ 152	U.S.$ 172	U.S. $464	U.S. $175	U.S. $533
Quality adjustment				-70		
Ocean transport and insurance		84	84	84	84	84
Price CAF, Abidjan FOB		236	256	478	259	
FOB						449
(US $1 = CFAF 210)		CFAF 49,560	CFAF 53,760	CFAF 100,380	CFAF 54,390	CFAF 94,290
Transport in Abidjan		7,000	7,000	7,000	7,000	7,000
Importer Commission		5,478	5,885	10,400	10,400	
Exporter Commission						8,454
Rail Transport Abidjan-Bobo		11,889	11,889	11,889	11,889	8,367
Handling in Bobo		1,751	1,751	1,751	1,751	1,751
Out of Depot Price - Bobo		75,678	80,285	131,420	85,430	68,718
Rail Transport Abidjan-Ouaga		16,969	16,969	16,969	16,969	11,065
Handling in Ouaga		1,751	1,751	1,751	1,751	
Out of Depot Price - Ouaga		80,758	85,365	136,500	90,510	66,020

Source: Economic Price Calculations for Sorghum, Rice and Groundnuts were taken from Banque Mondiale, "Haute Volta: Etude des Questions Agricoles," pp. 320-326. The Gulf Port Price of wheat came from USDA/FAS, Foreign Agricultural Circular, Grains, 1985, p. 30.

Table A8.2. Economic (Tariff Free) Price of Cotton Estimated at Point of Major Urban Markets.

	(1980 Price per Ton)			
	Cotton			
	Fiber		Seed	
	Mexican SM1-16 CAF Northern Europe		Cotton Seed CAF Europe	
Cost per ton	US $	1,811	US $	246
	FCAF	380,310		51,660
Less: Quality Adjustment		65,413		
CFDT Commission		6,298		
Sales Expenses in Europe		3,730		
Ocean Transport & Insur.		22,150		17,640
Price FOB Abidjan		282,709		34,020
Less: Transit Cost in Abidjan		7,380		6,960
Transport Abidjan to Bobo		10,439		9,195
CFDT Transit Cost (incl. commission)*		870		2,504
Insurance		3,050		
Storage, classification, ginning and packing		26,589		1,826
Ex-Factory Price, Bobo		234,381		13,535
Ouaga (less trans.)		232,158		11,925
Conversion (37% seed cotton): Bobo	(a)	86,721	(b)	4,737
(35% cotton seed): Ouaga	(a)	85,898	(b)	4,174
Less Costs from Farm to Mill:				
Storage and handling	(c)	760		
Collection and transport	(c)	12,948		
Seed multiplication and dist.	(c)	1,016		
Management	(c)	9,586		
Economic Price of Seed Cotton to Producers (a+b-c):				
Southwest		67,148		
Central		65,762		

Source: From Banque Mondiale, "Haute Volta: Etudes des Questions Agricoles," p. 320.

Appendix 9

Demand Parameters and Elasticity Estimates for Six Regions

Table A9.1. Demand Parameters and Elasticities for Regional LES Systems.

a) Northern Region.

Demand Parameters

	TOTAL MARKET DEMAND	OFFICIAL MARKET RATION	PRIVATE MARKET DEMAND	MINUMUM SUB. REQ.	AVG. BUDGET SHARE	MAR. BUDGET SHARE	PRICES
WS	83895.0	10580.0	73315.0	49070.4	0.0997	0.0947	83.0
RS	2065.0	0.0	2065.0	1084.1	0.0026	0.0024	76.0
ML	143779.8	828.0	142952.0	75877.8	0.1991	0.1891	85.0
MZ	23140.0	7636.0	15504.0	17326.0	0.0208	0.0156	82.0
RC	10270.0	1265.0	9005.0	7568.5	0.0226	0.0135	153.0
PN	11060.0	0.0	11060.0	6636.0	0.0283	0.0226	156.0
CT	0.1	0.0	0.1	0.1	0.0000	0.0000	0.1
WT	3340.0	177.1	3162.9	2391.1	0.0074	0.0044	143.0
OT	879310.7	0.0	879312.2	412742.4	0.6195	0.6575	43.0

Uncompensated Own-Price (E_{ii}), Cross-Price (E_{ij}) and Income (E_y) Elasticities

	EY	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	0.9500	-0.5247	-0.0013	-0.0993	-0.0124	-0.0150	-0.0161	0.0000	-0.0049	-0.2763
I = RS	0.9500	-0.0497	-0.4763	-0.0993	-0.0124	-0.0150	-0.0161	0.0000	-0.0049	-0.2763
I = ML	0.9500	-0.0497	-0.0013	-0.5743	-0.0124	-0.0150	-0.0161	0.0000	-0.0049	-0.2763
I = MZ	0.7500	-0.0393	-0.0010	-0.0784	-0.3848	-0.0119	-0.0127	0.0000	-0.0039	-0.2181
I = RC	0.6000	-0.0314	-0.0008	-0.0627	-0.0078	-0.3095	-0.0102	0.0000	-0.0031	-0.1745
I = PN	0.8000	-0.0419	-0.0011	-0.0836	-0.0104	-0.0126	-0.4136	0.0000	-0.0042	-0.2326
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.6000	-0.0314	-0.0008	-0.0627	-0.0078	-0.0095	-0.0102	0.0000	-0.3031	-0.1745
I = OT	1.0612	-0.0556	-0.0014	-0.1109	-0.0138	-0.0168	-0.0180	0.0000	-0.0055	-0.8392

Income Compensated Own-Price ($E_{ii|y'}$) and Cross-Price ($E_{ij|y'}$) Elasticities

	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	-0.4300	0.0012	0.0898	0.0074	0.0064	0.0107	0.0000	0.0021	0.3123
I = RS	0.0450	-0.4738	0.0898	0.0074	0.0064	0.0107	0.0000	0.0021	0.3123
I = ML	0.0450	0.0012	-0.3852	0.0074	0.0064	0.0107	0.0000	0.0021	0.3123
I = MZ	0.0355	0.0009	0.0709	-0.3691	0.0051	0.0085	0.0000	0.0017	0.2465
I = RC	0.0284	0.0007	0.0567	0.0047	-0.2959	0.0068	0.0000	0.0013	0.1972
I = PN	0.0379	0.0010	0.0757	0.0062	0.0054	-0.3910	0.0000	0.0018	0.2630
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.0284	0.0007	0.0567	0.0047	0.0041	0.0068	0.0000	-0.2987	0.1972
I = OT	0.0503	0.0013	0.1004	0.0083	0.0072	0.0120	0.0000	0.0024	-0.1818

Table A9.1. (Continued).

b) Eastern Region.

Demand Parameters

	TOTAL MARKET DEMAND	OFFICIAL MARKET RATION	PRIVATE MARKET DEMAND	MINUMUM SUB REQ.	AVG. BUDGET SHARE	MAR. BUDGET SHARE	PRICES
WS	38550.0	920.0	37630.0	20675.7	0.1069	0.1015	46.0
RS	3710.0	0.0	3710.0	1947.7	0.0096	0.0091	42.0
ML	26400.0	0.0	26400.0	13860.0	0.0766	0.0728	47.0
MZ	5910.0	920.0	4990.0	4038.7	0.0132	0.0099	43.0
RC	2000.0	184.0	1816.0	1455.2	0.0131	0.0079	117.0
PN	3410.0	0.0	3410.0	2046.0	0.0208	0.0167	99.0
CT	0.1	0.0	0.1	0.1	0.0000	0.0000	0.1
WT	710.0	64.4	645.6	516.3	0.0063	0.0038	158.0
OT	221923.2	0.0	221923.6	107295.2	0.7534	0.7783	55.0

Uncompensated Own-Price (E_{ii}), Cross-Price (E_{ij}) and Income (E_y) Elasticities

	EY	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	0.9500	-0.5283	-0.0048	-0.0382	-0.0079	-0.0087	-0.0119	0.0000	-0.0042	-0.3461
I = RS	0.9500	-0.0533	-0.4798	-0.0382	-0.0079	-0.0087	-0.0119	0.0000	-0.0042	-0.3461
I = ML	0.9500	-0.0533	-0.0048	-0.5132	-0.0079	-0.0087	-0.0119	0.0000	-0.0042	-0.3461
I = MZ	0.7500	-0.0421	-0.0038	-0.0302	-0.3812	-0.0069	-0.0094	0.0000	-0.0033	-0.2732
I = RC	0.6000	-0.0337	-0.0030	-0.0241	-0.0050	-0.3055	-0.0075	0.0000	-0.0026	-0.2186
I = PN	0.8000	-0.0449	-0.0040	-0.0322	-0.0066	-0.0073	-0.4100	0.0000	-0.0035	-0.2914
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.6000	-0.0337	-0.0030	-0.0241	-0.0050	-0.0055	-0.0075	0.0000	-0.3026	-0.2186
I = OT	1.0330	-0.0580	-0.0052	-0.0415	-0.0086	-0.0095	-0.0129	0.0000	-0.0046	-0.8928

Income Compensated Own-Price ($E_{ii}|_{y'}$) and Cross-Price ($E_{ij}|_{y'}$) Elasticities

	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	-0.4268	0.0043	0.0346	0.0047	0.0037	0.0079	0.0000	0.0018	0.3697
I = RS	0.0482	-0.4707	0.0346	0.0047	0.0037	0.0079	0.0000	0.0018	0.3697
I = ML	0.0482	0.0043	-0.4404	0.0047	0.0037	0.0079	0.0000	0.0018	0.3697
I = MZ	0.0381	0.0034	0.0273	-0.3713	0.0030	0.0063	0.0000	0.0014	0.2919
I = RC	0.0305	0.0027	0.0218	0.0030	-0.2976	0.0050	0.0000	0.0011	0.2335
I = PN	0.0406	0.0037	0.0291	0.0040	0.0031	-0.3933	0.0000	0.0015	0.3113
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.0305	0.0027	0.0218	0.0030	0.0024	0.0050	0.0000	-0.2989	0.2335
I = OT	0.0524	0.0047	0.0376	0.0051	0.0041	0.0086	0.0000	0.0020	-0.1145

Table A9.1. (Continued).

c) Western Region.

Demand Parameters

	TOTAL MARKET DEMAND	OFFICIAL MARKET RATION	PRIVATE MARKET DEMAND	MINUMUM SUB. REQ.	AVG. BUDGET SHARE	MAR. BUDGET SHARE	PRICES
WS	58499.9	920.0	57580.0	28414.4	0.0883	0.0839	54.0
RS	22310.0	0.0	22310.0	10653.0	0.0317	0.0301	50.0
ML	39800.0	0.0	39800.0	19004.5	0.0622	0.0591	55.0
MZ	8790.0	920.0	7870.0	5543.6	0.0118	0.0089	53.0
RC	2760.0	184.0	2576.0	1909.9	0.0091	0.0055	125.0
PN	5810.0	0.0	5810.0	3253.6	0.0198	0.0158	120.0
CT	0.1	0.0	0.1	0.1	0.0000	0.0000	0.1
WT	1170.0	96.6	1073.4	815.8	0.0039	0.0023	128.0
OT	389765.9	0.0	388766.6	169066.5	0.7731	0.7943	70.0

Uncompensated Own-Price (E_{ii}), Cross-Price (E_{ij}) and Income (E_y) Elasticities

	EY	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	0.9500	-0.5626	-0.0144	-0.0282	-0.0066	-0.0058	-0.0105	0.0000	-0.0025	-0.3194
I = RS	0.9500	-0.0401	-0.5369	-0.0282	-0.0066	-0.0058	-0.0105	0.0000	-0.0025	-0.3194
I = ML	0.9500	-0.0401	-0.0144	-0.5507	-0.0066	-0.0058	-0.0105	0.0000	-0.0025	-0.3194
I = MZ	0.7500	-0.0316	-0.0113	-0.0223	-0.4177	-0.0046	-0.0083	0.0000	-0.0020	-0.2522
I = RC	0.6000	-0.0253	-0.0091	-0.0178	-0.0042	-0.3337	-0.0067	0.0000	-0.0016	-0.2017
I = PN	0.8000	-0.0337	-0.0121	-0.0238	-0.0056	-0.0049	-0.4489	0.0000	-0.0021	-0.2690
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.6000	-0.0253	-0.0091	-0.0178	-0.0042	-0.0037	-0.0067	0.0000	-0.3316	-0.2017
I = OT	1.0275	-0.0433	-0.0155	-0.0305	-0.0072	-0.0063	-0.0114	0.0000	-0.0027	-0.9106

Income Compensated Own-Price ($E_{ii}|_{y'}$) and Cross-Price ($E_{ij}|_{y'}$) Elasticities

	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	-0.4787	0.0157	0.0309	0.0046	0.0029	0.0083	0.0000	0.0012	0.4150
I = RS	0.0438	-0.5068	0.0309	0.0046	0.0029	0.0083	0.0000	0.0012	0.4150
I = ML	0.0438	0.0157	-0.4916	0.0046	0.0029	0.0083	0.0000	0.0012	0.4150
I = MZ	0.0346	0.0124	0.0244	-0.4088	0.0023	0.0065	0.0000	0.0010	0.3277
I = RC	0.0277	0.0099	0.0195	0.0029	-0.3282	0.0052	0.0000	0.0008	0.2621
I = PN	0.0369	0.0132	0.0260	0.0039	0.0024	-0.4330	0.0000	0.0010	0.3495
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.0277	0.0099	0.0195	0.0029	0.0018	0.0052	0.0000	-0.3292	0.2621
I = OT	0.0474	0.0170	0.0334	0.0050	0.0031	0.0090	0.0000	0.0013	-0.1162

Table A9.1. (Continued).

d) Southwest Region.

Demand Parameters

	TOTAL MARKET DEMAND	OFFICIAL MARKET RATION	PRIVATE MARKET DEMAND	MINUMUM SUB. REG.	AVG. BUDGET SHARE	MAR. BUDGET SHARE	PRICES
WS	77194.9	92.0	77102.0	36908.7	0.0646	0.0614	44.0
RS	15085.0	0.0	15085.0	7203.1	0.0115	0.0109	40.0
ML	29830.0	0.0	29830.0	14243.8	0.0256	0.0243	45.0
MZ	46049.9	184.0	45866.0	27130.3	0.0376	0.0282	43.0
RC	6830.0	184.0	6646.0	4636.8	0.0146	0.0087	115.0
PN	7555.0	0.0	7555.0	4230.8	0.0140	0.0112	97.0
CT	0.1	0.0	0.1	0.1	0.0000	0.0000	0.1
WT	2140.0	96.6	2043.4	1465.7	0.0054	0.0032	139.0
OT	542616.2	0.0	542617.6	235062.6	0.8268	0.8521	80.0

Uncompensated Own-Price (E_{ii}), Cross-Price (E_{ij}) and Income (E_y) Elasticities

	EY	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	0.9500	-0.5518	-0.0052	-0.0116	-0.0210	-0.0093	-0.0074	0.0000	-0.0034	-0.3403
I = RS	0.9500	-0.0293	-0.5277	-0.0116	-0.0210	-0.0093	-0.0074	0.0000	-0.0034	-0.3403
I = ML	0.9500	-0.0293	-0.0052	-0.5341	-0.0210	-0.0093	-0.0074	0.0000	-0.0034	-0.3403
I = MZ	0.7500	-0.0231	-0.0041	-0.0092	-0.4291	-0.0073	-0.0059	0.0000	-0.0027	-0.2686
I = RC	0.6000	-0.0185	-0.0033	-0.0073	-0.0132	-0.3359	-0.0047	0.0000	-0.0022	-0.2149
I = PN	0.8000	-0.0247	-0.0044	-0.0098	-0.0177	-0.0078	-0.4463	0.0000	-0.0029	-0.2865
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.6000	-0.0185	-0.0033	-0.0073	-0.0132	-0.0059	-0.0047	0.0000	-0.3322	-0.2149
I = OT	1.0305	-0.0318	-0.0057	-0.0126	-0.0227	-0.0101	-0.0081	0.0000	-0.0037	-0.9359

Income Compensated Own-Price ($E_{ii}|_{y'}$) and Cross-Price ($E_{ij}|_{y'}$) Elasticities

	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	-0.4904	0.0057	0.0127	0.0147	0.0046	0.0058	0.0000	0.0017	0.4452
I = RS	0.0321	-0.5168	0.0127	0.0147	0.0046	0.0058	0.0000	0.0017	0.4452
I = ML	0.0321	0.0057	-0.5098	0.0147	0.0046	0.0058	0.0000	0.0017	0.4452
I = MZ	0.0253	0.0045	0.0100	-0.4009	0.0036	0.0046	0.0000	0.0013	0.3515
I = RC	0.0203	0.0036	0.0080	0.0093	-0.3271	0.0037	0.0000	0.0011	0.2812
I = PN	0.0270	0.0048	0.0107	0.0124	0.0038	-0.4351	0.0000	0.0014	0.3749
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.0203	0.0036	0.0080	0.0093	0.0029	0.0037	0.0000	-0.3289	0.2812
I = OT	0.0348	0.0062	0.0138	0.0160	0.0050	0.0063	0.0000	0.0018	-0.0838

Table A9.1. (Continued).

e) Ouagadougou

Demand Parameters

	TOTAL MARKET DEMAND	OFFICIAL MARKET RATION	PRIVATE MARKET DEMAND	MINUMUM SUB. REQ.	AVG. BUDGET SHARE	MAR. BUDGET SHARE	PRICES
WS	13160.0	4140.0	9020.0	9371.6	0.0622	0.0436	72.0
RS	0.1	0.0	0.1	0.1	0.0000	0.0000	66.0
ML	2440.0	0.0	2440.0	1415.2	0.0168	0.0118	72.0
MZ	2220.0	1840.0	380.0	2037.6	0.0025	0.0020	69.0
RC	6620.0	2599.0	4221.0	4414.0	0.0574	0.0546	142.0
PN	2630.0	0.0	2630.0	1288.7	0.0348	0.0296	138.0
CT	0.1	0.0	0.1	0.1	0.0000	0.0000	0.1
WT	3200.0	901.6	2298.4	1889.9	0.0291	0.0276	132.0
OT	154029.6	0.0	154029.9	57696.8	0.7971	0.8309	54.0

Uncompensated Own-Price (E_{ii}), Cross-Price (E_{ij}) and Income (E_y) Elasticities

	EY	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	0.7000	-0.4453	0.0000	-0.0068	-0.0009	-0.0173	-0.0119	0.0000	-0.0088	-0.2090
I = RS	0.7000	-0.0253	-0.4200	-0.0068	-0.0009	-0.0173	-0.0119	0.0000	-0.0088	-0.2090
I = ML	0.7000	-0.0253	0.0000	-0.4268	-0.0009	-0.0173	-0.0119	0.0000	-0.0088	-0.2090
I = MZ	0.8000	-0.0289	0.0000	-0.0078	-0.4810	-0.0198	-0.0136	0.0000	-0.0100	-0.2389
I = RC	0.9500	-0.0343	0.0000	-0.0093	-0.0012	-0.5935	-0.0162	0.0000	-0.0119	-0.2837
I = PN	0.8500	-0.0307	0.0000	-0.0083	-0.0011	-0.0210	-0.5245	0.0000	-0.0106	-0.2538
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.9500	-0.0343	0.0000	-0.0093	-0.0012	-0.0235	-0.0162	0.0000	-0.5819	-0.2837
I = OT	1.0424	-0.0376	0.0000	-0.0102	-0.0014	-0.0257	-0.0178	0.0000	-0.0130	-0.9367

Income Compensated Own-Price ($E_{ii}|_{y'}$) and Cross-Price ($E_{ij}|_{y'}$) Elasticities

	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	-0.4017	0.0000	0.0049	0.0008	0.0229	0.0124	0.0000	0.0116	0.3490
I = RS	0.0183	-0.4200	0.0049	0.0008	0.0229	0.0124	0.0000	0.0116	0.3490
I = ML	0.0183	0.0000	-0.4151	0.0008	0.0229	0.0124	0.0000	0.0116	0.3490
I = MZ	0.0209	0.0000	0.0057	-0.4790	0.0262	0.0142	0.0000	0.0133	0.3988
I = RC	0.0248	0.0000	0.0067	0.0011	-0.5389	0.0169	0.0000	0.0157	0.4736
I = PN	0.0222	0.0000	0.0060	0.0010	0.0278	-0.4949	0.0000	0.0141	0.4237
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.0248	0.0000	0.0067	0.0011	0.0311	0.0169	0.0000	-0.5543	0.4736
I = OT	0.0272	0.0000	0.0074	0.0013	0.0341	0.0185	0.0000	0.0173	-0.1058

f) Bobo Dioulasso.

Demand Parameters

	TOTAL MARKET DEMAND	OFFICIAL MARKET RATION	PRIVATE MARKET DEMAND	MINUMUM SUB. REQ.	AVG. BUDGET SHARE	MAR BUDGET SHARE	PRICES
WS	8630.0	1012.0	7618.0	5430.4	0.0618	0.0433	61.0
RS	0.1	0.0	0.1	0.1	0.0000	0.0000	55.0
ML	1380.0	0.0	1380.0	800.4	0.0114	0.0080	62.0
MZ	5000.0	1104.0	3896.0	3129.9	0.0306	0.0245	59.0
RC	4280.0	1288.0	2992.0	2574.6	0.0526	0.0499	132.0
PN	2395.0	0.0	2395.0	1173.5	0.0386	0.0328	121.0
CT	0.1	0.0	0.1	0.1	0.0000	0.0000	0.1
WT	2300.0	611.8	1688.2	1337.7	0.0274	0.0260	122.0
OT	89914.3	0.0	89914.5	33339.0	0.7777	0.8155	65.0

Uncompensated Own-Price (E_{ii}), Cross-Price (E_{ij}) and Income (E_y) Elasticities

	EY	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	0.7000	-0.4451	0.0000	-0.0046	-0.0111	-0.0158	-0.0132	0.0000	-0.0082	-0.2018
I = RS	0.7000	-0.0251	-0.4200	-0.0046	-0.0111	-0.0158	-0.0132	0.0000	-0.0082	-0.2018
I = ML	0.7000	-0.0251	0.0000	-0.4246	-0.0111	-0.0158	-0.0132	0.0000	-0.0082	-0.2018
I = MZ	0.8000	-0.0287	0.0000	-0.0053	-0.4927	-0.0181	-0.0151	0.0000	-0.0094	-0.2307
I = RC	0.9500	-0.0341	0.0000	-0.0063	-0.0151	-0.5915	-0.0180	0.0000	-0.0112	-0.2739
I = PN	0.8500	-0.0305	0.0000	-0.0056	-0.0135	-0.0192	-0.5261	0.0000	-0.0100	-0.2451
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.9500	-0.0341	0.0000	-0.0063	-0.0151	-0.0215	-0.0180	0.0000	-0.5812	-0.2739
I = OT	1.0487	-0.0376	0.0000	-0.0069	-0.0167	-0.0237	-0.0198	0.0000	-0.0124	-0.9316

Income Compensated Own-Price ($E_{ii}|_{y'}$) and Cross-Price ($E_{ij}|_{y'}$) Elasticities

	EI1	EI2	EI3	EI4	EI5	EI6	EI7	EI8	EI9
I = WS	-0.4018	0.0000	0.0033	0.0103	0.0210	0.0138	0.0000	0.0109	0.3425
I = RS	0.0182	-0.4200	0.0033	0.0103	0.0210	0.0138	0.0000	0.0109	0.3425
I = ML	0.0182	0.0000	-0.4167	0.0103	0.0210	0.0138	0.0000	0.0109	0.3425
I = MZ	0.0208	0.0000	0.0038	-0.4683	0.0240	0.0157	0.0000	0.0125	0.3915
I = RC	0.0247	0.0000	0.0045	0.0139	-0.5415	0.0187	0.0000	0.0148	0.4649
I = PN	0.0221	0.0000	0.0041	0.0125	0.0255	-0.4933	0.0000	0.0133	0.4159
I = CT	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
I = WT	0.0247	0.0000	0.0045	0.0139	0.0285	0.0187	0.0000	-0.5552	0.4649
I = OT	0.0272	0.0000	0.0050	0.0154	0.0314	0.0206	0.0000	0.0164	-0.1161

Table A9.1. (Continued).

Note: WS = white sorghum; RS = red sorghum; ML = millet; MZ = maize; RC = rice; PN = groundnuts; WT = wheat; and, OT = other goods and services. Income compensated and uncompensated own-price and cross-price elasticities were derived from limited data using the Frisch procedure, explained in Chapter VII. Income elasticies are taken from Chapter VII, Table 7.3. They are adapted from empirical studies, not derived from the estimation procedure.

VITA

VITA

Michael John Roth was born in Wamego, Kansas on December 25, 1951. He was graduated from Kansas State University with a B.S. in Agronomy in 1973, and a M.S. in Agricultural Economics in 1979. Mr. Roth served as a Peace Corps Volunteer in Malaysia from 1973 to 1975.