ECONOMIC ANALYSIS OF COTTON PRODUCTION

IN THE NORTHERN CÔTE D'IVOIRE

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CHAPTER I

INTRODUCTION

In the two decades following its independence in 1960, the Côte d'Ivoire experienced a fast pace of economic change. In the absence of mineral resources, the country has had to depend on agricultural (including forestry) exports to generate income and foreign currency needed to diversify its activities and its economy. Beginning with the First Five Year Development Plan (1967-70), the Ivorian Government adopted an economic growth plan based upon agricultural exports. To parallel the population growth, an average economic growth rate of 8 percent was to be achieved over the period. Goals of a 3.8 percent growth rate for the agricultural sector and a 15.4 percent in the industrial sector were established.

In agriculture, the strategy consisted of launching a diversification program of export crops to reduce the sensitivity of the economy to the international market price instability of the two traditional crops, coffee and cocoa. During the late 1960s and early 1970s, the long term strategic goal of economic diversification was pursued through the implementation of a wide range of projects and programs aimed primarily at expanding domestic agricultural and industrial production through more efficient and alternative uses of available resources. Crops such as oil palm, coconut, rubber, pineapple and banana, were introduced or developed in the forest zones of the South. Cotton and sugar cane were expanded in the North.

The Second Plan (1971-75) acknowledged the implementation and achievement of the objectives defined in the First Plan. However, a number of problems and deficiencies were diagnosed. A particular concern was the regional imbalances in economic growth. Growth in the northern areas had not progressed as rapidly as growth in other regions. The new strategy was to attempt to correct these disparities by 1980. A project that would intensify and increase both cotton and food crop production in the least privileged areas of the center and north was initiated.

The main project components included the strengthening of agricultural support services, land clearing, construction and improvement of roads, construction of a cotton gin and village wells, expansion of animal traction using oxen (ATO), and training. The Compagnie Ivoirienne pour le Développement des Textiles (CIDT), a joint venture between the Government and the French Compagnie Française pour le Développement des Fibres Textiles (CFDT), was assigned the responsibility for the implementation of the agricultural components of the project. Total project costs were estimated at 51 million U.S. dollars, to be financed by the World Bank (31 million), the Caisse Centrale de Coopération Economique (3.6 million) and the Ivorian Government (17.9 million), and to be disbursed over six years, from 1974 to 1980.

The basic technical package for cotton and food crop production was: 1) a rotational farming system whereby food crops would follow cotton, thus taking advantage of the residual effects of cotton fertilizer, and 2) improved cropping techniques, including optimal timing and density of planting, use of improved seeds, and suitable fertilization and weeding. Development of animal traction and introduction of small power tractors were to benefit food crops as well as cotton and to help resolve labor constraints. Research, training, preferential credit and input subsidies were some of the policy tools employed beside the technical assistance and land clearing, in pursuing the objectives. The food crops designated for technical assistance were rice, corn, and peanuts. However, yams, millet, and sorghum, which are component crops on farms in most of the areas involved, were also expected to benefit from the project.

At project closing, in March 1982, the economic rate of return (ERR) was estimated at 41 percent (47 percent at appraisal). The number of families benefiting from the project was 12 percent higher than estimated at appraisal. And farmers' incomes had increased by 150 percent in some categories to 500 percent in other categories. The Project Performance Audit Reports and Project Completion Reports document that the project has been relatively successful. However, some negative aspects and unanswered questions have been identified. Some of the concerns are as follows:

- The food component was significantly less successful in terms of adoption by farmers than the cotton component.
- Subsidies to cotton growers had risen beyond the financial capacity of the Government.
- Farmers seed more land area to cotton to qualify for subsidies but are not technically efficient in production.
- These concerns have resulted in the following research questions.
- Under land limitation and labor constraints, what, if any, is the degree of competition between cotton and food crops?
- Is cotton production likely to be severely affected by the elimination or reduction of subsidies?

Problem Statement

Farmers in the far northern Côte d'Ivoire, the Boundiali, Korhogo and Ferkessedougou (Ferké hereafter) areas have been the most concerned and involved in the cotton project from its start. For various reasons, adoption of the technological package has not reached satisfactory levels for most of the components. Land is not a major constraint in these areas. However, seasonal labor bottlenecks can limit the area that a household can cultivate and delay operations where timeliness is important. Because of the low level of chemical use in weeding and non-mechanized harvest, these two operations have been reported by the CIDT extension service as the most constraining operations in these areas (CIDT, Bureau des Enquêtes Statistiques, 1988). Discussions with CIDT extension workers have also revealed that delayed planting may result in substantial declines in cotton yields. A decadal (10 days) late planting from the optimal period may reduce the potential yield by 20 percent in the region. Farmers' records of planting dates show a delay in cotton planting relative to agronomic recommendations. These delays may result from either food crop competition or consideration of risk and uncertainty.

When the assumptions necessary for profit maximization, namely: 1) the presence of efficient markets, and 2) the absence or low level of risk and uncertainty, do not hold, the traditional African farmer is characterized as conservative with a high rate of leisure preference. Early literature was dominated by examples of backward bending supply curves for wage labor or cash crops (Byerlee and Eicher cited in Kajumulo-Tibaijuka, p. 12). The CIDT has offered assistance in both the production and marketing of cotton to the northern farmers. However, it is not clear how responsive the farmers have been to the different incentives. Although efficiency is an ambiguous and complicated concept, the World Bank study brings into question the technical efficiency component of production in the region.

Generally, small farmers are trying to fulfill two main objectives. One is to meet family subsistence. The other is to earn money income to meet cash requiring obligations such as education for children and new equipment. The first objective is common to all. The second objective depends on the level of integration of the individual family into the market economy, which may reflect attitudes toward modernization.

Objectives of the Study

The overall objective of the present study is to use the available limited data to test hypotheses and evaluate issues raised for the Boundiali, Korhogo, and Ferké farmers. Specifically, the objectives of the study are: 1) to estimate the supply response of the northern cotton farmer; 2) to investigate the possibility of a rainfall related justification for the delay in planting; 3) to investigate the technical efficiency of cotton farmers; and 4) to develop a simplified optimal farm plan taking into account the major agricultural activities in one area.

Sources of Data

The data used in this study were abstracted from various issues of published and unpublished materials from the Ministry of Agriculture, the CIDT, the National Agency of Aeronautics and Meteorology (ANAM), the World Bank, the International Financial Statistics of the International Monetary Fund (IMF), and the FAO. Discussions with the CIDT General Manager, the extension service, and farmers from Niellé in the Ferké areas have provided estimates for some statistics.

Because of the diversity of the objectives, the methodology exercised here is one which used several analytical techniques: multiple regression analysis for objectives one and three; probability distribution fitting for objective two and linear programming for four.

Organization of the Study

Chapter II contains a description of the environment within which the study took place, including characteristics of the Ivorian Agriculture, the farming systems, and the cotton project impact in the area under study. In Chapter III, the supply response of cotton farmers is investigated. Chapter IV includes an analysis of optimal planting dates in the Boundiali area for cotton. Technical efficiency among the Niellé cotton farmers in the Ferké area is the subject of Chapter V. Results of a simplified linear model which is used to determine optimal farm plans for the Niellé are reported in Chapter VI. The final chapter includes a summary of findings and proposals for further research. Each analytical chapter is organized so as to: 1) introduce the theme under consideration in the chapter; 2) to describe the model to be used based on previous studies; and 3) present empirical results and discussions.

CHAPTER II

AGRICULTURE IN THE NATIONAL ECONOMY AND IN THE NORTHERN CÔTE D'IVOIRE

Introduction

The Republic of Côte d'Ivoire, on the south coast of the western bulge of Africa, has an area of 322,463 square kilometers (124,503 square miles). It extends 808 km (502 mi) SE-NW and 780 km (485 mi) NE-SW and is bordered on the North by Mali and Burkina Faso, on the East by Ghana, on the South by the Gulf of Guinea and the Atlantic Ocean, and on the West by Liberia and Guinea. Except for the prolongation of the Guinea Highlands in the Northwest which has a high point of 1,752 meters (5,840 feet), the greater part of the country is a vast plateau, tilted gently toward the Atlantic Ocean. It is drained by four major seaward rivers running roughly parallel from north to south -- the Cavally (600 km) on the Liberian frontier, the Sassandra (650 km), the Bandama (950 km), and the Comoe (900 km).

The climate is tropical with four seasons in the south and in the central forest region and two seasons in the northern savanna region. In the coastal region the long dry season lasts from December to mid-May, followed by the great rainy season from mid-May to mid-July, then the short dry season from mid-July to October, and finally the little rainy season from October to November. In the central forest region, June-October and March-May are wet periods and July-August and November-March are dry. Farther north, only the period June-October is wet and the rest of the year is dry. The coastal region receives an average annual rainfall of 2,100 millimeters (82.7 inches). The rainfall decreases to 1,800 millimeters (70.9 inches) in the central forest and can go as low as 600 millimeters

(23.6 inches) in the northern region. Humidity corresponds to the rainfall and is highest in the south during the rainy season (up to 90 percent). Temperatures are related inversely to the rainfall and progress from an annual average of 23°C to 26.6°C (73 to 80°F) in the coastal region to 32 to 34.4°C (90 to 94°F) in the northern areas. The prevailing wind systems are the southwest monsoon and the northeast harmattan, a dry, scorching wind from the Sahara.

Based on the last official census held in 1985, the population was 9,810,000 and is expected to reach 11 million in 1990 with an annual growth rate of 3.8 percent. About 53 percent of the population is 20 years old or younger. The population is also characterized by a strong ethnic diversity unevenly distributed with heavy concentrations in the south-central and southeastern parts of the country. The northeastern and southwestern parts remain virtually uninhabited. The official language is French although 60 locally spoken languages exist in the country. Movements to cities has been a problem in recent decades. The proportion of urban dwellers has increased from 6.3 percent in 1950 to 42.7 percent in 1985. The former capital, Abidjan has an estimated population of 2,000,000. Flourishing economic activity over the period 1960-1980 has attracted large numbers of workers from neighboring countries. The foreign population was estimated at 2,000,000 Africans (non Ivorians), 100,000 from the Middle East, and 50,000 Europeans.

Agriculture in the Economy

Côte d'Ivoire achieved a relatively remarkable rate of economic growth between 1960 and 1980. GDP increased, in real terms, by an annual average of 11 percent in 1960-70 and 6 to 7 percent in 1970-80, which brought the country into the ranks of middle-income developing countries. During the early 1980s, however, growth rates declined as a result of a weakening in international prices for the country's major export commodities and the serious drought of 1982-84. GDP rose by only 0.2 percent in 1982 and fell by 2 percent the next two years. After a short recovery in 1985, a one percent drop was experienced in 1987.

Although the Ivorian economy is relatively diversified, it remains dependent on agriculture, which accounts for about one-quarter of the GDP. On a macro-scale, the functions of agriculture can be summarized as follows: 1) provision of food for the population; 2) supply of foreign exchange and government revenue; 3) contribution to GDP; and 4) source of employment and livelihood.

Provision of Food for the Population

Most food crops are produced on small, semi-subsistence farms in the country. Fifty-five percent of the total food crop production (1985) is consumed by the producers and their families. The primary objective of many farmers is to sustain the family. The inability of official institutions to efficiently store, transport, process, and distribute food crop production has often resulted in large imports of rice. In 1960, 30 percent of the domestic consumption of rice was imported. In 1985, 70 percent of domestic consumption was imported even though over 400,000 hectares of lowland and upland rainfed rice were grown. Inefficient distribution of available production and large post-harvest losses for other crops plague the economy.

Corn is produced in all ecological zones. Poultry and livestock sectors are being developed to use the corn. Increases in total area planted to corn is expected to occur in the future until self-sufficiency is achieved. Other cereals produced, but with limited demand, include millet, sorghum, and fonio (Digitaria exilis). These crops are grown in the savanna area of the north and used in the diet of the local populations. Yams are grown in the north, northeast, and central part of the country. Potatoes, sweet potatoes, cassava, coco yams, banana plantains, and peanuts are other food crops produced on family farms. Table 1 includes estimates of production for these crops for 1984-1986.

Table 1. Principal Food Crop Productions 1984-86 ('000 metric tons).

Crops	1984	1985	1986*
Corn	468	530	550
Millet	30	40	35
Sorghum	20	25	20
Rice (Paddy)	490	541	460
Potatoes	24	24	24
Sweet Potatoes	12	12	12
Cassava	1230	1500	1500
Yams	2600	2900	2996
Coco Yam	202	235	235
Peanuts (in shell)	98	80	86
Tomatoes	31	32	35
Eggplants	19	19	19
Bananas	148	170	170
Plantains	229	298	300
Other Vegetables	336	369	381

* FAO estimates.

Source: FAO, Production Yearbook 1985.

Supply of Foreign Exchange and Government Revenue

Agriculture contributes directly to foreign export exchange earnings and government revenue through either exports and export taxes, or profits earned by the state marketing agency, the CSSPPA (Caisse de Stabilisation et de Soutien des Prix des Produits Agricoles). The major cash crops are coffee and cocoa, which together provide about 50 percent of the country's export earnings. Coffee is grown in the southern and central parts, almost entirely on small holdings. Plantings occupy about 1,200,000 hectares on 200,000 farms. Production has often exceeded the country's international agreement quota. The Country is the third leading producer and exporter of coffee in the world. Since the early 1970s, cocoa production has increased markedly as a result of substantial area increase (497,000 hectares in 1974 to 953,000 hectares in 1984). Cocoa is the nation's leading cash crop and the Country is the world's leading producer and exporter.

Despite a downtrend in recent years because of over exploitation, exports of wood and wood products are another major component of trade. Agricultural diversification activities has developed palm products, rubber, pineapple, cotton, sugar cane, and banana. However, the traditional two primary commodities, coffee and cocoa, remain dominant as their share of exports still accounts for about 50 percent. The economy is highly sensitive to the international market for these two commodities (Table 2 and Figure 1).

The CSSPPA acts as a monopsony for coffee, cocoa, cotton, and sugar. The producer price is set based on three criteria: the available reserves of the CSSPPA, the international market outlook, and a profit price level for farmers. In practice, the prices of cocoa and coffee usually have been set well below the international average and the differential is collected by the marketing agency for future development funds.

Except for cotton and sugar cane, all of the other exportable crops are grown in the forest regions. Cotton is the only small farm produced cash crop in the North since sugar cane is grown on government owned and operated large holdings. To reduce the regional

Table 2. Primary Agricultural Commodities' Shares of Total Exports, 1980-1985 (Percent).

Exports	1980	1981	1982	1983	1984	1985
Coffee (raw and processed)	21.8	19.1	22.2	16.8	16.8	22.6
Cocoa (raw and processed)	29.4	33.7	26.6	25.3	39.5	36.9
Total Coffee/Cocoa	51.2	52.9	48.8	47.2	56.2	59.6
Cotton	2.2	2.6	2.4	4.0	2.8	2.5
Others	7.5	7.5	6.3	7.7	6.4	7.2
Total Export Crops	58.8	60.4	55.1	54.9	62.65	66.7
Woods	17.4	12.9	11.8	12.5	9.2	6.9
Other Products	23.8	26.7	33.1	33.5	28.2	26.4
Total	100	100	100	100	100	100

Source: Ministère de l'Economie et des Finances. La Côte d'Ivoire en Chiffres 1986-87. Inter Afrique Press 1988.

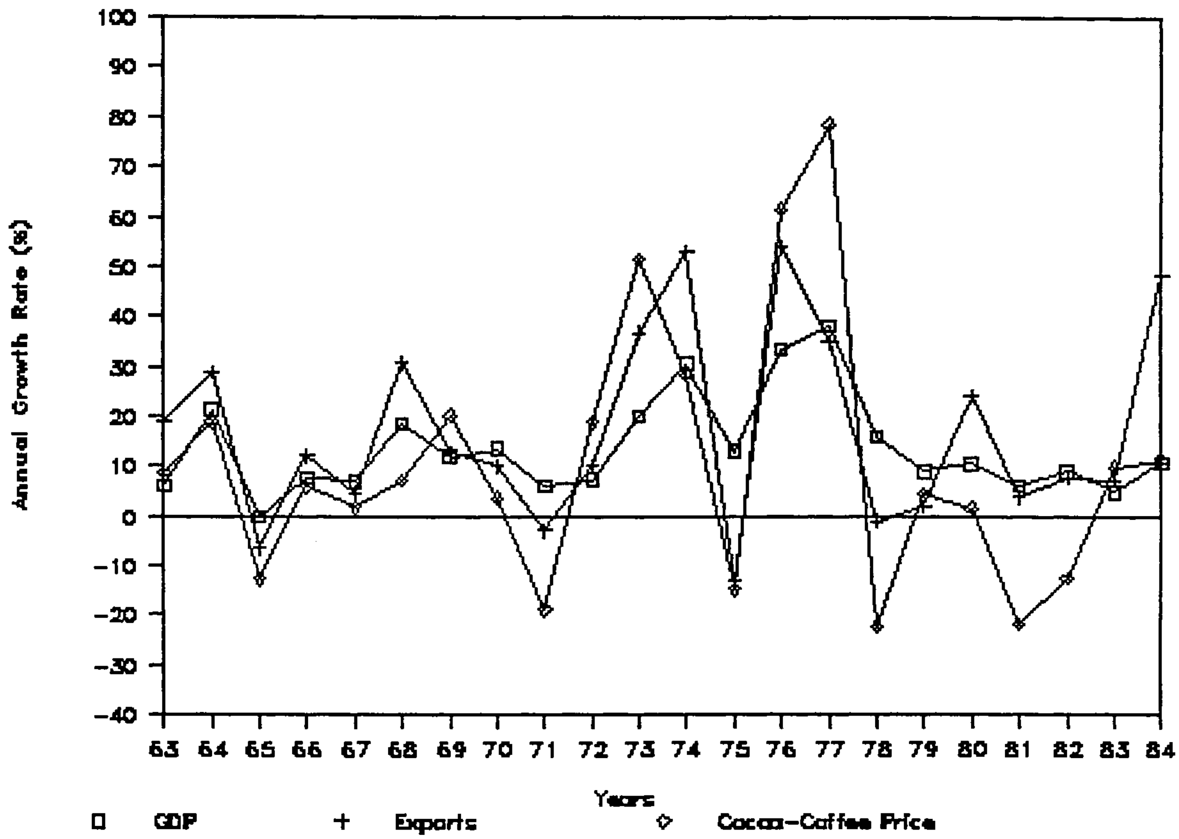

Figure 1. GDP, Exports and Annual Average Cocoa and Coffee Price Trends.

disparities, cotton production has been subsidized. However, its share of exports remains small.

Contribution to Gross Domestic Product

The data included in Table 3 show the size of the various agricultural components of the economy relative to GDP at current market prices. The impact of the drought of 1982-1984 on the annual growth rate is apparent. Nevertheless, agriculture represents over 25 percent of GDP, and employs about 60 percent of the economically active population.

Livestock production was not traditionally developed and is relatively insignificant in the Country. Consequently, despite the launching of cattle, sheep, and poultry projects in recent years, domestic livestock products are far from covering the domestic demand. Beef is imported mainly from the neighboring countries of Mali and Burkina Faso.

Agriculture in the Northern Côte d'Ivoire

The development of cotton production has played a major role in the agricultural activities in the northern part of the Country over the last three decades. The scope of intervention of the CIDT comprises 12 sectors. Each sector is divided into zones in Figure 2. In the present section and following chapters, the northern Côte d'Ivoire will refer to the three sectors of Boundiali, Korhogo, and Ferké.

Cotton in the Farming System in the Northern Region

Before the expansion of commercial cotton production in the area, rainfed rice, millet, sorghum, corn, yams, and fonio were the major crops. In an effort to achieve self-sufficiency, irrigated rice was introduced in the early 1970s. Although these crop production activities have not been displaced by cotton, yields have not significantly improved except for corn.

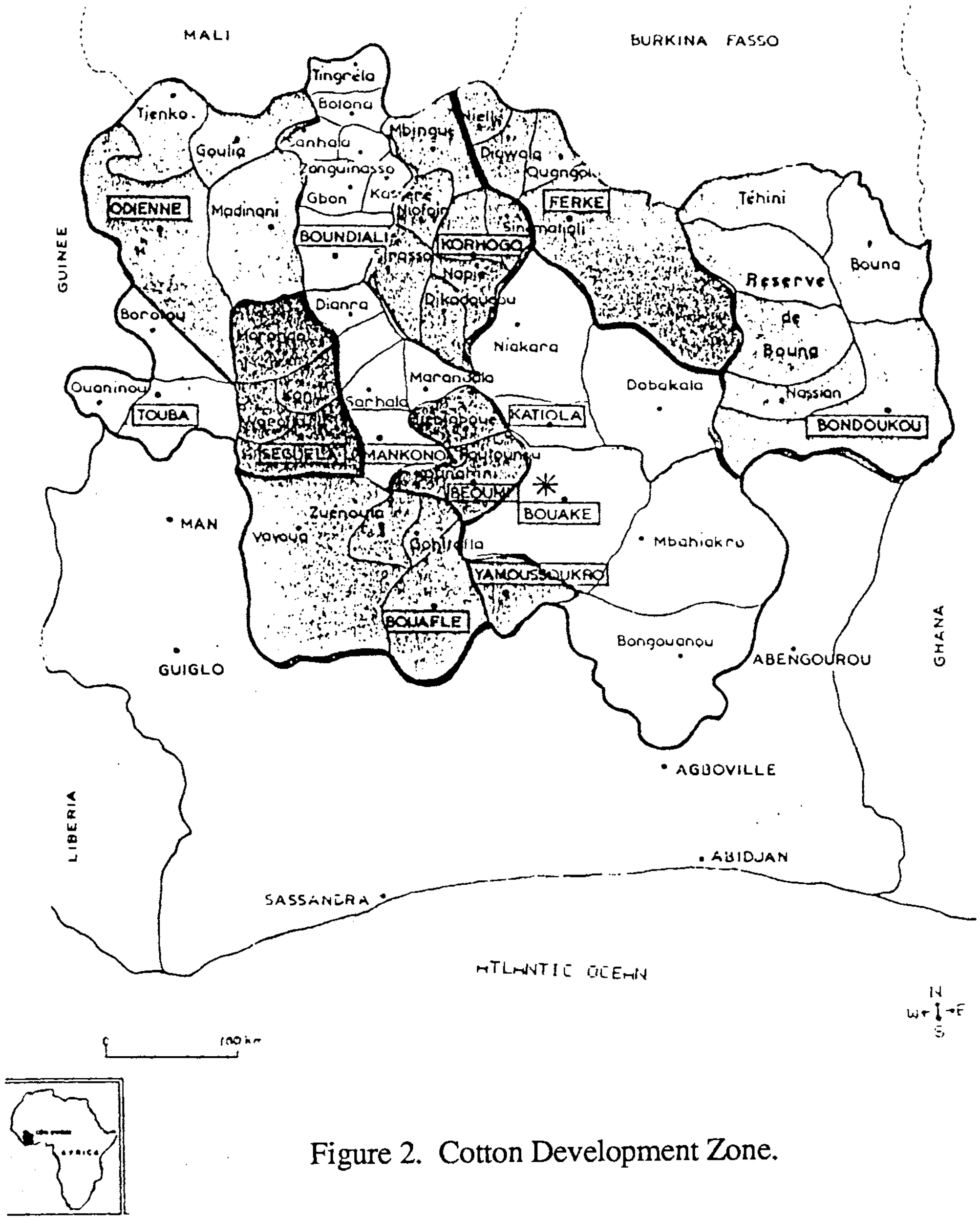

Figure 2. Cotton Development Zone.

Table 3. Agricultural Added Value (Percent) and GDP at Current Market Prices (Billions CFA F) 1980-1985.

	1980	1981	1982	1983	1984	1985
GDP	2150.0	2291.4	2486.5	2605.9	2883.3	3137.6
Food Crops	313.4	318.4	334.0	356.4	432.3	406.2
Export Crops	226.3	270.8	255.3	202.4	282.8	357.3
Forestry	59.8	49.8	51.2	60.2	58.2	53.9
Fishery	16.7	18.8	10.6	11.4	15.1	16.1
Total	616.3	657.9	651.1	630.4	788.4	833.5
Annual Growth Rate	14.1	6.3	-1.0	-3.2	25.1	5.7
Ag. Sector/GDP	0.287	0.287	0.262	0.242	0.273	0.266

Source: Ministère de l'Economie et des Finances. La Côte d'Ivoire en Chiffres 1986-87. Inter Afrique Press 1988.

In general, the term family is used to refer to the extended family where several brothers may farm together on common fields with their wives and children and other relatives. However, each member may also operate an individual field. Livestock production is absent. However, wealth is often converted into cattle placed under the supervision of hired Fulani herders. Fulfilling subsistence needs is the primary objective and little from the production of food crops is marketed. The major source of cash is cotton. However, in years of abundant rainfall, output may increase and surplus of food can be sold.

Labor is the binding constraint. No significant landless class of laborers exists in the region. However, transient workers from Mali or Burkina Faso, are available at times during their migration to the South. A survey by the CIDT (1986) has established a relationship between family size and type of farming. Small families tend to be manual cultivators (operations are executed using traditional hand tools such as hoes). Manual family farms have average sizes of 4.4 (Korhogo), 7.4 (Ferké), and 6.3 members (Boundiali). Families which use animal traction are larger and average 10, 13.9 and 9.6 members, respectively. Intermediate mechanization, using tractors, is practiced by large families of 26, 20.1, and 30.1 members. The role of women is very important in food production. Labor constraints limit farm sizes as shown in Table 4.

One major purpose of farm mechanization is to alleviate labor bottlenecks. Ox and tractor power can make possible more timely farming operations and increase production. However, acquisition of an ox may not result in improvements in labor availability. Some operations are still executed manually and the larger area planted requires more labor for these operations.

No land is sold or bought. In each village, land is vested in the "land's owner" often different from the chief of the village. The land is allocated to heads of households with rights of usufruct only. Immigrants may be granted land, but without security of tenure.

Table 4. Average Farm Size in the Boundiali, Korhogo and Ferké Areas, 1985-1986 (ha).

Area	Manual Farming	Animal Traction	Intermediate Mechanization
Boundiali	3.89	5.43	15.38
Korhogo	2.37	6.82	25.86
Ferké	4.37	7.77	22.47

Source: CIDT, Annual Report, 1984-86.

Manual farming involves little capital except for household food stock, wage funds, and hand tools replacement. Animal traction, intermediate and conventional mechanization, require more capital. Medium term credit for purchase of both animal traction and tractors and short term credit for inputs are available either through the CIDT or a farmer cooperative like organization (GVC).

Both pure stand and mixed cropping are practiced in the area. Farmers argue that mixed cropping can reduce labor constraints, weeding requirements, and land constraints in some cases. Several rotations have been identified. In the Tingrela zone, for example, the most common rotations can be classified in three categories: 1) fallow followed by four years of cropping; 2) fallow followed by three years of cropping; and 3) fallow followed by two years of cropping. Cotton, millet, sorghum, corn, and peanuts enter the cropping system. Rice is produced on lowlands and does enter the system in this area. The rotation may start with any crop other than peanuts.

Impact of the Cotton Project

A summary of trends in the adoption of recommended cotton production techniques in the whole area is included in Table 5. Progress in food crops has been less pronounced than with cotton (Table 6). Weed control remains mostly manual. Several factors may explain this phenomenon. Small farms rely upon labor from farm members in lieu of cash for herbicides. In addition, the involvement of women, who benefit less from technical assistance in food crop production (especially groundnut), and the market structure for food crops may explain low rates of herbicide adoption.

Low prices and difficulties in transportation are disincentives that limit market oriented farming. The observed increase in food crop area may be attributed to increases in the number of individual fields. No pesticide is applied to corn although disease and pest infestations are common. An often mentioned impediment to adoption of new technology by small farms relates to fixed cost of implementation. The theoretical literature suggests that large fixed costs reduce the tendency to adopt and slow the rate of adoption by small farms (Feder et al.). The adoption of new agricultural technology may require the adopter to accept a greater degree of risk and uncertainty. Farmers are often reluctant to use short term credit for input purchases because they fear that rainfall might affect production and they might not be able to repay the loan. Consequently, although they acknowledge the efficiency of chemical weeding, they usually treat only a small portion of the field and the remainder is done manually.

One of the achievements of the cotton project was the formation of village groups in cooperative like organizations (GVC). These GVC have the tasks of collecting, grading, weighing, and loading the group cotton production for the CIDT. Payment to the GVCs for their service are used to cofinance collective investment with the government such as health centers, schools, and maternity centers.

Table 5. Adoption of Recommended Techniques for Cotton in the Northern Côte d'Ivoire.

Region	Year	No. of Farmers	ATO Farmers (%)	Cultivated Area (Ha)	Fertilized Area (%)	Herbicided Area (%)	Optimal Date Planting (%)	Planting Density (%>70000/Ha)	Yield Distribution(%) <1000 kg/Ha	Yield Distribution(%) >1400 kg/Ha
Boundiali	1981/82	13,991	25.3	19,089	100	6.50	32.3	58.2	41.5	27.3
	1985/86	12,482	34.1	18,961	100	31.5	17.8	67.4	32.7	29
Korhogo	1981/82	20,785	14.1	29,025	100	3.4	38.2	33.9	54	17.8
	1985/86	19,995	24.8	34,247	99.5	24.7	13.1	66.4	43.1	24.2
Ferké	1981/82	8,688	30.9	17,300	100	13.2	30.7	37.1	60.4	12.1
	1985/86	9,254	35.1	19,146	98.8	31.9	29.2	78.2	31.6	38.2

Source: CIDT, Annual Reports, 1982, 1986.

Table 6. Adoption of Recommended Techniques for Major Food Crops in the Northern Côte d'Ivoire 1985-86.

Region	Crop	Number of Farmers	ATO Farmers (%)	Cultivated Area (Ha)	Fertilized Area (%)	Herbicided Area (%)	Insecticide Area (%)
Boundiali							
	Rainfed Rice	5,077	34.0	6,015	21.2	33.0	
	Irrigated Rice	83	68.7	80	100	23.7	37.5
	Corn	9,613	41.1	14,809	17.3	13.9	
	Peanuts	8,354	39.4	10,808	0.2	11.0	
Korhogo							
	Rainfed Rice	7,042	43.2	8,280	44.2	56.4	
	Irrigated Rice	9,448	0.5	6,074	78.6	6.0	47.6
	Corn	9,774	38.9	9,709	32.2	18.8	
	Peanuts	7,749	29.0	5,937	0.2	3.8	
Ferké							
	Rainfed Rice	1,469	82.6	1,400	56.0	47.6	
	Irrigated Rice	219	0	259	100	12.2	60.2
	Corn	6,090	46.6	11,105	27.5	23.0	
	Peanuts	2,703	52.1	3,405	0.0	0.2	

Distribution of inputs and cotton revenues are also assumed by the GVCs. Since 1983 at least 80 percent of the cotton production in the northern area has been marketed by the group.

A comparison of the three areas singles out the Ferké area as achieving the best performance in technology adoption. This result may be explained by the relatively smaller number of farmers in the Ferké areas as compared to the two other regions.

CHAPTER III

COTTON SUPPLY RESPONSE IN THE NORTHERN CÔTE D'IVOIRE

Introduction

In view of the importance of the agricultural sector for growth, best suitable policies for production stimulation are crucial for the Côte d'Ivoire. Since the early 1970's, the cotton sector has experienced a program of farm mechanization (conventional, intermediate, animal traction), input subsidy policies (pesticides, fertilizers) and government control over the cotton market. The fertilizer subsidy was removed in 1984.

A study by the World Bank, while acknowledging the relative success of the program, concluded that it has resulted in increased hectarage with little gain in yield per land unit. The program was launched in the northern region to reduce the income disparities with the south where perennial crops such as cocoa and coffee provide substantial revenues to farmers.

Some economists attribute the poor performance of African agriculture to either inadequate pricing policies or to a very risk averse subsistence sector which often results in perverse supply response (Bond). Farmers' response to price change reflects their flexibility in the use of production inputs, which has welfare and other policy implications.

The cotton program was essentially designed to benefit the northern farmer. It is of relevance to know how farmers in the region have responded to the different incentives.

Literature Review

The problems involved in modeling the response of crop production or hectarage to changes in output prices and other variables have concerned researchers for decades. Several streams of research have been pursued. But, judging by the number of related studies since the late 1950's, Nerlove's seminal formulation of agricultural supply response (1956, 1958) is certainly one of the most successful econometric models introduced into the literature. The surveys of Askari and Cummings (1976, 1977), and Henneberry provide clear evidence. The traditional Nerlovian model, which was originally formulated to evaluate the dynamics of supply in U.S. Agriculture, is as follows:

$$Q_t^* = a_0 + a_1 P_t^* + a_2 Z_t + u_t \tag{1}$$

$$P_t^* - P_{t-1}^* = \delta (P_{t-1} - P_{t-1}^*) + v_t \tag{2}$$

$$0 < \delta \leq 1$$

$$Q_t - Q_{t-1} = \lambda (Q_t^* - Q_{t-1}) + w_t \tag{3}$$

$$0 < \lambda \leq 1$$

In equation (1) it is assumed that the long-run equilibrium supply (Q_t^*) is a linear function of the expected price (P_t^*) and some other exogenous factors affecting supply at time t (Z_t).

Equation (2) implies that the expected price is adjusted in each period by a proportion of the difference between the previous period's actual price (P_{t-1}) and its expected price (P_{t-1}^*). The coefficient of expectations (δ) is associated with price uncertainty.

Equation (3) reflects the supply adjustment towards the long-run equilibrium supply. The coefficient of adjustment (λ) indicates the proportion of adjustment occurring in one time period. The justification for this coefficient is the time necessary to change fixed factors of production.

Manipulations on the three equations by elimination of the unobservable variables (Q^* and P^*) yields the reduced form:

$$Q_t = b_0 + b_1 P_{t-1} + b_2 Q_{t-1} + b_3 Q_{t-2} + b_4 Z_t + b_5 Z_{t-1} + e_t \tag{4}$$

where:

$$b_0 = a_0\delta\lambda \; ; b_1 = a_1\delta\lambda \; ; b_2 = 2 - \delta - \lambda \; ; b_3 = -(1-\delta)(1-\lambda); b_4 = a_2 \; ; b_5 = O_2\,(1-\delta)\lambda$$

In the absence of price uncertainty (for example, when the government announces prices) the coefficient δ takes on the value 1 and the reduced form (4) becomes:

$$Q_t = c_0 + c_1P_{t-1} + c_2Q_{t-1} + c_3 Z_t + e_t' \quad (5)$$

Estimation of the coefficients in equation (5) can be used to determine elasticities of supply with respect to the different variables in the model by the formula:

$$e_i = c_i \frac{\bar{X}}{\bar{Q}}$$

where $\bar{X}$ is the mean value of the relevant variable (P_{t-1}, Q_{t-1}, Z_t), $\bar{Q}$ the mean value of the output over the period under consideration and c_i is the corresponding estimated coefficient. When equation (5) is expressed in double-log form, the estimated coefficients are the short-run elasticities.

The large body of work on the application of the Nerlovian model in developing countries can be found in the studies by Askari and Cummings, Henneberry, and Bond and are not repeated in this study. It should be noted that none of these studies were on cotton supply response in the Côte d'Ivoire.

The econometric procedure used to estimate the adaptive expectation Nerlovian model has been strongly criticized (Baltas; Braulke; Colman; Jennings and Young). Ordinary Least Squares (OLS) are usually applied to equation (5). Some critics have expressed concern over the statistical problems which arise when using OLS. Others have questioned the adaptive expectations assumptions of the model. Muth criticized Nerlove's model in the light of his rational expectations model. The model was modified to consider rational expectations.

The second avenue of supply response analysis considered is mathematical programming. It has had few applications in developing countries and has limitations as well (Colman). Introduction of risk related variables in supply modeling is a growing field of study (Behrman; Just; Wolgin; Adesina and Brorsen).

Most studies on supply response in developing countries actually model hectarage rather than output responses. Hectarage is used as a proxy for output for two reasons. First, in an adaptive expectation framework, actual output may differ considerably from the desired output due to important environmental factors which are beyond the farmers' control. Ashakul hypothesized that in a drought year, production of a certain crop may be scarce, and as a result, price of that crop is pushed higher. There is a possibility that rainfall in the next year will be normal and hence, the supply will increase from the previous year. This situation might be incorrectly interpreted as a positive response to price change. Consequently, hectarage response is viewed as a better proxy for output. The second reason for the use of hectarage in lieu of output is based on the relation between output, hectarage and yield:

$$Q = A \bullet Y \tag{6}$$

where

Q = output, A = hectarage, Y = Yield;

From the relation, by differentiating with respect to any explanatory variable (say, price of output P), equation 6 yields:

$$\partial Q/\partial P = Y\partial A/\partial P + A\partial Y/\partial P \tag{7}$$

Assuming constant returns to scale (i.e. an increase in inputs will raise output by the same proportion), and multiplying (7) by P/Q, a relation between elasticities is defined as:

$$E_{qp} = E_{ap} + E_{yp} \tag{8}$$

where:

E_{qp} = elasticity of output (Q) with respect to price (P);

E_{ap} = elasticity of hectarage (A) with respect to price; and

E_{yp} = elasticity of yield (Y) with respect to price.

Dynamic models have ignored the elasticity of yield because of the low yields in developing countries as compared to the price variabilities experienced. Hence, the output response studies are conducted as hectarage response studies. However, in a period of rapid yield growth (induced by yield-augmenting technical changes such as irrigation, fertilizers and modern varieties), the determinants of output, hectarage and yield, would respond to price changes. It is only logical to conclude that at the early age of development in developing countries where land is abundant, farmers will respond to output price increases by expanding their planted area since land is easy to access. However, when the availability of marginal land to expand is a limiting factor, output response will be more linked to yield increase through alternative production practices. Input application rates depend on returns and costs. Economic theory suggest that costless (fully subsidized) inputs should be applied at a level per land unit until the marginal product is zero.

Model Specification

Under the assumption of response from the two determinants of output, hectarage and yield, one equation is defined for each component.

Hectarage Response Model

The primary interest of a supply response analysis is the price responsiveness. Therefore, the construction of adequate price indices is of great importance. Farmers in the area under study are expected to respond readily to changes in the price of cotton for two reasons. First, the guaranteed price system which has been applied to the sector is probably associated with less uncertainty at least in the short-run. Second, even though in some cases payments are delayed, the CIDT purchases all cotton produced. Past studies have considered different formulations for the price to be used in the model:

a) the absolute price of the crop actually received by farmers;

b) the price of the crop received deflated by some consumer price index;

c) the price of the crop deflated by some input index; and

d) the price of the crop deflated by some index of the prices of competitive crops.

Choice (a) would imply that farmers are under money illusion and respond by considering absolute price. This may be the case when dealing with a less monetized society. Choice (b) assumes that the farmer weighs potential revenue and cost of living. The weakness of this measure is that often the available consumer price index does not reflect the cost of living of the farmers under consideration. Choice (c), although more appropriate, poses the problem of interpretation of the coefficient once the estimation is achieved. Choice (d) also has the same concern but raises a more serious issue; sometimes the other crops compete for land but not for the objective of generating higher revenue. The market conditions of these crops may be less favorable even with higher prices. Including these prices as separate explanatory variables is more convenient. Rather than the prices, considerations can also be given to hectarages of the competing crops. In the areas under study, the competing crops are essentially food crops and are as follows:

•Boundiali: corn, peanuts, sorghum, millet;

•Korhogo: upland rice, yams, corn; and

•Ferké: corn, yams, upland rice.

Along with cotton price and the prices of competing crops, input prices may enter the model. Labor, fertilizers, pesticides, and machinery and equipment are the major inputs to account for in cotton production in these areas. Most of the labor is provided by the family except during harvest time when hired labor is necessary; casual labor may be required for weeding when herbicides are not used. The prospect of high cost labor at harvest (when the quantity of labor demanded is relatively high) may cause the farmer to reduce the hectarage to be planted. The average daily wage for unskilled labor in the cotton sector is considered as the relevant explanatory variable for labor cost. Because of the subsidy policy for fertilizers over the period 1977/78-1983/84, a dummy variable assigned a value of one during this period and zero otherwise is included in the model to incorporate the impact of the policy on the cotton supply in these regions. Because at least 70 percent of the farmers still practice the traditional farming as compared to the use of animal traction and tractors, including machinery cost would be inappropriate; but the impact of technology should appear in the model.

Improvements in technology are important factors of long-term shifts in agricultural supply functions. Tomek and Robinson defined an improvement in technology as something that enables firms to produce more output with the same quantity of inputs as previously. In technical terms, it shifts the production function upward so that producers will find it profitable to increase output at the same ratio of product to factor prices. Baltas has classified the shifters into two groups. First, the most important shift may be due to the introduction of new varieties. Second, more gradual technological improvements may take place (new cultivation practices, higher fertilizer use). When the new techniques are continuously and smoothly introduced, the instrumental variable used to capture technology has traditionally been a time trend. But Whittaker and Bancroft argued that if technology does not advance linearly then models accounting for technology with a linear trend are misspecified and likely will contain biased coefficients. In the cotton sector in the Côte d'Ivoire, the linear trend variable is justified by the two estimated equations below:

$$PCF = -701.158 + 0.4TIME + 4.33D \qquad (9)$$

$$(4.18) \qquad (4.25)$$

$$R^2 = 0.77$$

where

PCF = percentage of fertilized hectarage each period;

TIME = 1970, 1971,. . .1987;

D = 1 for TIME = 1978 - 1984, 0 otherwise; and

$$PCATO = -3498.22 + 1.775\ TIME \qquad (10)$$

$$(13.22)$$

$$R^2 = 0.91$$

where

PCATO = percentage of hectarage under animal traction.

The values in parentheses are t-statistics. The estimated coefficients are significant at the 1 percent level.

Another factor to account for in modeling supply response in developing countries is the weather. The most tangible factor weighing in the farmer's decision to plant or not is the rainfall amount. In the northern areas, farmers spread cotton planting during the months of June and early July to reduce the risk of failure of the crop and also to seed other crops entering their farming system. June rainfall is considered as primordial in the success of a crop year. The more it rains in June, the larger the hectarage is expected to be.

The uncertainty aspect is often introduced in models in a different manner. Instability in prices, yield and incomes are receiving more consideration from researchers. In his study on Thailand, Behrman included the standard deviation of the price of the crop of concern over the last preceding production periods relative to the standard deviation of the index of prices for alternatives over the same period; also the standard deviation of actual yield over the last preceding periods were conceived as a major risk variable. Adesina and Brorsen considered a weighted moving average of squared deviations of expected prices and actual prices. The expected prices were assumed to be the prices of the previous period.

This study uses both the standard deviation of cotton yield and the standard deviation of the revenue per hectare over the last three periods to account for farmers' attitude towards risk.

In summary, the overspecified hectarage model including all the variables is as follows:

$$A_t = f(A_{t-1}, PC_t, PA_{it}, Lab_t, t, W_t, R_t, e_t) \quad (11)$$

where:

A_t = area planted to cotton in period t (ha);

PC_t = expected producer price of cotton in period t (CFA F/kg);

PA_{it} = expected producer prices of competing crops in period t (CFA F/kg);

Lab_t = daily labor wage for unskilled labor (CFA F/day);

t = time, t = 1970, 1971,. . .1987;

W_t = total rainfall in June in period t (mm);

R = risk variable; and

e_t = disturbance term.

The expected producer prices and the labor cost are assumed to be the previous period prices deflated by the consumer price index (CPI). Assuming that the long-run desired level of planted hectarage is a log-linear function of expected prices, weather and level of technology, and also that the rate of growth of the long-run supply is an exponential function of the ratio of actual supply in the current period to the desired supply in the previous period, the hectarage response equation may be expressed in a double-log formulation:

$$L_n A_t = \alpha_o + \alpha_1 L_n A_{t-1} + \alpha_2 L_n PC_{t-1} + \alpha_3 L_n PA_{t-1} + \alpha_4 L_n Lab_{t-1} + \alpha_5 t + \alpha_6 W_t + \alpha_7 R_t + e_t \tag{12}$$

where $\alpha_{is'}$ are parameters to be estimated. They have the following expected signs: a higher expected cotton price will result in an hectarage increase ($\alpha_2 > 0$); but when expected competitive crops prices or labor wage are raised, a reduction in the planted hectarage is likely to occur ($\alpha_3 < 0$, $\alpha_4 < 0$). Some technology improvements, such as animal traction or conventional mechanization tend to expand hectarage ($\alpha_5 > 0$). As stated previously, rainfall during the planting period has a positive impact on hectarage ($\alpha_6 > 0$); and finally, because of their aversion for risk, farmers are expected to reduce hectarage with higher risks ($\alpha_7 < 0$).

The Yield Function

A comparison of the averages of cotton yield over the periods 1965-1970 and 1980-1987 shows an increase of 40 percent in the Boundiali area, 46 percent in the Korhogo area and 43 percent in the Ferké area. Over the same periods, the nominal price of cotton increased by 183 percent (Table 7). Is the increase in yield the result of the pricing policy and/or the technology package? The answer to this question may be found in the yield equation relating cotton yield to price, technology and other relevant factors such as climatic variables. Rainfall during the growing period of the plant is a suitable variable for climatic conditions. As in the hectarage equation, technology adoption is represented by a time trend. The effect of the fertilizer subsidy may also be estimated. Since the price of cotton is known well before the end of the crop year, it is reasonable to use the actual price in the model. The yield model may be summarized as:

$$Y_t = g(PC_t, t, GR_t, D, u_t) \tag{13}$$

Table 7. Five Year Average Cotton Yields (kg/ha) and Producer Price (CFA F/kg)

Period	Boundiali Cotton Yield	Korhogo Cotton Yield	Ferké Cotton Yield	Cotton Price
1965-70	879	785	813	33.7
1970-75	957	869	986	44.7
1975-80	1,089	1,054	1,137	76.6
1980-87	1,229	1,146	1,166	95.4

where

Y_t = cotton yield in period t (Kg/Ha);

PC_t = real producer price of cotton (CFA F/Kg);

t = time trend;

GR_t = total rainfall over the growing period (June-September) of the crop year;

D = dummy, 1 for the period of subsidy, 0 otherwise; and

u_t = disturbance term.

In a linear form the equation is:

$$Y_t = a_0 + a_1 PC_t + a_2 t + a_3 GR_t + a_4 D + u_t \qquad (14)$$

All of the explanatory variables are expected to have a positive effect on yield, that is all coefficients are expected to be positive.

Data and Estimation Procedure

For each region, annual data on actual planted hectarage, cotton yield and producer price of cotton were drawn from various issues of the CIDT yearly reports. Average daily labor wage in cotton farming and annual producer price of corn and rice were collected from the Agricultural Statistics Reports of the Ministry of Agriculture. Monthly precipitation for Boundiali and annual precipitation for Korhogo were obtained from the National Agency of Aeronautics and Meteorology (ANAM). Data on rainfall for the Ferké area were not available. The CPI reported by the International Financial Statistics series was used.

Analysis of supply response for a single commodity across different regions of a country falls into the category of estimation of equations for which the assumption of correlation between the random errors in the different equations may hold. Judge et al., (p. 315) pointed out that for these type of equations, at a given point in time, the disturbances are likely to reflect some common unmeasurable or omitted factors, and so would exhibit contemporaneous correlation. Zellner titled a method for joint consideration of all the of all the equations "Seemingly Unrelated Regression Estimation" (SURE) which proved to yield a gain in efficiency as compared to the OLS estimations of each equation. But, the Nerlovian model is a dynamic one including lags of the dependent variable (e.g. an autoregressive model). Very few studies have considered the SURE in a dynamic framework because the presence of lags in the model is likely to create autoregressive disturbances. Spencer (1979) has examined the case of a dynamic system for seemingly unrelated regression with autoregressive disturbances. The relevant finding of his study for the present analysis is that when the coefficient of the lagged dependent variable is large and/or the disturbances exhibit only weak correlation, for small samples, OLS estimates are preferred to the alternative SURE methods.

In light of this conclusion, and assuming that actual planted hectarage adjusts slowly to the long-run hectarage in the areas under study, OLS was applied to the collected data for the period 1969-1987. For each area, equation (12) including the relevant variables is estimated. Based on the values of the adjusted coefficients of determination ($\bar{R}^2$) and the t-ratios, the nonsignificant variables were eliminated and the final equations are presented in Table 8. In a dynamic model, the Durbin-Watson statistic (D-W) used to test for first-order autocorrelation of the error term is meaningless. However, the h-statistic suggested by Durbin and defined as

$$h = (1 - \frac{1}{2}DW)\sqrt{\frac{n}{1-nV(\alpha_1)}} \qquad (15)$$

where DW is the Durbin-Watson statistic, n the sample size, and $V(\alpha_1)$ the variance of coefficient on the lagged variable, is inappropriate for small samples (Cassidy).

Taking the above into account, it was assumed that there was first order serial correlation of the error term and the Cochrane-Orcutt iterative technique provided by the Time Series Processing (TSP) software was used to correct for autocorrelation in the hectarage equations. The t-value on the autoregressive coefficient (AR) was an indicator of

Table 8. Cotton Supply Functions in Boundiali, Korhogo, and Ferké Areas (1969-1987).[1]

Equations	Const.	$\ln A_{t-1}$	$\ln PC_{t-1}$	$\ln LAB_{t-1}$	W_t	t	D	AR	$\bar{R}^2$
Boundiali									
(a)	-56.748	.441***	.284***	-.133	.0009***	.031***	.047	-.48	.95
	(-3.86)	(3.87)	(3.15)	(-.96)	(2.82)	(3.96)	(.98)	(-1.82)	
(b)	-61.456	.430**	.319**	-.048	.0006**	.033***	.086		.94
	(-3.14)	(2.48)	(2.74)	(-.31)	(1.99)	(3.16)	(1.46)		
(c)	-53.504	.543***	.268***	-.229**	.001***	.030***		-.51	.95
	(-3.85)	(4.13)	(3.09)	(-2.29)	(3.03)	(3.97)		(-2.09)	
(d)	-51.778	.495***	.267**	-.177	.0007**	.028**			.94
	(-2.69)	(2.82)	(2.3)	(-1.32)	(2.23)	(2.72)			
Korhogo									
(a)	-105.01	.661**	.363	-.087		.054*	.178**	.072	.98
	(-1.63)	(2.27)	(1.57)	(-.46)		(1.58)	(2.23)	(.22)	
(b)	-97.05	.693***	.377**	-.084		.050***	.176**		.98
	(-2.90)	(4.128)	(1.96)	(-.046)		(2.78)	(2.52)		
(c)	-85.11	.715**	.317	-.398**		.045		.046	.98
	(-1.2)	(2.13)	(1.09)	(-2.31)		(1.18)		(.135)	

Table 8. (continued).

(d)	-79.91	.738***	.367*	-.403**	.042**			.98
	(-2.05)	(3.71)	(1.47)	(-2.58)	(2.00)			
Ferke								
(a)	-176.84	.424	.570***	-.261	.091**	.203	-.11	.97
	(-1.92)	(1.19)	(3.05)	(-.93)	(1.89)	(1.52)	(-.37)	
(b)	-193.08	.367*	.569***	-.277	.100***	.21**		.97
	(-3.83)	(1.81)	(2.89)	(-1.04)	(3.78)	(2.0)		
(c)	-133.0	.571**	.543**	-.563**	.070*		-.14	.97
	(-1.83)	(1.94)	(2.68)	(-1.96)	(1.80)		(-.55)	
(d)	-151.58	.504**	.522**	-5.78**	.079***		.97	
	(-2.98)	(2.39)	(2.4)	(-2.37)	(2.94)			

1 Figures in parentheses denote t-statistics
* Significant at the 10 percent level
** Significant at the five percent level
*** Significant at the one percent level

the existence of autocorrelation. OLS was applied to equation (14) for the yield response in each region.

Empirical Results

Hectarage Response

Table 8 shows the best equations for each area. Equation (a) includes both the dummy variable and autoregressive correction (AR) equation (b) excludes AR from (a) when not significant. Equation (c) excludes the dummy from (a), and (d) excludes AR from (c) when not significant. The insignificance of the competing food crop prices suggests that farmers do not respond to food crop price changes. Since food is produced for family consumption, only a small proportion is sold. Moreover, none of these crops has an efficient market structure such as the cotton market. The competition for land cannot be captured entirely by prices. A better variable could be the average per capita on farm food consumption, which is not available. The risk variable also fails to be a good explanatory variable. The cost of borrowing money from the National Bank for Agricultural Development (BNDA) or from individual lenders could represent a better measure of the risk. Although the former is available, small farmers borrow much more from private individuals than from the bank and the use of bank rate would lead to a misspecification. Statistics on private rates are not available.

The high explanatory power of the different functions is to be expected because of the presence of the lagged dependent variable and, in some cases, the dummy variable. Some relevant variables may not be included in the model. The parameters, although not all are significant, have the expected signs. Consideration of the dummy variable alters the significance of some coefficients. This relates more to a statistical problem than an explanatory problem. In fact, the dummy variable is of relevance only in the Korhogo model (b). This suggests that the subsidy policy has resulted in a more significant increase in cotton hectarage in the Korhogo region. An explanation is this area has a much higher population density relative to the other areas. Farmers initiating cotton production might have been attracted by the policy. For the Boundiali area, model (c) provides the most significant results. The corresponding elasticities for these models are presented in Table 9.

Table 9. Elasticities, Coefficients of Adjustment and Periods of Adjustment.

Area	Equation	Elasticities of Prices: Short Run	Elasticities of Prices: Long Run	Wage	A_{t-1}	Coefficient of Adjustment λ	Number of years for adjustment within 5 percent of full adjustment
Boundiali	(c)	.268	.583	-.229	.543	.457	5
Korhogo	(b)	.377	1.02		.693	.307	8
Ferké	(d)	.522	1.05	-.578	.504	.496	4

From the results of the analysis it can be concluded that farmers in the northern Côte d'Ivoire are responsive to cotton price changes. Farmers in the Ferké area exhibit a higher response both in the short and long runs. They also adjust faster than farmers in the other regions. Comparing this result to the trend in yields across the areas, it may be inferred that more efficient areas adjust faster. This also relates to the cost of labor. Farmers respond to hired labor wage changes in the areas where they adjust faster. An explanation of the differences is that in the Ferké area, the number of farmers is much lower than in the other regions. Also, the farmers have adopted animal traction earlier and the percentage of farms under traditional farming has been decreasing over the period of study at a higher rate than in the neighboring areas as shown by the farm size distributions.

The long run elasticity of cotton price in the Korhogo and Ferké areas is about 1, meaning that in the long run, an increase in price by 1 percent induces an increase in planted hectarage by 1 percent. Bond argued that long run elasticity is not expected to be too much different from the short run elasticity for annual crops. However, in the present study it is at least twice the short run elasticity in two areas. Where traditional farming is very dominant, average cotton hectarage is low and confined mostly to family farming. Therefore, labor wages do not influence significantly the hectarage. The Korhogo area has the largest number of farmers, but also the largest proportion of traditional farming, which explains why the coefficient on the hired labor wage is not significant. The weather variable, when available (Boundiali), proved to influence the planted hectarage. The variable expressing technical progress in all cases was statistically significant.

Yield Response

While quite satisfactory results were obtained with the hectarage functions, the yield functions performed poorly. Table 10 shows the estimated equations for the cotton yield over the period 1970-1987 in the three areas.

The results in Table 10 provide evidence that yield does not respond to price changes because the coefficient on the price of cotton is not statistically significant in any area. The hectarage response is therefore a fair approximation of the output response to price changes.

Table 10. Cotton Yield Functions in Boundiali, Korhogo, Ferké Areas (1970-1987).

Area	Constant	PC_t	t	WR_t	D	$\bar{R}^2$	DW
Boundiali	-39900.5 (-2.4)	-2.018 (-.95)	20.75 (2.49)	.121 (1.16)	7.698 (.098)	.51	2.89
Korhogo	-68828.93 (-3.6)	1.439 (.96)	35.261 (3.66)	-.023 (-.18)	-53.457 (-.69)	.49	2.37
Ferké	-58870.06 (-2.92)	1.335 (.84)	30.262 (2.98)		-93.521 (-1.25)	.36	1.42

Conclusions and Limitations

In this chapter, cotton output response to price changes was estimated by analyzing its components, hectarage and yield. A pure partial adjustment model was applied to annual data over the 1970-1987 period for three areas in northern Côte d'Ivoire. In all cases, planted hectarage was significantly influenced by producer price of cotton. The model used to estimate yield response performed poorly and no response to price changes seemed evident. These results comply with the hypothesis that in the developing countries, yield does not respond to prices and justifies the approximation of supply response by hectarage response.

The Nerlovian model suffers some shortcomings. It tends to underestimate short run elasticities because some key variables may be missing. Technology variables are usually poorly measured and not accurately represented in the model. The data use in the estimation also have some deficiencies. Environmental variables are weakly included. The CPI used as a deflator is a measure of the cost of living of the country as a whole. A better deflator could be the CPI in the different areas. In general, econometric modeling of annual time series has a statistical constraint of requiring a sufficient number of observations to increase the degrees of freedom. However, the larger the number of years the less accurate information are included in the model and it cannot be assumed that the behavioral parameters remain unchanged for long periods of time, particularly for developing countries. In fact, for prediction purposes, current behavioral responses are more relevant than long past responses. Limited numbers of observations on the other hand, tends to reduce the number of explanatory variables, leading to a misspecification of the model and sensitive parameters to the presence or the removal of some variables. Farming system analysis involving micro-level studies look more attractive for policy purposes.

CHAPTER IV

RAINFALL ANALYSIS AND OPTIMAL PLANTING DATE FOR COTTON

Introduction

Knowledge of rainfall estimates in a given geographical area is important for development of suitable strategies for agricultural activities. Planting at the right time, for example, may result in a substantial gain in yield. In rainfed agriculture, farmers' planting decisions take into account the risk linked to the occurrence or nonoccurrence of precipitation in a given period. Cotton farming requires a minimum annual rainfall of 700 millimeters over the growing period. But, as with most crops, the total annual rainfall is of less relevance than the distribution over a specific period. The start and end of the rainy season and the risk of dry spells are major concerns for farmers.

In the northern Côte d'Ivoire, the optimal cotton planting period suggested by extension services and agronomists for most areas includes the last decade of May and the first decade of June. Unfortunately, experience has shown that these dates were seldom respected by farmers. Table 11 shows that for the Boundiali and Ferké areas, less than 50 percent of the cotton crop was planted during the recommended period in the crop years 1980/81 through 1985/86. Decadal percentages of planted area for food crops are not available. But, in 1984/85 and 1985/86, 72 and 76 percent of the corn crop and 50 and 66 percent of the rice crop were planted in the month of June in the area under study. This raises different questions such as the potential of labor shortages during the period, and

Table 11. Decadal Planted Cotton Hectarage (Percent) in June in the Boundiali and Ferké Areas (1980/81-1985/86).

Year	First Decade	Second Decade	Third Decade
Boundiali			
1980/81	29.7	37.4	29.5
1981/82	32.2	36.5	16.6
1982/83	29.3	37.7	26.2
1983/84	11.5	23.1	41.1
1984/85	13.6	43.7	33.9
1985/86	16.3	27.2	40.4
Ferké			
1980/81	20.6	33.1	39.6
1981/82	30.7	33.9	32.1
1982/83	20.5	36.9	38.1
1983/84	11.4	30.0	42.6
1984/85	21.9	32.0	36.7
1985/86	28.0	38.1	26.2

Source: CIDT Annual Reports, 1981-1986.

potential of a food safety-first attitude among farmers. The result may be a high risk of cotton crop failure due to insufficient rainfall over the growing season.

The rainfall impact can be noted from Table 11. Late rains in the 1983/84 crop year, for example, resulted in delayed plantings and only about 11 percent of the cotton was seeded over the recommended period. In the absence of data on labor use, only the latter question is investigated in this chapter. The study is limited to the Boundiali area for which 25 years of daily observations on precipitation were available from the National Agency for Aeronautics and Meteorology (ANAM) for the period 1961-1985.

Rainfall and Cotton Farming Schedule

Crop growth, and the sequences of crops grown during a year are determined by the interaction of climate, soil, plant, and management parameters. Any crop will grow when the minimum requirement of the plant growth factors, such as water, energy, nutrients, and mechanical support, are available. Water conditions can be characterized either by the rainfall amount or by the water balance defined as:

$$P + I - R - Dr + \Delta H - ETr = 0 \qquad (16)$$

where

P = precipitation;

I = irrigation (if any);

R = runoff;

Dr = drainage;

ΔH = variation of soil moisture; and

ETr = real evapotranspiration.

The potential demand for water at a given location is defined as the potential evapotranspiration (PE). When PE is known for a certain length of time (day, week, month, etc.), the mapping with the corresponding rainfall determines useful information for planning agricultural strategies . The computation of PE requires many environmental variables. A simple and convenient formula was suggested by Lhomme and Monteny for the Côte d'Ivoire:

$$PE = aX_1 + bX_2 + c \quad (17)$$

where

X_1 = location latitude North (degrees);

X_2 = location longitude West (degrees); and

a,b,c are monthly coefficients shown in Table 12.

Table 12. Daily Potential Evapotranspiration for each Month in Boundiali (April-November).

Month	April	May	June	July	August	September	October	November
a	.37	.35	.44	.27	.28	.24	.27	.37
b	.04	.02	.01	.05	.04	.02	.05	-.01
c	2.63	2.4	1.03	1.77	1.44	2.22	2.5	2.53
PE[1]	6.411	5.861	5.283	4.664	4.364	4.634	5.394	5.987

[1] PE is obtained from equation (17).

The formula is applied to determine the PE for Boundiali which is located at 9°31′ latitude N. and 6°29′ longitude W. The monthly PE is broken down into decadal PE. This procedure makes the assumption of a constant PE over the three decades of each month.

Figure 3 represents decadal rainfall, PE, and 1/2 PE for the period April-October. Based on this graph, the theoretical calendar of agricultural activities is as follows:

AB = Mid-April-Mid-June = pre-humid period = planting period;

BC = Mid-June-Mid-October = humid period; and

AD = plant growth period.

Depending on the cycle of the plant under consideration, the different stages of growth (flowering, maturation), must be timed with the appropriate period when the water requirements are met. For example, the cotton flowering stage occurs between day 80 and 120 after planting for the 170-day variety. Over this period, rainfall must be at least 3/4 of PE. This rainfall will likely occur during the period Mid-September-Mid-October. This flowering period would result from a planting period of Mid-May-Mid-June. Maturation occurs in the last month of the cycle and must correspond to a relatively dry period with rainfall equal to at most 1/4 of PE.

Decadal rainfall and PE used are average values. In rainfed agriculture, one may be interested in how much rainfall can be expected during a certain time interval in, say, 3 out of 4 years. In other words, what is the probability of a certain level of precipitation or how much rainfall is expected with a certain probability level? Replacing the averages with frequencies of occurrence, will provide answers to these questions.

Rainfall Probability Estimation

Hargreaves defined a dependable precipitation as the rainfall amount received at 70 percent probability. However, the level of dependability is related to the demand for moisture of a plant at different phenological stages. In determining rainfall probabilities, it is a common approach to fit a mathematical function to rainfall data and to compute the probabilities from this function. Frequency distributions have been used to estimate rainfall probabilities. There is a basic duality between frequency distributions and probability

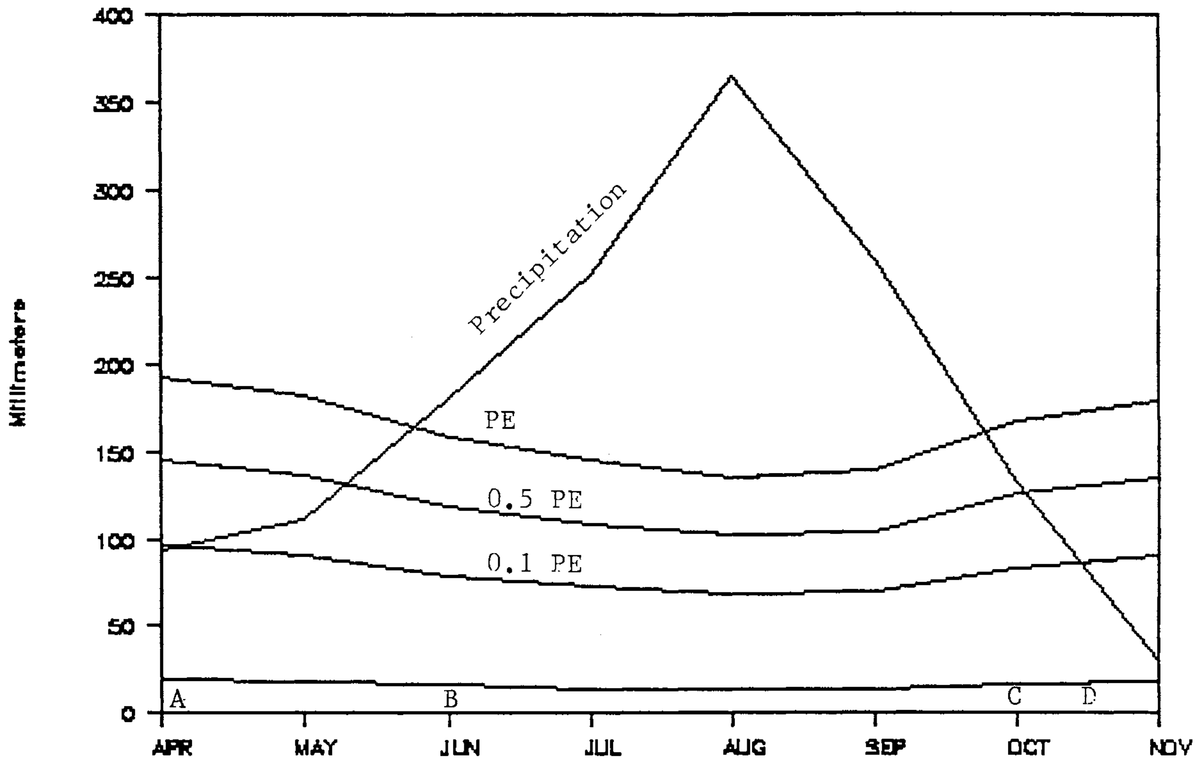

Figure 3. Decadal Rainfall and Potential Evapotranspiration at Boundiali.

distributions in the sense that statistical models can usually be described either in terms of a frequency distribution or a probability distribution at choice.

For countries in West Africa, agroclimatologists have either fitted daily, weekly, or decadal rainfall data to a gamma distribution, or modeled rainfall using a Markov process framework. Gigou applied a 3-day moving period of 6 days precipitations for 25 climatic stations in the Côte d'Ivoire to model constant probabilities using 30 to 47 years of data. Sivakumar et al. computed constant precipitation probabilities and constant probabilities of precipitation for Niger (1980), Mali (1984). All these studies emphasized the necessity of having at least 25 years of data to obtain reliable estimates. In this study the gamma distribution and Markov chain model are used to derive probabilities of precipitation and dry spells in the Boundiali area based on 25 years of daily rainfall data.

The Gamma Distribution

The gamma distribution belongs to the family of continuous random variable distributions. The normal distribution is bell-shaped and thus symmetric. There are situations where the variable under study has a skewed distribution. The gamma family of probability density functions (pdf) yields a wide variety of skewed distributional shapes.

A continuous random variable X has a gamma distribution if the pdf of X is:

$$F(x; \alpha,\beta) = \begin{cases} \dfrac{1}{\beta^{\alpha}\Gamma(\alpha)} x^{\alpha-1} e^{-x/\beta} & x \geq 0 \\ 0 & \text{Otherwise} \end{cases} \qquad (18)$$

where the parameters α and β are positive and represent the shape and scale of the distribution; and $\Gamma(\alpha)$ is the gamma function defined by:

$$\Gamma(\alpha) = \int_{0}^{\infty} x^{\alpha-1} e^{-x} \, dx \qquad (19)$$

When X is a standard gamma random variable (β =1), the cumulative distribution function (CDF) of X defined by

$$F(x, \alpha) = \int_{o}^{x} \frac{y^{\alpha-1}e^{-y}}{\Gamma(\alpha)} dy \qquad (20)$$

is called the incomplete gamma function. The distribution is said to be truncated when the frequential analysis shows that the number of observations equal to, say, zero millimeter for rainfall for example, is not equal to zero. The CDF is in this case defined as:

$$F(x; \alpha,\beta) = P_o + (1-P_o) \frac{1}{\beta^{\alpha}\Gamma(\alpha)} \int_{o}^{u} u^{\alpha-1}e^{-u}du \qquad (21)$$

$$u = \frac{X - X_o}{\beta}$$

where

X = random variable (precipitation);

X_o = the lower value of the X range; and

P_o = truncage parameter, e.g. the probability of no precipitation.

The Markov Chain Model

The Markov process of first order assumes that, in the case of rainfall, the probability of rain in any period depends only on events of the preceding period. The model is usually formulated in terms of occurrence and nonoccurrence of rainfall in any period. The amount of precipitation does not enter the model directly. But, the modeler may define rainfall by any level of precipitation. In general, a Markov process assumes that the population to be modeled can be classified into various groups (S1, S2,. . .Sn) and the movements between groups or states can be regarded as a stochastic process quantifiable by probabilities. The states are defined so that the event can only be in one state at a time. A transition occurs when there is a shift from one state to another. The chain is also defined by its order; for a discrete variable x, a process is said to be of order k if for any n, the following relating the conditional probabilities is satisfied (Chin):

$$P(x_n|x_{n-1},x_{n-2},..\, x_{n-k-1},...) = P(x_n|x_{n-1}, x_{n-2}, ...,x_{n-k}). \tag{22}$$

In the case of rainfall, two states may be defined: wet for rainfall occurrence and dry for nonoccurrence on any day. The model parameters are the two conditional probabilities:

$$P_1 = P(\text{wet day} \mid \text{previous day wet}) \tag{23}$$

$$P_o = P(\text{wet day} \mid \text{previous day dry})$$

The probability transition matrix from one state to the other has the following form:

State	Dry	Wet
Dry	$1-P_o$	P_o
Wet	$1-P_1$	P_1

The Markov process approach was used by Gabriel and Neumann (1957, 1962); Katz; Chin; Jovanovic et al.; Oldeman and Frere; Stern; Stern et al.; Sivakumar et al., (1980, 1984) and Sivakumar and Gnoumou, to model rainfall occurrence. In these various studies, the assumption was made that the probability distribution of dry or wet spells was geometric. A spell is defined as a consecutive number of periods (days, weeks, decades, etc..) receiving (or not) a threshold amount of precipitation.

From the transition probability matrix, probabilities of spells of any length can be derived. The probability of a wet spell with length w or a dry spell with length d are obtained by:

$$P(x=w) = (1-P_1)\, P_1^{w-1} \tag{24}$$

$$P(x=d) = P_o(1-P_o)^{d-1}$$

The transition matrix enables estimation of the equilibrium or steady state probabilities π_1 and π_2 corresponding to dry and wet days and are given by:

$$\pi_1 = \frac{1 - P_1}{1-P_1 + P_o} \tag{25}$$

$$\pi_2 = \frac{P_o}{1-P_1 + P_o}$$

From these probabilities, the expected number of dry (wet) periods are derived as:

Expected number of dry days = n π_1

Expected number of wet days = n π_2

where n is the number of days in the period under consideration. A useful property of the Markov chain model is the expected length of a dry or wet spell derivation given by:

$$E(D) = \frac{1}{P_o} \tag{26}$$

$$E(W) = \frac{1}{1-P_1}$$

Empirical Analysis

Constant Probability Estimation

The daily precipitation at the Boundiali station for the period 1961-1985, was used to derive decadal precipitation. But, before estimating the probabilities, it was necessary to verify that there was no significant shift in the weather pattern over years. Simple time trend regressions were estimated for each decade over the period 1961-1985. The results, shown in Table 13, reveal no change as all coefficients on the time variable are insignificant.

The Statgraphics microcomputer software package was used to fit the data to a gamma distribution. The estimated parameters are reported in Table 14. The Kolmogorov-Smirnov test was used to evaluate goodness-of-fit. The test relates the cumulative relative frequencies of the data set to that of the theoretical distribution. The largest difference between the two overall feasible values of the variable compared to a tabulated critical value determines the significance of the estimates. Only the estimates for eight decades are shown in Table 14 because of their relevance to the study. The estimated parameters were used to calculate probabilities of certain amounts of precipitation or more. Results are presented in Table 15.

Table 13. Time Trend of Decadal Precipitation at Boundiali 1961-1985.

Decade	Intercept	Slope	t-value	$\bar{R}^2$
May 21-31	75.561	-0.506	-0.49	0.01
June 1-10	35.923	0.418	0.40	0.007
June 11-20	29.242	0.453	0.41	0.007
June 21-30	81.67	-0.331	-0.35	0.005

Table 14. Gamma Distributions of Decadal Precipitations, Boundiali 1961-1985.

Decade	May	June			September		October
	21-31	1-10	11-20	21-20	10-20	21-30	1-10
α	1.12	3.187	2.49	3.031	1.909	1.76	1.746
β	0.029	0.048	0.04	0.05	0.019	0.025	0.03
K.S.	0.146*	0.142*	0.139*	0.121*	0.135*	0.129*	0.094*

* Significant at the 5 percent level.

Table 15. Decadal Precipitations and Related Probabilities.

Decades	Probability Levels (Percent) 90	75	50	10
	Rainfall (millimeters)			
May 21-31	5.0	12.4	28.0	86.5
June 1-10	25.0	39.0	59.6	116.0
June 11-20	20.0	33.0	54.0	115.0
June 21-30	21.2	33.2	51.3	101.8
Sept 11-20	24.8	45.8	81.3	192.0
Sept 21-30	16.5	31.5	57.6	141.0
Oct 1-10	13.5	26.0	47.5	117.0

The analysis revealed that during the period from September 11 through October 10 there is a 75 percent chance of 103.3 millimeter of rainfall or an average of 34.4 for each decade. The maturation water requirement is 3/4 of the PE which is about 50 millimeters on average for each decade. Plantings scheduled for the first decade of June will have a higher probability to meet this water requirement later. However, if a wet decade (at least 20 millimeters) must precede the planting, the optimal planting would range from late first decade through the second decade of June. This conclusion differs slightly from the extension service recommendation but reflects more the actual behavior of farmers in the Boundiali area. From the data included in Table 11, it is apparent that for most years, the largest percentage of cotton is planted during the second decade of June. The labor constraint, even though restrictive, might not be the major explanation for the deviation between actual and recommended practices.

To take the analysis one step further, it may be of interest to investigate some conditional probabilities and the chance of dry spells after planting. This might confirm the previous analysis.

Conditional Probabilities and Dry Spells

The first step in the Markovian model is to define the states. For the purpose of this study, a day was defined wet if it received at least 2 millimeters; otherwise the day is defined to be dry. The conditional probabilities in a Markov chain are estimated in a straightforward manner by the appropriate relative frequencies. These are maximum likelihood estimates (Anderson and Goodman). Table 16, includes the results for the decades May 21-31, June 1-10, June 11-20, and June 21-30.

The three decades of June have the same number of expected dry days (Table 16). Relative frequencies were used to estimate the probabilities of a dry spell of that length in each decade. They were found to be 0.28, 0.20, and 0.24 for the three decades of June. Although the chance of a long dry spell is low in each case, the second decade presents a lower risk than both the preceding and the following decades. Over the first three weeks of June, the expected length of a wet spell varies from 1 to 2 days, whereas that for dry days varies from 3 to 4 days. After about 4 days of a dry days period, a wet day is expected to occur. Over that period, the expected length of a cycle is about 5 days.

Based on the analysis, there does not seem to be a significant difference in risk of dry spells between planting during the first or the second decade of June. Since early planting is advised, the decade June 5-15 may be a suitable planting period. This complies with adequate corresponding flowering period in late September and maturation period early November.

Table 16. Estimation of Conditional Probabilities of Daily Rainfall from Relative Frequencies for the Period 1961-1985 at Boundiali (Wet = at least 2 millimeter)

Decades	Preceding Day	Actual Day		Conditional Probabilities	
		Wet	Dry	Wet	Dry
May 21-31	wet	16	52	0.23	0.77
	dry	52	155	0.25	0.75
	total	68	207	0.25*	0.75**
	Steady state probabilities			0.25	0.75
	Expected number of wet days			3	
	Expected number of dry days			8	
	Expected length of a wet spell			1	
	Expected length of a dry spell			4	
June 1-10	wet	25	28	0.47	0.53
	dry	53	144	0.27	0.73
	total	78	172	0.31*	0.69**
	Steady state probabilities			0.34	0.66
	Expected number of wet days			3	
	Expected number of dry days			7	
	Expected length of a wet spell			2	
	Expected length of a dry spell			4	
June 11-20	wet	11	56	0.16	0.84
	dry	61	122	0.33	0.67
	total	72	178	0.29*	0.71**
	Steady state probabilities			0.28	0.72
	Expected number of wet days			3	
	Expected number of dry days			7	
	Expected length of a wet spell			1	
	Expected length of a dry spell			3	
June 21-30	wet	23	61	0.27	0.73
	dry	53	113	0.32	0.38
	total	76	174	0.30*	0.70**

Table 16. (continued)

Steady state probabilities	0.30	0.70
Expected number of wet days	3	
Expected number of dry days	7	
Expected length of a wet spell	1	
Expected length of a dry spell	3	

* Unconditional probabilities for wet days.
** Unconditional probabilities for dry days.

Limitations to the Planting Analysis

The analysis in the previous section of this chapter has provided useful information for evaluating cotton planting dates in the northern Côte d'Ivoire. Nevertheless, the analysis remains incomplete in some ways. First, the soil type in the area can play a major role in the determination of the amount of precipitation required to plant. Soils with high retention capacity may allow the plant to support dry spells, which allows for early planting. Second, the analysis could have been carried out by considering yields of cotton from alternative dates of planting. This approach would provide reliable conclusions for extension purposes. The present analysis could be useful for any other crop entering the farming system in the Boundiali area.

CHAPTER V

EFFICIENCY MEASUREMENT AMONG COTTON FARMERS

Introduction

In Chapter II, the Ferké area has been singled out as achieving the best results in cotton production as measured by average yield and adoption of different components of the technology package. Another finding was the improvement in yield distribution after the removal of the fertilizer subsidy. This yield improvement may be explained by a combination of economic rationale and improvement of managerial skill over years of practice.

A measure of this combination is embodied in the notion of economic efficiency which was questioned by the World Bank's study. If it can be shown that the farmers are inefficient in their practices, then it follows that output can be increased at little cost to the economy.

Since the removal of the subsidy in 1984, only insecticides continue to be freely distributed to farmers; all other costs are paid by the producers. The impact of the change in the subsidization policy on efficiency among producers has not been determined. The best approach would be to compare efficiency during and after the subsidy period in each of the three areas under study. Unfortunately, data limitations confine the analysis to only one area after the subsidy given that it is assumed that farmers were to an extent inefficient during the subsidy.

The Concept of Efficiency

Efficiency in production can be defined in terms of the production function that relates the level of output to the levels of various inputs. The beginning point of discussions of efficiency measurement is the work of Farrell. In his pioneering study, Farrell identified two components of production efficiency: Technical efficiency is a measure of a firm's success in producing maximum output from a given set of inputs, and allocative efficiency, which Farrell called "price efficiency", and is a measure of the firm's success in choosing an optimal set of inputs. Graphically, the decomposition of Farrell's efficiency is as follows. Consider a firm using two inputs x_1 and x_2 and producing y, and assume that the firm's production function is

$$y = f(x_1, x_2) \tag{27}$$

Under the assumption of constant returns to scale, the function may be written as

$$1 = f(x_1/y, x_2/y) \tag{28}$$

The unit isoquant can characterize this function frontier (II′ in Figure 4). If the firm is observed using (x_1^0, x_2^0) to produce y_0, point A may represent $(x_1^0/y_0, x_2^0/y_0)$, the ratio OB/OA measures technical inefficiency. It is the ratio of inputs needed to produce y_0 to the inputs actually used to produce y_0, given the input mix used. EE' represents the ratio of input prices. Since the cost of point D is the same as that of the allocatively efficient point C, the ratio OD/OB measures allocative inefficiency. The ratio OD/OA is a measure of total efficiency.

This procedure does not specify any functional form for the production function, but maintains the assumptions of constant returns to scale and a perfectly competitive industry. In addition, observations cannot lie below the frontier.

Since the initial work of Farrell, there have been numerous studies to estimate production efficiency by means of deterministic and stochastic production frontiers (Forsund et al.; Kopp ; Schmidt ; and Suarez).

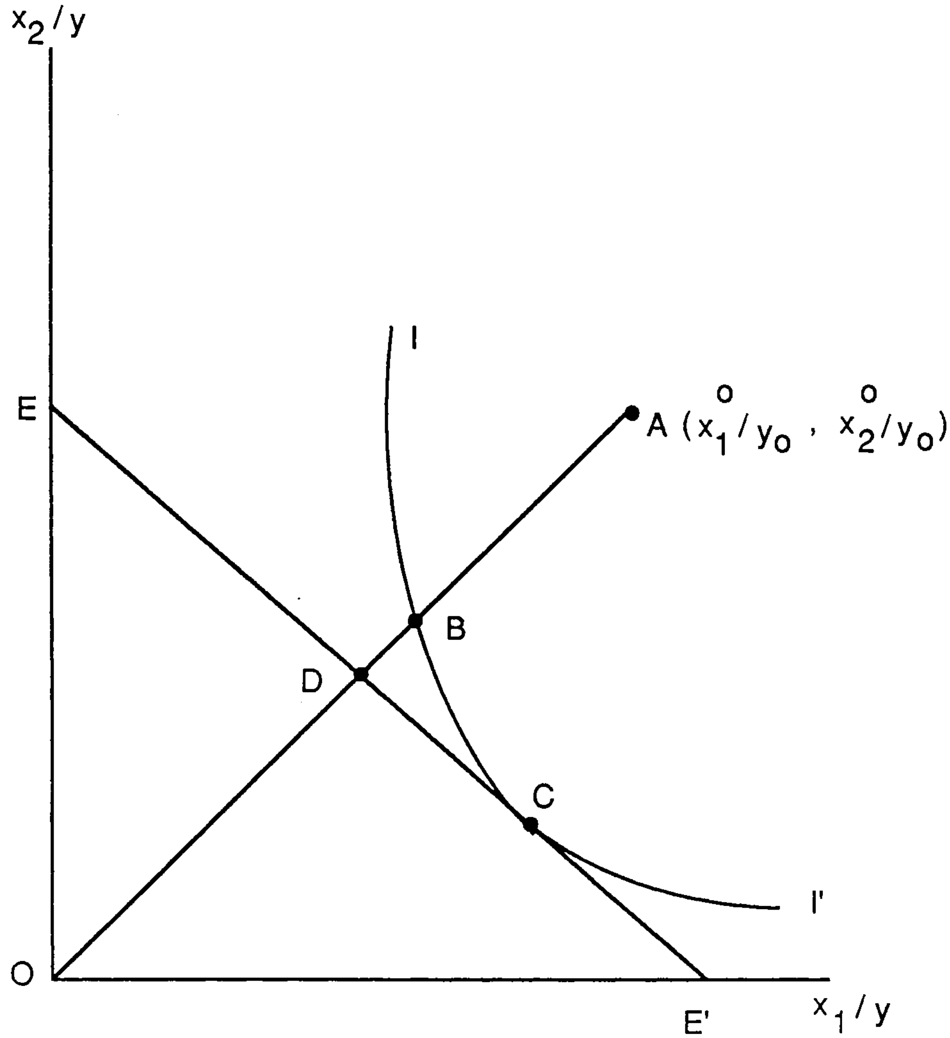

Figure 4. Farrell's Decomposition of Economic Efficiency.

Aigner and Chu specified a homogeneous Cobb-Douglas deterministic production frontier and required all observations to be on or beneath the frontier. The model was of the form:

$$\ln y = \ln f(x) - u \tag{29}$$

$$\ln y = a_o + \sum_{i=1}^{n} a_i \ln x_i - u \qquad u \geq o$$

where ln is the natural logarithm of the variable, u is a one-sided error term forcing $y \leq f(x)$. Linear or quadratic programming can be used to estimate the parameters of the model. The approach allows the determination of average efficiency of the industry. Forsund et al. argued that the technical efficiency of each observation could be computed directly from the vector of residuals, since u represents technical inefficiency. The major criticisms to this procedure are the inability to undertake statistical inference about the parameters, the sensitivity to outliers, and the tendency to determine only as many technically efficient observations as there are parameters to be estimated when using linear programming.

Timmer applied a probabilistic production function to measure the technical efficiency of U.S. agriculture for the period 1960 to 1967. He used an average farm for each state for each year. He specified a Cobb-Douglas production form, relaxed the homogeneity assumption, and used linear programming to generate both deterministic and probabilistic frontiers. The results were compared with ordinary least squares and analysis of covariance estimates of the production function. The error term was constrained to be less than or equal to zero. The probabilistic frontier constrained x percent of the observations to fall outside the frontier. The model is summarized as follows:

Maximize $\quad Q = f(x, \beta) + w \qquad (30)$

subject to $\quad Pr(f(x,\hat{\beta}) \geq Q) \geq Po$

where w is an unspecified random shock and Po a defined probability.

Afriat improved Aigner and Chu's model by specifying the form of the disturbance term:

$$Q = f(x,\beta)w \tag{31}$$

where

$w = e^{-z}$ and z is distributed in the range [0, ∞] ; w indicates the efficiency with which the firm uses inputs.

A two parameter (α,β) beta distribution for w was proposed, where α is the shape parameter and β the scale parameter. This is equivalent to a gamma distribution for z. The procedure resulted in measure of average sample efficiency using the maximum likelihood method of estimation. Richmond in the same line, used an adjusted ordinary least squares method to measure average efficiency by the expected value of w, E(w). Aigner, Amemiya and Poirier defined the shock term differently:

$$w = \begin{cases} \dfrac{w^*_i}{\sqrt{1-\varphi}} & \text{if } w^*_i > 0 \\ \dfrac{w^*_i}{\sqrt{\varphi}} & \text{if } w^*_i \leq 0 \end{cases} \tag{32}$$

$w^*_i \sim N(0\ \sigma^2)$ for $0 < \varphi < 1$

w^*_i ~ Negative truncated normal distribution for $\varphi = 1$ and

w^*_i ~ Positive truncated normal distribution for $\varphi = 0$

The models considered to this point are referred to as full frontier models. An alternative formulation has found many advocates in the subsequent literature on efficiency in production. It is the stochastic frontier model which was developed to include the influence of factors outside the control of the firm and their impact on technical inefficiency. Aigner, et al.,(1977), and Meeusen and Van den Broeck adopted the general form of the stochastic frontier function as:

$$Q = f(x, \beta)\, e^{v-u}$$

where v is characterized by a symmetric distribution and u, as in the full model, is a one-sided negative disturbance.

In the Aigner-Lovell-Schmidt model:

$w = u + v$ $v \sim N(0, \sigma_v^2)$, $u \sim$ truncated $N(0, \sigma_u^2)$; the model collapses to a deterministic frontier when $\sigma_v^2 = 0$ and to an average function when $\sigma_u^2 = 0$. The efficiency measure is defined by the maximum likelihood estimate of the ratio

$$\lambda = \frac{\sigma_u}{\sigma_v}$$

In the Meeusen-Van den Broeck model, u is specified to have an exponential distribution. The efficiency is defined by the MLE of $E(e^{-u})$.

Both full and stochastic models have been applied to a variety of data sets from Developing Countries, including data on Brazilian manufacturing (Lee and Tyler), farmers in the Geita District in Tanzania (Shapiro and Muller), rice farmers in the Philippines (Herdt and Mandac), irrigated paddy farmers in Coimbatore District in India (Kalirajan), Thai, Korean and Malaysian farmers (Jamison and Lau), traditional farmers in Southeastern Brazil (Taylor and Shonkwiler), rice farmers in Malaysia (Kalirajan and Shand), farm families in Nepal (Belbase and Grabowski), rice farmers in Colombia (Suarez), individual farms in Northwestern India (Huang and Bagi).

But, despite the abundant literature on efficiency measurement, the efficiency concept remains fuzzy. Pasour argued that the efficiency concept is difficult to define and loses its usefulness under real world conditions of uncertainty. Inefficiency inference may be unwarranted in many cases as demonstrated by Stigler (p. 213).

". . .The entrepreneur does not seek to maximize the output of corn; he seeks to maximize utility, and surely other products including leisure and health as well as corn enter his utility function. When more of one goal is achieved at the cost of less of another goal, the increase in output due to (say) increased effort is not an increase in "efficiency"; it is a change in output. . . " In other words, variation from farmer to farmer in performance measures of efficiency does not necessarily imply that an individual decision maker is foregoing a superior alternative.

Efficiency Among the Niellé Farmers

To determine the extent to which the cotton farmers in northern Côte d'Ivoire are technically efficient, data obtained from the Niellé District were analyzed. The district is recognized by the extension service of CIDT as relatively homogeneous for the package adoption.

In the district, 56 villages which include 2,074 farmers are involved in cotton production under the assistance of the CIDT. For the crop year 1987/1988, 432 were traditional farmers, 1,619 were using animal traction (oxen), and only 23 had intermediate mechanized farms. The data in Table 17 indicate that, except for fertilizers, the farmers still experience some malpractices in cotton production. The data also suggest a high level of manual weeding to substitute for herbicide use. Harwood argued that when a farmer does begin to buy production inputs, he will tend to spend scarce cash first for those inputs that most severely limit production and which cannot be secured from other, noncommercial sources. Fertilizer is usually high on the shopping list. Herbicides which can be substituted for by hand labor, with or without animal traction, are usually low priorities.

A plant density of 70,000 plants per hectare is suggested to farmers. Except for the crop year 1985/86, a low percentage achieved the suggested density. The optimal period of planting covers the last decade of May to the first decade of June. Here again, farmers fail to comply with these recommendations. It is hypothesized that either, food crop activities compete for planting time or, by experience, farmers have concluded that the recommended planting period is not necessarily optimal. Corn, upland rice, peanut, yam, millet, and sorghum are planted on most farms. Planting of the first three of these take place during the same period as cotton.

Table 17. Trends in Intensified Cotton Hectarage by Factor of Production (Percentage)

Factors	Crop Year 1982/83	1983/84	1984/85	1985/86	1986/87
Fertilizers	100	99.5	99.72	97.	99.5
Herbicides	14	13.79	26.55	36.14	33.0
Plant Density (70,000/Ha)	25	22.	58.78	87.7	46.44
Optimal Planting Period	NA	12.73	26.35	NA	38.44

Source: Niellé District Annual Reports, CIDT 1983, 1984, 1985, 1986, 1987.

The Nonstochastic Approach

Following Russell and Young, the Timmer measure of technical efficiency is estimated. From the general form:

$$Q = f(x, \beta)\, e^{u} \qquad u \leq 0 \text{ and } u \sim iid \tag{33}$$

the specific Cobb-Douglas functional form is considered to yield:

$$\ln Q = \alpha_0 + \sum_{i=1}^{n} \beta_i \ln x_i + u_i \tag{34}$$

The ordinary least squares method gives the best linear unbiased estimates of the coefficients for this model. The intercept term is then corrected by shifting the function until no residual is positive and at least one is zero (e.g. located on the frontier). The technical efficiency score for each farm is calculated by taking the ratio of the actual to the potential level of output. The potential level of output is computed by substituting the quantity of each input actually used by the farmer into the corrected function. To correct for the sensitivity of the model to outliers, the model is usually reestimated after deletion of the outliers and the rest of the procedure is carried out. The Timmer Technical Efficiency is calculated for the ith farmer using the formula:

$$TE_i = \text{Exp}\ (u_i) \tag{35}$$

where Exp is the exponential function,

$u_i = f(x,\hat{\beta}) - f^*(x,\hat{\beta})$

$f^*(x,\hat{\beta})$ is the potential value of the function for each farmer.

One hundred twenty-one farmers were selected from six villages based on the availability of data on cotton hectarage planted in the crop year 1987/88, the fertilized and herbicide hectarages, cotton production, experience with animal traction, and cotton planted by the optimal planting date.

The study considers a revenue function formulated as follows:

$$TR_i = f(Land_i,\ VC_i,\ u_i) \tag{36}$$

where

TR = value of the marketed cotton (CFA F)

Land = total land planted to cotton (hectares)

VC = variable costs comprising fertilizers and herbicides costs (CFA F)

The Cobb-Douglas form is:

$$TR = A(Land_i)^{\beta_1}\ (VC_i)^{\beta_2}\, e^{u_i} \tag{37}$$

which yields the estimable logarithmic form:

$$\ln(TR_i) = \alpha_o + \beta_1 \ln(Land_i) + \beta_2 \ln VC_i + u_i \tag{38}$$

Since larger planted hectarage and higher variable costs are expected to be associated with larger production, β_1 and β_2 are therefore expected to be positive.

Results of Estimation

Corrected OLS estimates of equation (38) are presented in Table 18. The first equation in the table represents the estimated equation with the original 121 farmers data.

Five outliers were singled out and the second equation is the reestimate of the 116 remaining farmers.

Table 18. Total Revenue Function Estimates in the Niellé District (1987/88).

Sample Size	Constant	Land	Variable Cost	$\bar{R}^2$
(1) 121 farmers	6.7949 (2.89)	0.6597** (2.70)	0.4874* (2.18)	0.73
(2) 116 farmers	5.7702 (3.03)	0.4529* (2.29)	0.5791** (3.31)	0.78

[1] Figures in parentheses are t-values.
* Significant at the 5% level.
** Significant at the 1% level.

The estimated functions were used to calculate the TEi's from which a distribution of farms by technical efficiency ratio was derived. Results are included in Table 19.

Based on the nonstochastic formulation of the revenue function, 23 percent of the farmers have a TE ratio of at least 0.70. Over the samples, the average ratios are 0.56 and 0.60 for the two estimates. This denotes a high level of inefficiency. Given that the crop year was not a particularly bad one as far as the weather is concerned, it may indicate that there is room for improvement in the practices of farmers in the Niellé area.

Table 19. Niellé Farms Distribution by Technical Efficiency Ratio (1987/88)

TE Range	Proportion of Farmers 121 Farmers	116 Farmers
0.9 or above	2.48	1.72
0.9 > TE ≥ 0.8	3.31	4.31
0.8 > TE ≥ 0.7	19.83	17.24
0.7 > TE ≥ 0.6	26.43	23.28
0.6 > TE ≥ 0.5	28.10	31.90
0.5 > TE ≥ 0.4	13.22	17.24
0.4 > TE ≥ 0.3	4.96	4.31
0.3 > TE ≥ 0.2	1.65	---

Although the farms are relatively homogeneous, differentiation in farm soils and probably in farming priorities may result in inefficiency. To account for these types of factors influencing the level of production, the stochastic frontier function was applied to the same samples.

The Stochastic Frontier Function

It is postulated that the function is a stochastic frontier with the characteristics described in Aigner et al. (1977). From this formulation, Battese and Corra have defined

$$0 \leq \gamma = \frac{\sigma_u^2}{\sigma^2} \leq 1 \tag{39}$$

as a measure of the total variation in output from the frontier which is attributed to technical efficiency. Beside the MLE approach, an alternative corrected least squares approach, different from the previous one, was proposed by Olson et al. The method uses OLS to estimate β. Except for the constant term, the OLS estimator is unbiased and consistent with covariance matrix equal to:

$$\sigma^2(x'x)^{-1}$$

The bias of the constant term is the mean of w, and equals:

$$\mu = -\sigma_u\sqrt{2/\pi} \tag{40}$$

The variances σ_u^2 and σ_v^2 are consistently estimated by

$$\hat{\sigma}_u^2 = \left[\sqrt{\frac{\pi}{2}}\left(\frac{\pi}{\pi-4}\right)\hat{\mu}_3'\right]^{2/3} \text{ and } \sigma_v^2 = \hat{\mu}_2' - \frac{\pi-2}{\pi}\hat{\sigma}_u^2 \tag{41}$$

where $\hat{\mu}_2'$ and $\hat{\mu}_3'$ are the second and third moments of the OLS residuals. The constant term is then corrected by adding the negative of the estimated bias. The mean level of technical inefficiency is given by:

$$E(u) = \sigma_u\sqrt{2/\pi} \tag{42}$$

Individual farm efficiency can be calculated from the formula suggested by Jondrow et al., it is the expected value of u_i conditional on w_i:

$$E(u|w_i) = \frac{\sigma_u \sigma_v}{\sigma} \left[\frac{f(w_i \lambda/\sigma)}{1-F(w_i \lambda/\sigma)} - w_i \lambda/\sigma \right] \quad (43)$$

where f(.) and F(.) are the values of the standard normal density function and the standard normal distribution function evaluated at $w_i \lambda/\sigma$ and $\lambda = \frac{\sigma_u}{\sigma_v}$. The percentage measures of technical efficiency is then defined as:

$$TE_i = Exp\ (-E(u_i|w_i)) \quad (44)$$

Results of Estimation

The procedure described above was applied to the OLS equation estimated from the data obtained from the 116 farmers. Relevant estimated parameters are presented in Table 20. The results indicate that 72.4 percent of the variation in total revenue can be attributed to technical efficiency. The mean level of technical inefficiency is found to be about 0.21. The stochastic model yields higher estimates for the TEi's as compared to the nonstochastic approach.

A correlation coefficient of 0.08 was found between the farmers' experience in animal traction and the technical coefficient. This is not statistically significant but, the positive sign implies that more experienced farmers are more efficient. To test for consistency of the two measurements (nonstochastic and stochastic) a significant correlation of 0.90 was derived between the two.

Table 20. Stochastic Frontier Parameters Farm Distribution by Technical Efficiency Ratio.

Parameters	Estimates	TE Range	Percentage of Farmers
$\hat{\mu}_2'$	0.0504	0.9 or above	49.10
$\hat{\mu}_3'$	-0.0038	$0.9 > TE \geq 0.8$	38.80
$\hat{\sigma}_u^2$	0.0677	$0.8 > TE \geq 0.7$	8.60
$\hat{\sigma}_v^2$	0.0258	$0.7 > TE$	3.50
σ^2	0.0953		
γ	0.724		
λ	1.62		
$E(u_i)$	0.2076		

Summary and Conclusions

The objective of the material included in this chapter was to compute a measure of the technical efficiency of cotton farmers in northern Côte d'Ivoire following the removal of the fertilizer subsidy in 1984. Two approaches found in the literature, the nonstochastic and the stochastic frontier functions were applied to data obtained from 121 farmers in a relatively homogeneous district (Niellé) in the Ferké region. The results of the former method called for substantial potential improvement in the farming practices while the latter yielded reasonable figures compatible with the CIDT extension service point of view about the area.

Nevertheless, the reliability of these results is somewhat questionable due to the lack of some key variables such as the labor cost measurement, maintenance costs for the equipment and data on other activities entering the farming system. Also, one crop year is insufficient to draw strong conclusions about the efficiency of a farmer. The approaches are applied to cross-sectional data; this may raise some statistical problems such as heteroscedasticity. Nonetheless, it must be retained that the approach can be used to differentiate among farmers when the appropriate data are available.

CHAPTER VI

A LINEAR PROGRAMMING MODEL OF THE REPRESENTATIVE SMALL FARM IN THE NORTHERN CÔTE D'IVOIRE

Introduction

The previous chapters have addressed issues relating to cotton production solely. However, as mentioned in Chapter II, cotton is only one component of the farming system. It was also argued that the introduction and development of cotton in the northern areas had not significantly displaced food crop activities. A family farm is first a home rather than a business, and is usually characterized by a diversification of crop activities and limited resources.

Empirical Techniques

Determination of optimum cropping pattern and input mixes under particular resource limitation conditions, have been achieved by agricultural production and farm management economists by the use of several quantitative techniques. The theoretical basis for optimal resource use and production combinations is essentially the theory of the firm. This theory is usually approached through neoclassical marginal analysis based on the concept of a production function. The production function is a relationship between factors of production and their corresponding outputs determined by physical conditions within the firm. By assuming perfect competition and that the objective of the firm is to maximize net revenue, maximization of profit is accomplished by determining the optimal mix of products and factors. At equilibrium, the marginal rate of substitution between two products or two factors is equal to the ratio of their prices. Determination of an exact functional form taking into account all relevant factors has made it difficult to rely solely on functional analysis.

Budgeting is one of the two modelling approaches used for farming system analysis. It is a technique that uses economic theory, farm records, and price expectations to synthesize a near optimum physical and financial plan for the operation of a given farm for some future period of time. Complete budgeting is normally concerned with the organization of the entire farming business and is associated with total costs and total returns. Partial budgeting, on the other hand, is usually concerned with the effect of a change in farm organization on net receipts. Enterprise budgets can be used to estimate the net return forthcoming from producing a given quantity of a specific enterprise. The technique has the advantage of simplicity and flexibility. However, the technique has some limitations including the inability to take some conditions into consideration (inefficient markets, risk).

Mathematical programming is a popular alternative for farm modelling. It is a method of constrained optimization. This appears to match the reality of small farmers striving, with limited resources, to improve their lots (Anderson et al., 1985). The most commonly employed tool is linear programming (LP) which is a special case of mathematical programming. In a linear programming model, there is an implicit assumption of production functions which are linear and homogeneous. However, multiple activities can be defined to approximate smooth marginal productivity curves as in the neoclassical theory of marginal analysis (Baumol). Other strong assumptions of linear programming models are divisibility of resources and activities, additivity of resources and single valued coefficients.

Functional analysis is well developed in Varian, Henderson and Quandt, and Beattie and Taylor. A complete discussion of the theory of mathematical programming, and linear programming applications to agriculture, are found in Heady and Candler, Beneke and Winterboer, Intriligator, and Hazell and Norton.

For its future use in this study, it is worthwhile to succinctly present the linear programming structure. The LP model is of the general form for a farm:

$$\text{maximize} \quad \sum_{j=1}^{n} c_j X_j \tag{45}$$

$$\text{subject to} \quad \sum_{j=1}^{n} a_{ij} X_j \leq b_i \tag{46}$$

$$X_j \geq 0$$

where a_{ij} = the units of the input i required for one unit of farm activity j;

c_j = the net revenue per unit of activity j;

X_j = units of activity j (activity level); and

b_i = the available units of resource i.

A number of studies conducted to evaluate problems in West Africa have used linear programming techniques to model household production activities. (See Spencer (1972) for Sierra Leone; Balcet and Candler and Crawford for Nigeria; Delgado, Jaeger, Roth et al., for Burkina Faso; Niang for Mali; Niang and Bourliaud et al., for Senegal). The common feature of these models is the importance of the labor constraint.

The distinction between risk and uncertainty has not been clearly defined for practical applications. Therefore, some authors have tended to use both terms interchangeably (Hazell; Harwood). Anderson et al., (1977) have defined risk as representing a situation where an outcome is not certain but a mathematical probability of alternative outcomes can be established through a priori calculations or from statistics of past experience and personal knowledge. Risk denotes a probability of loss whereby there is a lack of stability in production and returns. Based on these definitions, farmers in the northern Côte d'Ivoire operate in a very risky environment. Kireta-Katewu has defined uncertainty as ranges within which no valid basis for calculating probability of outcome exists. Yields, input and product price variabilities are the major sources of risk in agriculture. Reviews of literature on risk and uncertainty in farm planning decisions have often singled out the Markowitz model of income -- variance (E-V) criterion as the most commonly used (Anderson et al., 1977; Barry; Boisvert and Bailey). Quadratic programming (QP) models consider risk in relation to expected returns (E) and an associated variance (V). Quadratic programming models can be used to develop a set of feasible farm plans where variance is minimal for any associated expected returns. The decision criterion stipulates that if A and B are two uncertain actions with means and variances of outcomes of (μ_A , σ_A^2) and (μ_B , σ_B^2), if $\mu_A \geq \mu_B$ and $\sigma_A^2 \leq \sigma_B^2$ with at least one strict inequality,then A is preferred to B.

Other models have been developed to evaluate risk in the farm model. For example, the minimization of total absolute deviation (MOTAD) model was introduced by Hazell (1971). Under this criterion, the mean and the mean absolute deviation of outcome distributions are used to order alternatives. Both (E-V) and MOTAD models require that the decision maker be risk averse. A person is a risk averter relative to, say a lottery, if the utility of its expected value is greater than the expected value of its utility. Such a person prefers a certain outcome to an uncertain one with the same expected value.

Given the objective of the small farm household unit in developing countries in general, models taking the survival or safety first conditions are intuitively appealing. Safety-first models are designed to help a decision maker (a farmer for example) insure that he attains the minimum income necessary to meet his fixed costs (including credit payment) and to meet his family's living costs each year. Safety-first models are suitable for small poor farmers who often are semi-subsistence farmers.

One of the earliest safety-first models was proposed by Roy. Given that some minimal income Y_o is required for the farm family to survive, Roy's criterion calls for selection of the farm plan that minimizes the probability that income Y_t could fall below Y_o. That is, choose the plan such that P_r ($Y_t \leq Y_o$) is minimum. Under the assumption of normally distributed farm income, the optimal plan is identifiable as a member of the mean-variance set.

Low has proposed a different model that selects the farm plan that has an income equal to or greater than Y_0 in every state of nature, and which maximizes expected income E.

Boussard and Petit, by relaxing the normal distribution of returns assumption and the probability approach of the two models above, introduced the focus-loss model. The focal loss of a risky activity is defined as the level of loss that a decision maker would be "very surprised" to realize. For any farm plan, a maximum permitted loss is defined as the difference between expected total gross margin and the minimum income required to cover farm fixed costs, essentially family living costs and debt repayment.

A more recent and attractive model was proposed by Tauer. By modifying the MOTAD model, he developed a model called Target MOTAD. Tauer showed that Target MOTAD is computationally efficient and generates solutions which are in the second degree stochastic dominance (SSD) set. The model is formulated as follows:

maximize $$E = \sum_j \bar{c}_j X_j \qquad (47)$$

subject to $$Y_0 - \sum_j c_{jt} X_j - Z_t^- \leq 0, \text{ all } t \qquad (48)$$

and $$\sum_t p_t Z_t^- = \lambda \qquad (49)$$

$$\sum_t a_{ij} X_j \leq b_i, \text{ all } i \qquad (50)$$

$$X_j \; Z_t^- \geq 0, \text{ all } j, t$$

where

E = expected income;

Y_0 = target level of income;

$\bar{c}_j$ = average gross margin for activity j;

c_{jt} = return of activity j for period or state of nature t;

Z_t^- = deviations in income below the target Y_o;

p_t = probabilities of the state of nature t;

λ = constant parameterized from M a large number to 0;

X_j = level of activity j;

a_{ij} = technical requirement of activity j; and

b_i = level of resource or constraint i.

Equation 47 maximizes expected returns of the solution set. Equation 50 fulfills the technical constraints. Equation 48 measures the revenue of a solution under state of nature t. If that revenue is less than the target Y_o, the difference is transferred to equation 49 via variable Z_t^-. Equation 49 sums the negative deviations after weighting them by their probability of occurring p_t. Since the objective function and the constraints are linear, a linear programming algorithm can be used to solve the model.

A Linear Programming Model of Small Farms in the Niellé Area

A deterministic model is built to determine the pattern of resource allocation that would maximize total net returns to land and family labor for animal traction with open farms.

A tableau representing the basic structure of the deterministic LP model is shown in Figure 5. $X_{j's}$ are the levels of activities 1 through j. Household consumption behavior is incorporated by adding lower bound constraints on the production of the required crops. Consumption activities ($h_{j's}$) are included for crops other than cotton. Selling activities ($S_{j's}$) are also included. When necessary, hiring labor activities over the crop season are included. Workers from neighboring countries (Mali and Burkina Faso), provide seasonal labor while on their way to the south. The $Y_{j's}$ are crop yields. L_{mj} are the labor requirements for the different activities in each month from June to November.

	Production Activities	Selling Activities	Household Consumption	Hired Labor	Cash Borrowing	
	Xj	Sj	hj	Month		Resources
Objective Function	−cj	pj	pj	−w	−r	
Consumption						
Crop Balance	−Yj	1	1			= 0
Crop Consumption			1			>= Rj
Labor Requirements Month	Lmj			−1		<= LAB
Capital	cj				−1	<= K
Land	1					<= A
Rotation						= 0

Figure 5. Basic Farm Linear Programming Model.

It is assumed that all plantings start in June. The c_j's are the per hectare cost of inputs actually used by the farmer. The producer prices of the different crops grown are p_j's. The hired labor wage is w and r is the interest rate charged by money lenders.

The decision maker is assumed to be a profit maximizer, maximizing the function:

$$\pi = \sum_j p_j Q_j - \sum_j c_j X_j - \sum_m w L_m - rB \qquad (51)$$

where

p_j = the producer price of crop j (CFA F/kg);

Q_j = quantity of crop j produced (kg);

X_j = level of activity j (ha);

w = labor wage (CFA F/day);

L_m = level of hired labor in month m (days);

c_j = per hectare fertilizer and herbicide costs;

r = interest rate; and

B = total amount borrowed (CFA F).

The objective is to maximize the gross value of production (sales plus value of output consumed by the household) less expenditures for inputs. The cost of seeds costs are not included in the model since they are not purchased inputs. Input costs incurred for the animal traction team are also omitted.

Crop Enterprises and Land Availability

In all, six crops in pure stand are considered in the model: cotton, rainfed rice, corn, peanuts, millet, and sorghum. These are the typical activities for the household as a whole. Members may, on individual plots, grow other crops but these are not included in the model.

The land issue was discussed in Chapter II. The access of household to land is influenced by the land tenure system. In this area, land shortage is more due to declining soil fertility than population pressure. Average total land allocated to the six crops was 8.6 hectares over the period 1983/84 to 1986/87. However, land suitable for rice production is a major constraint. On average, one hectare or less is available.

Labor Supply

The average family size in the Ferké area on animal traction farms is 13.9 with 7.1 active workers and 6.6 members of age 14 or under (CIDT, 1986). Total available monthly labor is calculated, taking into account the number of days devoted to the common farm operations. Jaeger has found that the task performance of an ox team was about 7 times the traditional farming using hoes to plow and weed. For these operations, the total labor available includes the man days equivalent of the ox team.

The labor requirements for each activity are specified in man days using those reported by the CIDT (1983) although they are average figures for animal traction farming (See Appendix Table 27).

Capital Availability

In small farming, capital includes such items as simple tools and equipment, crop storage structures, and stocks of inputs like seeds, fertilizers, pesticides, and herbicides. In addition to real capital employed directly on the farm, there is money capital that can be used to purchase goods and services needed for production. Short term credit is available for fertilizer and herbicide at 12 percent. The quantity of available cash money for a representative family was difficult to obtain. Instead, it was estimated that 150,000 CFA F. are available to the household. This is not an average figure and reflects only the point of view of an extension service agent as well as the amount identified by one farm in the area. However, it seems reasonable since it represents the per hectare gross revenue for cotton among ATO farmers for the 1986/87 crop year.

Crop Rotation

Among the different rotations practiced in the area, the most common for farms growing the six crops is cotton followed by corn, followed by peanuts, followed by millet and sorghum.

Food Crop Consumption Constraints

In the absence of actual per household consumption, the model complies with the FAO/WHO requirements relating to the average daily energy for developing countries. Taking into account the family size and composition (age), a daily requirement of 2600 kilocalories (kcal) was selected for each individual. Given the importance of cereals in the diet in this area and referring to Hansen and McMillan who found that about 72 percent of the caloric intake in West Africa was provided by cereals, the derived annual cereals requirement is 2750 kg per family. On average, one kg of cereal provides 3475 kcal. Taking next years seed requirement into consideration and the number of times a week each cereal is consumed, the percentages of 40 for corn, 20 for rice and millet and 10 percent for sorghum were distributed. This may either underestimate or overestimate the consumption of one food crop because quantities consumed may not be proportional to frequency of consumption. The estimation yields 1150 kg for corn, 600 kg for rice and millet and 325 kg for sorghum. Peanut consumption was estimated at 200 kg because peanut butter stew is an integral part of the diet in the area.

Crop Yields and Prices

The model uses five-year average yields (1984/85 to 1988/89) in the area and the 1986/87 prices for crops and inputs as reported by the CIDT. Applying the rate of input use as determined in Chapter II, per hectare cost of inputs for each crop is computed and represents the c_j in the model. Daily wage rate is from 500 to 600 CFA F. The model included the highest rate.

Estimation and Results of the LP Model

Given the estimated yields and prices, and assuming that hand weeding, when applied at the optimal period has the same effect on output as herbicide, five alternatives were considered: 1) family labor only and the actual input use level defined in Chapter II, 2) family labor only and herbicide applied to 100 percent of the cotton, corn, and rice area, 3) seasonal labor hiring and the actual input use level, 4) alternative (2) and the effect of a decrease in herbicide cost by 50 percent, and 5) seasonal labor hiring and 100 percent herbicided areas and 50 percent decrease in cost. For each alternative, technical requirements and the objective function coefficients were adjusted accordingly.

The MUSAH86 linear programming software developed by the Department of Agricultural Economics at Oklahoma State University, was used to solve the models. The results are summarized in Table 21. The results show the importance of labor constraints in the farming system of the area.

Peanuts and millet use the largest share of the land under family farming without labor hiring activities, if the market allows the marketing of all products with the same opportunity. When seasonal labor can be hired, cotton production increases. This confirms the hypothesis that cotton and food crops compete for labor, and the importance of credit availability to farmers to afford the hiring. The amount of borrowing is reasonable since apart from the input short credit, farmers through the National Bank for Agricultural Development or their respective GVC, can borrow up to 50,000 for respective hard time periods. The opportunity cost for labor is the amount that a simple profit maximizer would be willing to pay to acquire one additional man day of labor in month "m". When no hiring is possible, in alternative (1), the opportunity cost of labor is 1066.9 CFA F in June, 197.3 and 1048.9 CFA F in September and November. June and November are critical months

Table 21. Cropping, Land Use Patterns and Returns Predicted by the Base Model under Five Alternative Labor Use Scenarios.

	Crop Activities (hectares)								Opportunity Costs of Labor (CFA F)		
Alternatives	Cotton	Rice	Corn	Peanuts	Millet	Sorghum	Returns (CFA F)	Borrowing (CFA)	June	September	November
1	0.86	0.66	0.78	1.78	0.67	2.93	396650.9		1066.9	197.3	1048.9
2	0.90	0.66	0.78	1.86	0.67	2.86	381421.4		1010.1	353.4	918.8
3	3.73	0.66	0.78	0.24	0.67	2.52	479868.8	23964	600		600
4	0.90	0.66	0.78	1.86	0.67	2.86	399185.8		1052.5	236.9	1015.9
5	3.73	0.66	0.78	0.24	0.67	2.52	471250.3	35229.3	600		600

since they correspond to the rush period of planting in June and cotton harvest in November. The model overstates the wage rate usually paid.

When using herbicide and family labor only, the opportunity cost of labor for these two months is less than above. Reduction of herbicide cost by 50 percent does not affect significantly the result. This may be attributed to the fact that use of pre-emergence herbicide even at 100 percent level does not exclude a second weeding a month later. So the labor pressure is not totally removed.

The results presented above are derived from average yields of the different crops. They do not reflect the risk involved in the variability of these yields.

Estimation and Results of the Safety-First Model

Reliable results of risk model estimation require a substantial number of observations on the variables to use to capture the risk. In the case on hand, it is assumed that the source of variability in income is due to yield variability. This implies that the pricing policy is fixed at the current level. Satisfactory data series on yields to comply with these assumptions are only from the 1984/85 to 1988/89 crop years where, the nominal producer prices have not changed, fertilizer and herbicide use levels have not significantly varied and the proportion of animal traction farmers is almost the same in the area. However, five year data are insufficient to capture significant variability. Nevertheless, a variance-covariance matrix can be obtained from these data. The derived matrix may be used to simulate observations on normally distributed yields. This procedure was applied to the five available observations to generate 30 observations of normally distributed yields for cotton, rice, corn, peanuts, millet, and sorghum for the Niellé area (See Appendix). The technique is subjective, but it is an improvement over ignoring risk when modelling farm mixtures. The model described by equation 47 to 50 was applied to these data. To insure self sufficiency in food crops, additional constraints to satisfy the minimum yearly consumption requirements were imposed on food crop land. Hectarages were set to be equal to or greater than the area needed to produce the family requirements.

McCamley and Kliebenstein argued that for some Target MOTAD applications, only enterprise mixtures associated with a single target level are of interest. However, in most cases, knowledge of other Target MOTAD enterprise mixtures provides useful information. The complete set is a finite number of closed convex subsets that can be identified by parametric programming. They also pointed out that for well-behaved problems, only two parameters, target income level and expected deviations needed to be varied to identify the set of Target MOTAD mixtures. In this study, only expected deviations are parameterized for three different target income levels and the results are presented in Table 22. The model considered only the case of hiring labor and current level of technology adoption. To test for the sensitivity to the number of observations, one solution was obtained with 20 observations. The self sufficiency in food crops land constraints were then removed, and the model solved with the initial 30 observations.

The number of observations, when drawn from the same simulated sample, does not seem to have an effect on the results. For the target income of 350,000 CFA F, the same farm plans were optimal with both 30 and 20 observations. When food crop land constraints are imposed, plan III appears to be close to the LP solution (alternative 3 in Table 21). However, in all cases, cotton, rice, and millet are relatively stable. A farmer who is most concerned about survival might well choose the plan having the smallest possible deviation. However, the choice must take into account the consumer's taste and preference for food in the area. Given the importance of corn in the diet, and the difficult market conditions for sorghum and millet, the most suitable plan may be plan VI which yields the lowest return. Under this plan, the representative farmer in the Niellé area will grow 3.27 hectares of cotton, 0.7 of rice, 2.86 of corn, 0.68 of peanuts, 0.69 of millet and 0.40 of sorghum.

Table 22. Crop Mixtures and Returns from the Safety-First Model

Farm Plan	Targe Income (CFA F)	Total Deviations (CFA F)	Returns (CFA F)	Crop Activities (hectares) Cotton	Rice	Corn	Peanuts	Millet	Sorghum	Borrowing (CFA F)	Hired Labor June	November
30 Observations with Food Crop Area Constraints												
I	300000	990000	475784	3.71	0.7	1.71	0.24	0.69	1.54	36871	129.7	101.6
II	350000	989920	468490	3.42	0.7	2.86	0.52	0.69	0.4	41211	198.6	52.9
III	350000	987404	478356	3.71	0.7	0.8	0.24	0.69	2.46	24641	75	129
IV	350000	899962	467711	3.37	0.7	2.86	0.58	0.69	0.4	39091	198.6	50.2
V	350000	899506	472548	3.71	0.7	2.86	0.24	0.69	0.4	52265	198.6	67.2
VI	400000	896708	466305	3.27	0.7	2.86	0.68	0.69	0.4	35259	198.6	45.3
20 Observations with Food Crop Area Constraints												
VII	350000	899943	467711	3.37	0.7	2.86	0.58	0.69	0.4	39091	198.6	50.2
VIII	350000	899880	468490	3.42	0.7	2.86	0.52	0.69	0.4	41211	198.6	52.9
IX	350000	899259	472548	3.71	0.7	2.86	0.24	0.69	0.4	52265	198.6	67.2
X	350000	896102	478356	3.71	0.7	0.8	0.24	0.69	2.46	24640	75	129

Table 22. (continued)

30 Observations with no Constraint on Food Areas												
XI	300000	900000	478744	3.95	0.7	2.07	-	-	1.88	50982	151	102.9
XII	300000	897887	484580	3.95	0.7		-	-	3.95	23221	27	165
XIII	350000	900000	474144	3.95	0.7	3.7	-	-	2.48	72861	249	54
XIV	400000	897789	468464	3.6	0.7	3.95	0.35	-	-	62679	264	29
XV	400000	897523	473445	3.95	0.7	3.95	-	-	-	76191	264	46.5

The analysis was carried out without imposing market conditions; despite this omission, cotton is in the optimal plan. Food crop pricing under the current conditions, is less attractive than cotton pricing.

When constraints on food crop land are removed, cotton activity remains dominant. The major difference here is that some activities (peanuts, corn, millet, and sorghum) do not enter some of the derived plans. In plan XV, the farm will devote equal land area to cotton and corn and purchase peanuts, millet, and sorghum. However, this plan has the highest demand for hired labor in June. The most suitable plan may be plan XI. However, it has the highest negative deviation from the target level of income. If farmers are willing to buy corn for consumption, plan XII would be attractive.

Limitations of the Analysis

Modelling of a representative small farm is a difficult task that requires consideration of several types of data. Environmental, agronomic, and socioeconomic variables must be available. Combinations of these characteristics may allow the modeller to identify homogeneous systems that can be modelled. The present study was conducted with limited data and relied upon extrapolation. Moreover, the model considered average farm size (based on family size and hectarage). Different soils could be another source of differentiation. The models did not include constraints on food crop markets. In some cases, nonagricultural activities may be important enough not to be omitted in such model. The assumption of normally distributed yields might be inaccurate.

CHAPTER VII

SUMMARY OF FINDINGS AND POLICY IMPLICATIONS

Summary of Study Findings

This study is concerned with the low rate of adoption of a technology package introduced in the Northern Côte d'Ivoire to develop cotton and food crop production. In accordance with the various five year development plans since independence in 1960, the cotton development program was to be the stepping stone of economic progress for the Savanna regions of the North. The objective was to reduce the existing income gap relative to that of the South.

Cocoa and coffee are the traditional cash crops that have dominated the Country's agricultural economy. These two major crops have provided likelihood for both native and allochthonous farmers in the forest zones of the South. They also contribute significantly to the GDP and government revenue.

The overall satisfactory achievements reported at the project closing in 1982 did not overlook areas of less successful results. Although the project was accompanied by an input subsidy policy and intensified technical assistance by the parastatal agency, the CIDT, the food crop component showed a low rate of adoption. The observation that delays in cotton planting occur has raised questions of competition between food crops and cotton at planting time.

There is only one rainy season lasting about six months (May-October). Planting operations take place late in May and early in June. The cotton hectarage has significantly increased by 232 percent while yield has improved by 44 percent. Given the financial burden supported by the government through the subsidy, it was argued that the incentives have enticed farmers to grow more cotton but not necessarily better. In other words, the technical efficiency of cotton production was brought into question.

In light of the research objectives and the concerns outlined above, an attempt was made to estimate the cotton supply response to prices by estimating separately its components, hectarage and yield. The study has also investigated this rainfall pattern in the early period of the rain season to determine an explanation for the delay in cotton planting and determine an optimal planting date. CIDT extension service personnel contend that the Niellé region, located at the Mali and Burkina Faso borders, has shown relatively good results in cotton production. The analysis of the production frontier was used to evaluate technical efficiency. Lastly, a simplified whole farm plan was designated for the animal traction farmer in the Niellé area through the construction of a linear programming model taking risk into consideration.

Supply Response

The hectarage response to cotton price measured by the short-run elasticities for the period 1969-1987, were found to be 0.268, 0.377, and 0.522 for the Boundiali, Korhogo, and Ferké areas, respectively. The derived long-run elasticities were 0.583, 1.02, and 1.05. The coefficients of adjustment varied from 0.307 in Korhogo, 0.457 in Boundiali, and 0.496 in Ferké. Cotton hectarage did not show any response to food crop prices in any of the three areas. The yield component exhibited no response to cotton price. An estimate of the cotton supply response is therefore well captured by the area planted in relation to prices.

Labor wage was found to be an explanatory variable in the supply response of the Boundiali and Ferké area. This was explained by the farm population level in these areas. The Korhogo area has the largest population and the largest number of small farms on which family labor is the major, and sometimes only, source of labor. The dummy variable introduced to reflect the subsidy period proved to be significant only in the Korhogo area.

Optimal Planting Date

Decadal rainfall precipitation in the Boundiali area were fitted to a gamma distribution and to a Markov chain process. Estimates of constant probabilities, conditional probabilities of rainfall, and the expected length of wet and dry spells, in the only rainy season were obtained. The period June 5-15 was found to be a suitable planting date for cotton. This result suggest that time is available for food crop planting before or after cotton. However, this result is valid provided that rainfall is not delayed or sporadic at this period.

Technical Efficiency

The production function analysis provided mixed result. Both nonstochastic and stochastic approaches were used. The nonstochastic approach revealed that only 23 percent of the farmers in the area have a technical efficiency ratio of 0.70 or higher. This implies the existence of room for improvement in the production system. On the other hand, the stochastic frontier, which includes an element that captures sources of inefficiency beyond the control of the farmer, showed that at least 49 percent of the farmers have a ratio of 0.9 or higher. Only 3.5 percent have technical efficiency ratios between 0.7 and 0.8. If repeated estimation for several crop years result in similar estimates, it could be inferred that farmers in the Niellé area are relatively technically efficiency.

Whole Farm Modelling

Land, labor, capital, and food self sufficiency constraints were incorporated into a linear programming model with the objective of maximizing household returns. For the static model, not taking risk into consideration, five alternative combinations of labor and herbicide were considered. These include: 1 family labor and the current level of input use, 2) family labor and herbicide applied to all cotton, corn, and rice hectarage, 3) labor hiring combined with the current input level use (this is the current situation), 4) the effect of a 50 percent decrease in herbicide cost in alternative two, and 5) the combination of labor hiring and 100 percent herbiciding areas in cotton, corn, and rice.

The model confirms that labor is very limiting at planting and harvest. When hiring was allowed in the model, the shadow prices on labor in June and November substantially exceeded the current wage rate (1066.9 and 1048.9 CFA F for alternative one, 1010.1 and 918.8 for alternative two 1052.5 and 1015.9 for alternative four). Consequently, cotton hectarage was limited to less than one hectare in these cases. When hiring was included, cotton was predominant. The decrease in herbicide price did not show significant shifts in cropping patterns. This may be due to the existence of a second weeding which is necessary because preemergence herbicide application does not always provide 100 percent weed control This is especially true in years of abundant rainfall. Alternatively, it may be the result of malpractice with regards to estimates of labor requirements.

The safety-first model constructed in the Target MOTAD framework, generated optimal plans complying with the farmers' objectives of assuring an adequate minimum level of food, optimization of family labor expended, maximizing expected income, and minimizing income variation. To comply with the cultural characteristics of the farmers in the area, the optimal plan found is to grow 3.27 hectares of cotton, 0.7 of rice, 2.86 of corn, 0.68 of peanuts, 0.69 of millet, and 0.4 of sorghum. The expected income is 466,305 CFA F. The average animal traction farmer in the region had cotton sales of 424,000 CFA F in 1983/84 and increased to 530,000 CFA F in 1986/87. In all models, cotton activity remained predominant despite its labor requirement and relatively high cost of production. The cotton price is highest and cotton yields are high on average relative to the food crops except for corn.

Since land is not a major constraint in the area, the shadow price or marginal value product (MVP) of land was not evaluated.

Policy Implications

The success of non food cash crops such as coffee, cocoa, and cotton in the Côte d'Ivoire, depend on the efficiency of marketing services and producer prices. As the national economy remains vulnerable to international market prices, farmers emphasizing cotton production exclusively may suffer in years of low prices, as no cash would be available to purchase food crops. Should cotton supply be responsive to food crop prices, under relatively efficient marketing services, income stability may be achieved even with crop diversification and, food self sufficiency may be reached.

The cotton project has considered the advantages of coordination with a system of crops rather than as a separate enterprise. However, in practice the technical assistance has placed more emphasis on the cash crop. It is beyond the scope of this study to carry out a proposed technical assistance scheme. However, reduction of rice imports, supply of livestock feed, and diet diversification are incentives to consider in food crop development. The present economic outlook of the country does not suggest the possibility of a producer price increase. For example, coffee and cocoa prices were reduced by almost 50 percent in October, 1989. The remaining alternative for policy makers is to reduce the cost of production. Considering the low level of input use in general in the country by the large number of small farmers, the companies dealing with modern input must be making enough profit to maintain their business. A close revision of their pricing policy could provide a potential adjustment in variable costs incurred by farmers.

The normative analysis in the study showed that current prices are too low for some food crops to justify production in excess of family consumption requirements. Reductions in input prices would provide incentives for farmers to use more of the inputs with a corresponding increase in output.

The production system analyzed in this study has voluntarily omitted livestock activities which are traditionally carried out by nonfarmers. However, integration of livestock production must be considered for future farm planning. Farm population are getting younger and more educated. The long term effect would be increases in domestic production and a decrease in livestock product imports.

The mechanization of agriculture to alleviate labor constraints and increase productivity has not reached satisfactory levels. Some farmers are only partially equipped with the necessary tools. For example, the animal traction farmer may possess only a pair of oxen and a plow with no seed drill. Hence the capital assets are not balanced. The area plowed may be too large for the limited labor available for seeding and weeding. The credit system should be flexible enough to allow acquisition of tools. Because of the fear of default, many farmers are reluctant to purchase the necessary equipment.

The less successful results of low food crop yields have been blamed on farmers. However, it has been observed that for both fertilizers or herbicides, the same rates are recommended and applied all over the CIDT zone. The rationale is that it is not economically feasible for the country to undertake locale specific studies to design and implement relevant rates for each area. It has also been argued that some farmers switch to a less costly rate recommended for a different area. These arguments should not overshadow the need for integrated research on improvement of soil fertility and plant breeding which are long term solutions to the yield problem.

Tentative weather forecasts should be made prior to planting dates. The cost of a timely forecast would be less than the cost of replanting or the cost of rushing into the fields and making poor decisions. Even though it is a probabilistic approach, weather forecasting is an improvement over fatalism.

A major component not emphasized in this study is the role of women in food crop production. The technical assistance has not been extended enough to them and this may be another source of the yield problem. Alternative energy and water supplies may prove to increase their availability and consequently the output of food crops.

In short, there are no short cuts to development. The process of developing and extending improved technologies requires substantial investments in human and physical capital.

Limitations of the Study and Need for Future Research

The present analysis bears some inherent weakness due basically to data unavailability. Farm level data were not used to make reference about individual farmers. The Nerlovian model applied to estimate supply response has received substantial criticism on the grounds of the expectations model involved. The variables involved may not be relevant because of the quality of data and conclusions drawn might be misleading for the response to food crop prices. The rainfall analysis was carried out for only one area. Due to the similarities in rainfall pattern with other areas in the Northern part, generalized conclusions have been started.

The efficiency analysis, although useful, is only a partial estimate of a farmers' technical efficiency since only cotton production was considered. The farm plans generated in Chapter VI are incomplete since some important activities were not included in the model.

Resource constraints in terms of funding and time were major factors limiting the planning process and scope of this research. The author had to rely on his own resources and the cooperation of the CIDT to accomplish the data collection. The study has, however, raised pertinent issues that need future investigation. The farming system research approach appears to be a consistent way of, at least, getting information about farmers in a specific area. Several crop years are necessary to perform such task. From these information, efficiency considered in its entire concept, can be evaluated. Farm plans may be diversified as they comply with different types of farming identified by the research.

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APPENDICES

APPENDIX A

ACRONYMS

ACRONYMS

ANAM: Agence Nationale de l'Aéronautique et de la Météorologie (National Agency for Aeronautics and Meteorology).

ATO: Animal Traction Using Oxen.

CFA F: Franc de la Communauté Financière Africaine (Franc of the Africain Financial Community). US $1.00 = 303 CFA F (1988).

CFFDT: Compagnie Française pour le Développement des Fibres et Textiles (French Agency for Fibres and Textiles Development).

CIDT: Compagnie Ivoirienne pour le Développement des Textiles (Ivoirian Agency for Textiles Development)

CSSPPA: Caisse de Stabilisation et de Soutien des Prix des Produits Agricoles (Agricultural Product Prices Stabilization Funds)

APPENDIX B

SUPPLY RESPONSE DATA

Table 23. Cotton Hectarage and Production in the Northern Côte d'Ivoire (1964/65-1986/87).

	Boundiali		Korhogo		Ferke	
Year	Area (ha)	Production ('000 tons)	Area (ha)	Production ('000 tons)	Area (ha)	Production ('000 tons)
1965	495	605	574	23	15	112
1966	1,188	928	553	121	50	365
1967	1,915	1,982	3,406	2,767	1,064	795
1968	4,168	3,478	4,589	3,657	1,700	1,525
1969	7,436	6,900	6,211	4,935	3,244	2,989
1970	8,270	8,012	5,842	4,828	2,239	1,909
1971	8,113	5,846	4,406	2,356	1,996	1,281
1972	11,252	10,891	4,906	950	2,781	2,795
1973	13,051	13,788	6,093	6,046	3,941	4,386
1974	12,118	12,832	6,286	6,498	4,219	5,142
1975	13,075	12,711	6,952	7,117	4,581	4,971
1976	14,694	16,310.3	8,435	8,561.5	5,767	6,199.5
1977	14,535	12,340.2	10,561	10,381.5	7,679	8,408.5
1978	15,806	18,319.1	13,756	14,760.2	9,200	10,302.6
1979	17,834	19,724.4	17,424	17,075.5	11,417	13,272.2
1980	18,479	24,780.3	21,345	26,723.9	15,253	19,676.4
1981	19,041	20,868.9	25,548	23,938.5	17,004	16,782.9
1982	19,089	22,372.3	29,025	30,534.3	17,300	16,037.1
1983	18,022	21,500.2	29,393	30,862.6	16,845	17,670.4
1984	18,802	21,434.3	29,981	32,619.0	16,845	18,765.3
1985	17,589	23,111.9	31,460	43,949.0	19,146	25,081.3
1986	18,961	24,156.3	34,245	40,751.5	20,610	28,400.6
1987	20,526	26,868.5	34,522	41,564.0	20,610	26,257.1

Source: CIDT Annual Reports, 1981, 1987.

Table 24. Producer Prices(CFA F/kg) and Labor Wage Rates (CFA F/Day).

Year	Cotton	Corn	Rice	Labor Wage	CPI(1980=100)
1965	33.5	12	18	156	25.5
1966	33.5	12	18	156	27.0
1967	33.5	12	18	156	27.0
1968	33.5	12	18	156	29.0
1969	33.5	12	20	156	30.0
1970	34.59	12	22	156	32.0
1971	39.57	12	22	156	32.0
1972	39.60	13	22	156	32.0
1973	39.77	19	25	160	35.0
1974	44.84	19	65	200	42.0
1975	69.90	20	65	200	46.0
1976	69.92	25	65	250	52.0
1977	79.86	36	65	250	66.0
1978	79.92	60	65	274	75.0
1979	79.95	60	65	274	87.0
1980	79.95	68	65	302	100.0
1981	79.95	72	50	309	109.0
1982	79.96	50	60	309	117.0
1983	79.93	58	60	560	124.0
1984	99.73	50	80	560	129.0
1985	114.65	40	80	560	131.0
1986	114.87	40	80	560	140.0
1987	114.55	40	80	560	148.0

Sources: 1. CIDT Annual Report , 1987.
2. Ministry of Agriculture, Statistical Report, 1986.
3. IMF, International Financial Statistics, 1988.

APPENDIX C

BOUNDIALI RAINFALL DATA

Table 25. Decadal Precipitations (mm) at Boundiali, April 1- November 15, 1961-85.

Year Decades	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972
Apr 1-10	0.6	27	1.6	9.3	7.5	80.8	21.8	62.4	58.5	83.2	10.2	0
6-15	23.1	26.2	13.2	0	40.5	50.5	37.2	62.7	43.7	80.4	14.6	0
11-20	22.5	21.6	13.2	4.5	80	61.1	26.3	8.9	16.5	43.1	21.9	43.6
16-25	73	116.9	2	10.5	56.5	25.6	21.8	37.4	18.2	56.8	50.1	132.1
21-30	75	176.8	20.9	11.5	82	0	37.6	44.9	20.9	28.4	61.3	104.9
26-5	9	86	26.2	82.5	82.5	0	39.7	38.7	12	46	78.1	77.1
May 1-10	7	21.8	42.6	49.2	23.5	0	13	22.6	0	49.7	74	63.7
6-15	10	29.5	35.3	61.1	31	35.5	20	9.2	1.2	33.1	24.6	3
11-20	10	34.4	17	57	50.5	35.5	25	12.5	7.5	32.2	37.3	24.8
16-25	15.5	24.7	35.2	42.1	58.3	0	11	7.5	15.6	64.2	123.6	39.3
21-30	15.5	17	50.4	4.5	46.8	25.3	20	49.9	25.2	162.6	107.4	87.4
26-4	38	27.1	45.2	107.5	68.5	50.6	23	113.3	15.9	151.1	73	193.7
Jun 1-10	39.2	53.4	26.3	116.3	54.5	48.3	9	88.9	60.9	101.2	51.9	146.6
6-15	8.5	89.4	28.6	11.3	78	47	30.9	84.4	64.7	80.4	27.1	86.7
11-20	8.3	55.2	60.5	31.8	110	24	30.9	123.5	15.9	69.8	113.1	103.4
16-25	52	41.7	70.5	46.9	59	3.5	15	83.1	41.4	55.4	112.4	72.5
21-30	129.5	75.2	49.6	56	110	13.4	25.5	24.3	72.9	14.7	59.3	90.5
26-5	142.5	55	68.3	39.1	182.5	45.4	41.8	12.6	60.1	57.1	32.9	68.7
Jul 1-10	98	54.4	106.5	22.1	210.3	35.5	51.8	43	61.5	43.9	0	8.2
6-15	59	122.5	84.5	37.9	160.8	97.6	71.8	32	131.3	100.9	63.7	28.1
11-20	40.5	101.3	115.5	50.3	60	163.3	51.3	0	98.8	149.6	104.7	60.9
16-25	50.5	51.2	221	186	72	100.7	0	32.2	69.8	150.2	75.5	56.4
21-30	66	34.4	219.6	281.5	148.3	53.3	0	78.5	89.6	149.6	100.1	137.8
26-4	94	58.7	118.5	178.7	175.8	83.9	40.8	85.2	132.3	192.4	200.3	114.2
Aug 1-10	87	64.4	50.4	78.8	169.5	126.6	102.6	57.7	168.3	306.3	219.1	43.2
6-15	97.7	85.4	45.3	114.8	106.8	61	61.8	70.3	129.9	225.2	222	149.1
11-20	95.7	114.9	151.9	219.1	134.3	140	20.4	66.1	118.6	117.4	177	156.8
16-25	22	106.2	165.5	133.7	132.5	373	40.8	35.2	90.8	107.8	144.5	158.5
21-30	58	115.7	95.4	86.7	60.5	305.2	41.4	43.5	45.9	106.8	189.7	219.3
26-4	79	109.2	147.7	231	125	154.4	67.4	68	66.3	178.4	181.2	280.5
Sep 1-10	121.7	146	131.7	183	107	99.5	111.5	102.9	96.6	169.5	272.8	333
6-15	135.7	148.3	55.5	79.5	145.5	67.5	87.8	112.4	54.8	78.3	186.9	191.7
11-20	45.8	122.3	26.4	91.7	337.4	86.2	76.5	61.6	63.5	37.7	68.8	43.9
16-25	28	122	44.8	105.9	266.9	76.8	141.2	20	131	142.4	126.2	61.6
21-30	43.5	102.4	29.5	105.7	75	121.4	110.1	49	83.1	196.2	90.5	66.6
26-5	49.5	54.6	37.8	56.7	97.7	90.8	33.6	45.8	88.7	63.2	41.9	47.1
Oct 1-10	28.9	133.8	62.4	9.5	101.2	10.2	35.6	9.8	140	4.2	66.5	48.1
6-15	16.5	173.1	142.7	16	42.5	0	64.3	0	82.6	0	66.5	22.4
11-20	10.8	56.5	130.6	16.2	21.5	0	55.6	0	113.3	21	62.2	89.2
16-25	4.8	16.3	12.5	12.8	71	0	45.4	0	116.9	50.4	66.2	142.3
21-30	12.3	18.8	14.4	18.1	152.8	0	29.4	0	48.6	51.1	23.5	106.6
26-4	20	2.5	17.4	25	101.3	57.6	1.6	0	42.8	21.7	0	53.5
Nov 1-10	15.7	12.4	3	25	19.5	85.6	1.6	0	119.8	0	0	0
6-15	21.6	64.2	0	9.5	0	40.3	0	0	94.5	0	0	0

Table 25. (continued)

1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
19.5	21.5	14.5	0	4.5	25.5	0	10	13.2	0	3.2	0	8.6
8.2	46.9	0	0	0	40	0	10	13.2	61.5	1.6	7.1	8.6
18.9	25.4	0	28	0	60	0	8	0	68.8	12.9	13.6	0
35.3	74.6	0	86.1	0	20	0	10.5	16.4	39.5	11.3	9.2	18.5
31.1	74.6	30.8	107.6	21.5	20.3	25.5	27.4	65.4	38.6	52.5	16.4	38.4
6.5	0	57.4	51.1	32.5	31.1	25.5	53.4	55.5	9.4	67.6	51.1	19.9
55.5	0	26.6	91.9	21	10.8	54.5	52.5	45.7	31.9	17.6	80	0
55.5	25.5	55.5	103.3	61	20.3	126	32.3	39.2	42.3	2.5	42.6	30.2
0	50.9	104.7	14.2	51	20.3	71.5	11.5	37.2	28.1	19.2	25.6	63.7
14.5	25.4	49.2	9.4	0	8.3	21.5	18.9	44.9	46.9	19.2	28.1	42.6
27.7	15.4	0	57.9	21.5	29.7	21.5	56	57.2	32.8	6.5	13.3	13.6
26.4	90.2	0	107.2	37	76.3	0	54.1	63	39.5	33.3	40.3	4.5
29.4	151.8	0	82.1	85	72.5	56	106.9	61.8	52.5	61.1	60	46.6
32.6	96.9	87.6	49.4	159.5	17.6	67.5	100.1	93.7	13.6	65.8	32.9	103.9
35.8	60.9	120	30.8	112	5.5	117	83.2	78.6	12.8	52.7	24.8	78.7
35.6	57.4	47.1	6	22	14	176.5	76.2	72.3	22.1	44.8	74.7	54.1
53	32.8	14.7	84	41.5	71.1	82	7	60.6	35.2	64.7	114.8	54.6
64.9	40.9	104.8	88	47.5	62.6	43.5	8	44	88.4	54.5	88.5	104.8
75.2	128.1	169.3	4	6	0	72.5	29.3	101.4	78.7	63.1	49.2	82.9
112.7	181.4	64.5	0	0	0	71.3	29.5	90.8	23.2	82.9	36	97.2
65.5	200.7	0	55	0	0	84	128	45.8	38	54.8	57.9	120.2
43	228.8	41.8	133.5	0	97.6	113	180.6	71.4	115.2	21.6	45.8	68
126.2	210.5	107.3	118	24	141	91.6	120.8	58.2	84.2	0	31.5	85.3
101.6	199.8	98.6	39.5	61.5	131.3	77.6	95.8	95.6	69.1	51.6	104.5	122.2
85.3	194.3	101.7	33	111.5	87.8	206.3	28.8	123.4	100.7	70.4	97.4	174.1
229.7	126.2	97.3	46	137	0	201.1	14.7	96.6	65.4	33	30.8	186.9
292	210.9	82.3	88	76.5	50.3	85.9	158.5	55.6	46.1	15.3	7.1	189.6
210.7	360.4	53.6	81.5	80.5	54.9	246.6	166.6	7.5	69.8	65.8	49.3	128.5
174.7	233	114.4	6.5	67	54.1	297.7	50.6	29.2	103	112.6	75.9	47.3
181.9	187.6	173.1	4	0	147.9	123.5	152.6	87.9	67.4	83.6	103.3	26.7
96.9	180.9	108.9	91.5	73.5	190	63.1	127.7	70	94.7	46.5	104.6	65.8
78.2	74.2	239.5	211	144.5	106	137.2	42.2	56.8	98.3	32.3	61.1	62.4
91.4	167.1	239	149	125.5	44.7	134	59.7	54	35.8	41.4	112.2	128.1
73.4	181.6	154.3	25.5	79.5	84.5	45.5	26.8	33.4	19.1	21.9	77.4	127.6
176.1	76.4	155.6	29	83	68	25.9	13	35.7	19.9	2	1.9	9.1
251.5	83.3	70.3	40	132	34.3	39	77.9	59.6	28.9	27.3	14.8	34.4
164.8	116.9	19.3	48.5	74	38.3	48.7	71.3	72.3	17.8	32.2	32.7	63.3
80.2	101.7	0	62.5	0	17.8	22.4	33.7	33.9	0	4.9	35.7	36.3
42.8	38.9	0	52.5	0	34.6	0	42.1	12.2	6.3	9.8	47.3	15.9
24.5	48.4	0	92.5	7.8	79.6	0	18.6	18.9	12.3	35.5	50.8	12
81.9	52.6	0	82.5	19.6	45	0	34.1	17.1	16.6	39.5	22.6	3.5
101.4	12.4	0	17.5	11.8	22.6	0	91.5	3.8	39.6	84.8	1.3	88.6
44	0	0	43	0	22.6	0	68.2	3.8	29	92.8	0	88.6
0	0	0	85.5	0	0	0	0.6	0	0	34.7	12.9	0

APPENDIX D

NIELLÉ FARMERS DATA

Table 26. Cotton Hectarage, Input Uses, Total Production, and Animal Traction Experience (1987/88).

Farmer	Total Hectarage (ha)	Fertilizers NPK (kg)	Fertilizers Urea (kg)	Herbicide (Liters)	Total Cotton Production (kg)	Starting Year in ATO
1	6	1,200	300	12	1,081	1976
2	5	1,000	50	12	8,214	1976
3	5	1,000	250	16	8,900	1977
4	5	1,000	250	8	9,300	1978
5	4	800	200	4	7,206	1977
6	3	600	150	0	5,467	1985
7	2	400	100	0	3,523	1981
8	4	800	200	0	798	1977
9	4	800	200	0	7,806	1976
10	5	1,000	250	4	8,948	1974
11	6	1,200	300	12	9,169	1980
12	5	1,000	250	4	9,637	1975
13	2	400	100	4	3,200	1982
14	5	1,000	250	16	8,543	1979
15	4	800	200	8	8,017	1979
16	5	1,000	250	8	9,500	1978
17	3	600	150	4	5,528	1982
18	8	600	400	12	13,247	1978
19	3	600	150	0	6,343	1979
20	3	600	150	12	4,601	1978
21	5	1,000	250	12	11,291	1977
22	5	1,000	250	8	9,780	1976
23	4	800	200	0	4,783	1986
24	2	400	100	0	2,366	1981
25	2	400	100	0	3,148	1980
26	4	800	200	12	664	1974
27	5	1,000	250	0	9,000	1974
28	6	1,200	300	24	11,230	1974
29	5	1,000	250	16	8,900	1975
30	5	1,000	250	16	9,420	1974
31	3	600	150	0	5,700	1977
32	5	1,000	250	16	11,639	1975
33	4	800	200	0	7,350	1976
34	2	400	100	8	3,320	1978
35	2	400	100	8	3,470	1979
36	2	400	100	0	3,098	1985
37	3	600	150	12	8,338	1974
38	3	600	150	4	6,567	1974
39	2	400	100	8	4,723	1975
40	3	600	150	8	4,725	1975
41	2	400	100	4	4,616	1976
42	4	800	200	10	8,804	1975
43	7	1,400	350	0	8,209	1972

Table 26. (continued)

44	3	600	150	4	6,731	1975
45	3	600	150	2	3,824	1975
46	3	600	150	12	4,852	1976
47	5	1,000	250	8	7,149	1976
48	4	800	200	0	6,304	1976
49	3	600	150	4	6,065	1972
50	3	600	150	8	7,034	1976
51	3	600	150	8	3,203	1975
52	3	600	150	4	3,175	1972
53	3	600	150	4	2,500	1974
54	2	400	100	0	1,711	1975
55	3	600	150	0	3,321	1975
56	2	400	100	0	4,346	1972
57	3	600	150	8	7,401	1983
58	2	400	100	0	3,395	1972
59	2	400	100	0	5,223	1986
60	5	1,000	250	16	10,245	1973
61	5.5	1,000	250	16	7,284	1978
62	4	800	200	0	6,540	1979
63	3	600	150	8	4,235	1976
64	4	800	200	4	6,322	1977
65	6.5	1,200	300	24	11,409	1976
66	5	1,000	250	8	8,168	1976
67	3	600	150	4	3,488	1976
68	3	600	150	0	5,629	1981
69	2	400	100	0	3,696	1985
70	3	600	150	6	5,203	1983
71	3.5	600	150	4	4,749	1977
72	4	800	200	16	8,005	1981
73	2	400	100	4	3,257	1985
74	1.5	300	50	6	4,186	1979
75	3	600	150	0	3,138	1985
76	4	600	150	0	4,507	1987
77	3	600	150	12	4,307	1975
78	3	600	150	4	3,465	1974
79	3	600	150	8	5,656	1975
80	4	800	200	4	8,447	1974
81	3	600	150	0	5,840	1975
82	2	400	100	4	929	1976
83	3	600	150	0	3,441	1975
84	3	600	150	4	6,520	1977
85	3	600	150	8	4,023	1979
86	3	600	150	0	2,542	1979
87	4	800	200	12	7,564	1979
88	3	600	150	8	5,155	1975
89	2	400	100	4	4,312	1980
90	2	400	100	0	2,841	1987
91	3	600	150	6	3,705	1986
92	5	1,000	250	4	11,003	1975
93	8	1,600	400	20	13,530	1975

Table 26. (continued)

94	4	800	200	4	11,208	1978
95	3	600	150	8	5,717	1978
96	3	600	150	8	3,743	1978
97	3	600	150	8	6,761	1979
98	4	800	200	8	7,285	1980
99	3	600	150	8	4,736	1980
100	3	600	150	8	6,233	1980
101	3	600	150	10	5,515	1980
102	2	400	100	4	3,202	1981
103	2	400	100	4	3,054	1980
104	4	800	200	0	7,841	1986
105	3	600	150	0	5,047	1986
106	1	200	50	0	511	1979
107	1	200	50	0	1,118	1985
108	2	400	100	0	2,561	1980
109	5	1,000	250	20	8,094	1975
110	5	1,000	250	8	8,258	1975
111	4	800	200	4	6,486	1976
112	3	600	150	0	4,619	1975
113	3	600	150	4	4,326	1976
114	2	400	100	0	3,196	1976
115	2	400	100	0	3,430	1975
116	2	400	100	4	3,228	1979
117	3	600	150	8	4,441	1976
118	2	400	100	4	3,796	1975
119	1	200	500	0	1,320	1977
120	3	600	150	8	3,086	1986
121	2.5	500	125	8	2,202	1981

Source: CIDT, Niellé Zone, 1987/88.

Table 27. Labor Requirements (Man-Days/ha).

Operations	Cotton	Rice	Corn	Peanuts	Millet	Sorghum
Land Preparation	40	40	40	40	40	40
Planting	12	1	10	15	1	1
Fertilizers	3	3	3	2	3	3
Herbicide	1	1	1	1	1	1
Manual Weeding	25	40	25	30	25	25
Insecticide	6					
Surveillance		20				
Harvest	50	40	25	35	30	30
Total						
with Herbicide	140	105	79	93		
no Herbicide	164	144	103	122	100	100

Source : CIDT, Service Formation, September 1983.

Table 28. Simulated Crop Yields (kg/ha).

Obs.no	Cotton	Rice	Corn	Peanuts	Millet	Sorghum
1	1414.936	805.9627	909.7533	752.9245	870.1235	812.4536
2	1326.587	909.6622	1394.781	932.2168	1098.997	830.2238
3	1310.019	771.4801	1441.395	600.8750	870.1528	999.3185
4	1504.340	884.8704	1915.321	760.5773	1071.586	1053.371
5	1500.381	897.2026	1378.912	890.8032	1033.501	849.4079
6	1333.033	1017.967	1906.679	780.0106	1149.573	846.9472
7	1197.902	644.8883	1264.098	649.2327	488.3423	761.8097
8	1352.985	814.7450	1357.321	736.0111	919.8695	865.5101
9	1365.567	914.0664	1397.905	901.8842	801.8618	877.1010
10	1329.238	786.9662	1450.860	706.6807	739.0191	897.6430
11	1302.601	947.3407	1213.566	923.0590	1051.152	950.0008
12	1264.087	597.3782	294.8284	444.5271	572.3171	514.0506
13	1159.151	757.4795	877.0873	697.3796	554.1831	945.3032
14	1521.693	940.6062	1839.497	990.5623	970.6052	1426.554
15	1231.047	752.9375	953.3566	684.5463	558.6274	805.1194
16	1432.617	924.8890	1040.434	825.0087	876.1655	773.6968
17	1376.787	1011.272	1441.259	833.0669	1017.714	937.2600
18	1100.945	836.7618	666.3629	781.7351	806.1271	753.4339
19	1268.219	921.5316	1133.878	779.9882	686.6181	816.4967
20	918.9711	647.3176	841.4266	616.9679	341.9530	627.5906
21	1079.743	808.0382	1036.664	720.3816	759.3482	801.9499
22	1362.721	1008.965	1644.151	927.3551	1112.693	1039.323
23	1145.877	718.8359	696.6226	351.0131	477.3680	706.4397
24	1116.820	886.3606	1350.402	933.8350	745.0147	1046.072
25	1035.157	805.8751	1236.767	621.1565	581.0871	550.5605
26	1354.278	895.4623	1840.863	932.1919	1033.828	1018.643
27	1313.969	1027.149	1890.206	911.9944	817.2398	989.0578
28	1326.022	1017.151	1739.799	904.4931	1231.093	1096.859
29	1407.122	854.8514	1050.611	912.7404	923.9245	963.0136
30	1404.121	1029.780	1735.027	1046.238	1191.192	956.0244
Mean	1291.898	861.2599	1297.994	784.9819	845.0428	883.7080

Table 29. Fertilizer and Herbicide Costs (1986/87).

Crop	Per ha		Cash Cost		Credit (12 %)	
	Unit	Rate	Unit Cost	Per ha Cost	Unit Cost	Per ha Cost
Cotton						
Fertilizer						
N.P.K.	kg	200	136	27,200	152	30,465
Urea	kg	50	140	70,000	157	7,840
Herbicide	1	4	3,475	13,900	3,892	15,568
Rainfed Rice						
Fertilizer						
N.P.K.	kg	150	136	20,400	152	22,800
Urea	kg	75	140	10,500	157	11,775
Herbicide	1	4	5,025	20,100	5,628	22,512
Corn						
Fertilizer						
N.P.K.	kg	200	136	27,200	152	30,465
Urea	kg	50	140	7,000	157	7,840
Herbicide	1	4	3,150	12,600	3,528	14,112
Peanut						
Fertilizer						
N.P.K.	kg	100	136	13,600	152	5,200

Source: CIDT, Rapport Annuel (Synthese), 1986/87.

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