THE EFFECTS OF EXPORT AND FOOD CROP STRATEGIES ON FARM INCOME AND FOOD SELF-SUFFICIENCY IN EASTERN SENEGAL AND UPPER CASAMANCE: A LINEAR PROGRAMMING ANALYSIS

By

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CHAPTER I

INTRODUCTION

A. The Purpose of the Paper

The purpose of this paper is to analyze some effects of export and food crop strategies on farm income and food self-sufficiency at the household level in the Eastern and Upper Casamance regions of Senegal. The objectives of the government of Senegal include food self-sufficiency and export crop expansion through crop diversification. Over the last twenty years, extension programs have emphasized the introduction of cotton and maize. Although maize seems to have found its way easily in the existing farming system, the performance of cotton is less clear. After an initial rapid expansion, cotton acreage and production started to decline from the mid 70's. This raises questions about the long-term suitability of cotton and emphasizes the need for additional research into what happens when new crops are introduced into the farming system, with possible implications for policy-making.

Crop diversification as a strategy of development is dictated by the necessity to diversify national export earnings and reduce risk and uncertainty at the farm level. However, a policy which might appear sound at the macro level may be seen in a different light by the small farmer. There are two major questions about cash crops. First, are the returns in good years sufficient to offset the losses in bad years? Second even in good years, are the returns to cash crops high enough to enable the farmer to meet the food needs of his family? A personal observation is that the Senegalese small farmer asks himself these types of questions, particularly the second one. Whatever may be the tenor of the official crop diversification policy, priority is likely to be given to the food crops in his farming system.

A central hypothesis of development theory is that farmers respond to prices and that farmers maximize income subject to certain constraints such as meeting family food needs. Therefore a policy of diversification which does not take into account farm level constraints, such as minimum food production, has little chance of success. In an agriculturally based economy, the macro and micro issues are so interrelated that it would be unwise to look at them separately. This paper undertakes a preliminary analysis of a particular crop diversification strategy—introduction of cotton—taking into account farm level constraints which might influence farmers' decision-making.

B. Background

The Republic of Senegal is a small country on West Africa in the Soudano-Sahelian zone. It covers 196,722 square kilometers, with a population estimated in 1980 at 5.7 million and growing at 2.8 percent annually. The climate is characterized by two seasons: a dry season (from November to June) and a rainy season (from July to October). The volume of rainfall increases from north to south and also from west to east, ranging from about 300-400 millimeters in the north and west to 1300-1400 millimeters in the east and south.

As in many LDC's, agriculture plays a basic role in the Senegalese economy: it employs about 70 percent of the active population and is the basic source of foreign exchange earnings. Peanuts, millet/sorghum and rice have for a long time been the major crops of Senegal: peanuts for export to provide foreign exchange, the other grain crops for food. From the early 60's, cotton and hybrid maize have been gradually introduced as diversifying crops. Cotton flourished in Eastern Senegal and Upper Casamance but reached a peak of 45,000 T in 1977. It then declined steadily to 20,000 T in 1980 (Table 1).

Maize is grown mainly in Eastern Senegal, Casamance and the Fleuve regions. SONED (1980) reports the following proportions of maize production among regions between 1974 and 1976: Casamance, 33 percent; Fleuve, 15 percent; and Eastern Senegal, 43 percent. There is evidence also that the demand for maize seeds is strong. Self-sufficiency in maize as well as in other food crops has not yet been achieved.

The six priorities of the Senegalese agricultural policy are laid out in the Sixth Four Year Development Plan, 1981-1985 as follows:

1. Food self-sufficiency: because of the low growth rate of cereal production (1.6 percent) is a high population growth rate (2.8 percent), emphasis will be placed on increasing cereal production through price incentives, rationalizing post-harvest operations such as marketing, storage, processing and distribution, and changing consumption patterns to reduce cereal import, mainly rice and wheat.

2. Improvement of the rural standard of living, mainly through a better remuneration for agricultural production.

TABLE 1

Evolution of Cotton Production in Senegal
for the Period 1968/69 - 1980/81

YEARS	HECTARAGE (Ha)	PRODUCTION (T)	YIELD (Kg/ha)
1968/69	6,447	938	1,534
1969/70	9,805	11,500	1,172
1970/71	13,618	11,843	870
1971/72	18,318	21,547	1,176
1972/73	20,359	23,461	1,161
1973/74	28,630	33,077	1,155
1974/75	38,588	43,375	1,098
1975/76	37,483	30,685	819
1976/77	43,845	45,207	1,031
1977/78	47,109	37,166	789
1978/79	48,299	33,805	700
1979/80	30,908	26,868	869
1980/81	29,913	20,607	688

Source: SODEFITEX Annual Reports, 1979/80, 1980/81.

3. Reduction of the variability of agricultural production through better water control.

4. Reduction of regional differences—more responsibility given to the regional development agencies, the objectives of which have been enlarged to an "integrated development."

5. Promotion of rural participation in the management of rural activities, mainly through cooperatives which will take care of the marketing of agricultural products and gradually the organization of the seed supply.

6. Improvement of the balance of trade, through the development of crops for import substitution and the diversification of agricultural export products. (Marchés tropicaux, 1981)

C. Problem Statement and Objectives

The steady decline of cotton production since 1977 raised concerns about the long-term prospects for cotton and has led to increased research into alternative paths for agricultural development in Eastern Senegal and Upper Casamance. Beginning in the late 70's a study was undertaken by SONED (Societé Nationale d'Etudes de Développement) and Courtoy to analyze a major integrated rural development project (Projet de développement rural au Sénégal Oriental et en Haute Casamance) in Eastern Senegal and Upper Casamance. The major objectives of the proposed project were to:

- achieve food self-sufficiency
- increase cotton production

- increase peanut production or at least stabilize production

The main proposed approach for attaining these objectives was through intensification. Intensification involves the introduction of high yielding varieties, advanced cultivation practices, and animal traction.

This paper picks up on some of the questions raised by the SONED-Courtoy study, particularly:

1. To what extent can the use of animal traction equipment assist in achieving the three project objectives?

2. Can the introduction of additional animal traction equipment (seeder and weeder) increase cotton and peanut production without reducing food production?

3. How much of an incrase in income can a small farmer expect from the introduction of additional animal traction equipment?

To answer these questions a linear programming model will be constructed. The model will maximize revenues above variable costs, subject to the provision of an adequate level of family food supplies.

The specific objectives of this study are to:

1. To develop a linear programming model of a representative farm household in three natural zones of Eastern Senegal and two in the Upper Casamance. The model incorporates an improved level of agricultural practices, including the use of fertilizer and animal traction for plowing purposes on certain crops (maize, cotton, rice). The model requires each household to produce 80 percent or more of its food consumption requirements.

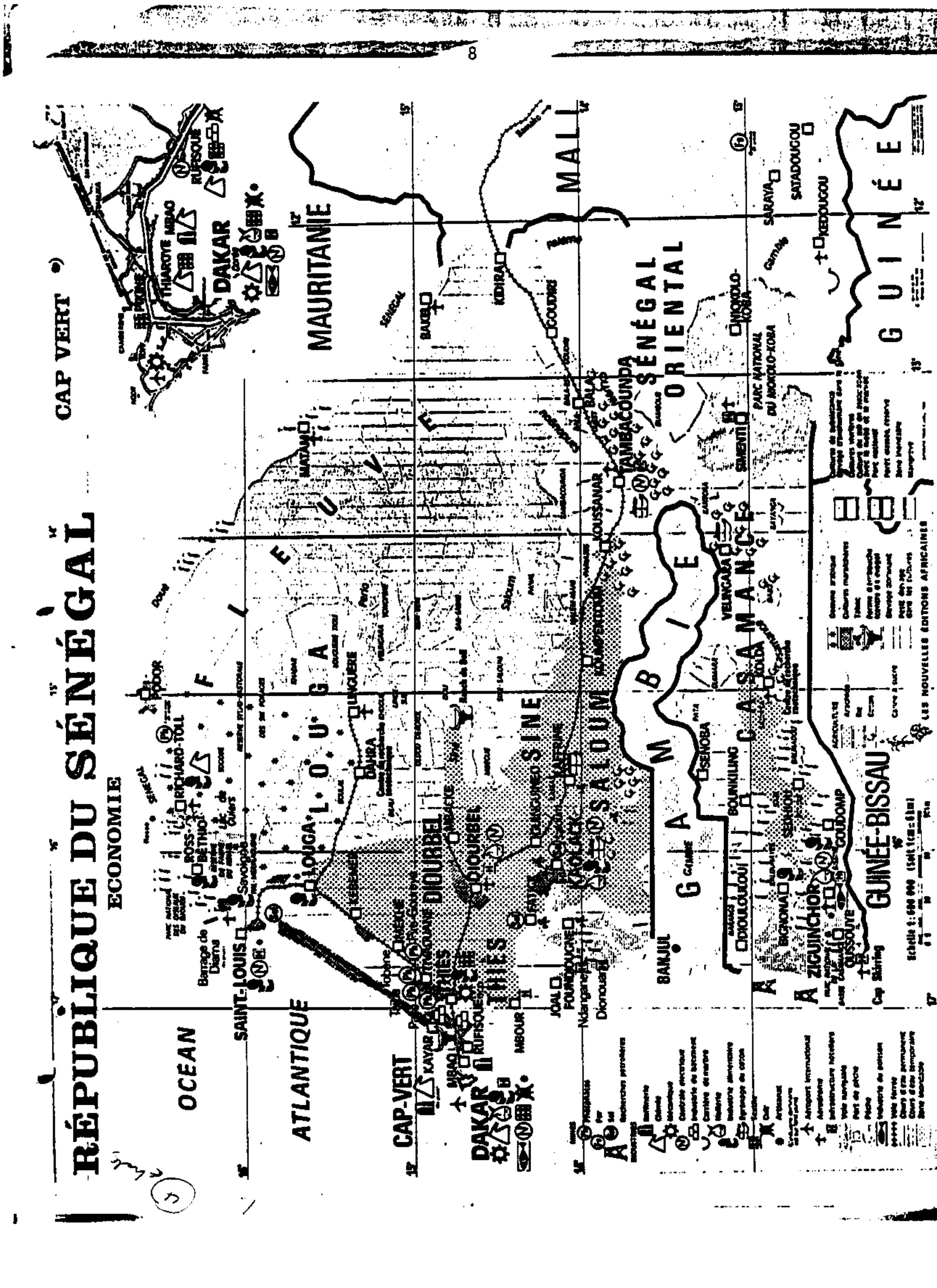
2. To analyze the trade-off between export and food crops, with particular attention to the effects on farm income. Sensitivity analysis was performed by introducing changes in the relative prices, level of technology, and level of food self-sufficiency at the household level.

3. To derive policy implications.

D. Description of the Area

The zone of interest is within the region covered by the extension service SODEFITEX (Societe de Developpement des Fibres Textiles). It covers approximately 72,000 square kilometers, with a population density of 7.7 inhabitants per square kilometer. The rainfall varies from 900 millimeters in Tambacounda to 1300 millimeters in Kedongou in Eastern Senegal and from 1073 millimeters in Velingara to 1230 millimeters in Kolda in Upper Casamance (SONED, 1980). The rainy season usually starts in June and ends in October.

An initial study by SONED-SODETEG (1977) disaggregated the region of Eastern Senegal into five natural zones—zones A, B, C, D, E—according to the climate, geomorphology, the availability of arable soils and types of agriculture (rainfed or irrigated). The Upper Casamance was considered as one natural zone and was represented by the letter F.[1] Each natural zone has been subdivided into homogeneous natural subzones according to the pedology and agricultural orientation. Thus, zone A is subdivided into A1 and A2; zone B into B1, B2,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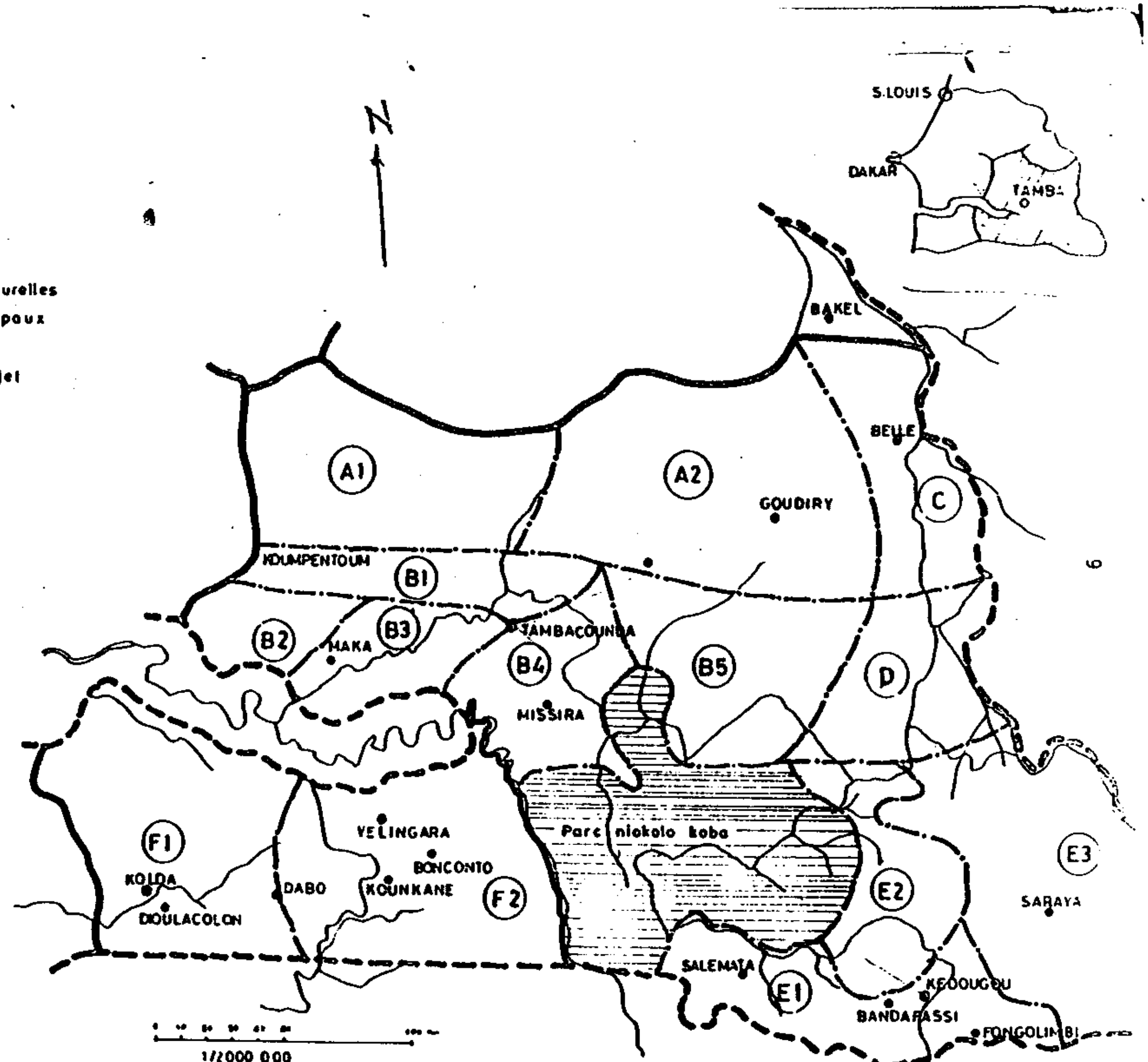
ECONOMIE
CAP VERT
OCEAN
ATLANTIQUE
MAURITANIE
MALI
GUINÉE
GUINÉE-BISSAU
GAMBIE
FLEUVE
LOUGA
DIOURBEL
THIES
SINE SALOUM
CASAMANCE
SÉNÉGAL ORIENTAL
CAP-VERT
DAKAR
SAINT-LOUIS
ZIGUINCHOR
KAOLACK
TAMBACOUNDA
BANJUL
LES NOUVELLES ÉDITIONS AFRICAINES

CARTE A

...ion du Projet et Zones Naturelles

- (A1) Zones naturelles
- Limites de zones naturelles
- Cours d'eau principaux
- Limite d'ETAT
- Limite zone du projet
- Aire du projet



...NED AFRIQUE-COURTOY

B3, B4 and B5; zone E into E1, E2 and E3; zone F into F1 and F2. An exception, however, occurs in zones C and D where "pedological particularities" were not found by the SONED study.

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[1]Eastern Senegal and Casamance are two different administrative regions, but the area under study covers Eastern Senegal and part of Casamance, namely Upper Casamance, where cotton is grown.

CHAPTER II

ECONOMIC FRAMEWORK FOR THE ANALYSIS OF THE PROBLEM

A. Macro Rationale for Crop Diversification

1. Diversification of Export Earnings

One of the top priorities of the sixth Development Plan (1981-1985), besides national food self-sufficiency, is the "improvement of the balance of trade through import substitution and diversification of agricultural export products" (Marchès tropicaux, 1981). For a long period peanuts have been Senegal's primary export crop, averaging 50 percent of the total value of exports from 1967 to 1977 despite a downward trend since 1968 (see Table 2). But as pointed out by C. Jabara (1979), the "revenues from peanuts are highly susceptible to variations in world prices and to variations in domestic yields." Out of concern for this variability, the government of Senegal in the early 60's favored the introduction of a more drought-resistant crop, cotton, which from 1969 to 1977 provided benefits to the government through the "Price Stabilization Fund" (Caisse de Péréquation et de Stabilization des Prix) (see Table 3). Nevertheless the share of cotton of total agricultural export products is small (about 2 percent) relative to peanuts (about 25 to 77 percent).

TABLE 2

Exports of Peanut Products and Total Products in Senegal 1967 - 1978

YEAR	Value of Peanut Products Exports[a] (millions CFA)	Total Value of Exports (millions CFA)	Percentage of Total Exports
1967	25,317	34,045	77.3
1968	25,914	37,485	71.8
1969	17,153	31,900	53.8
1970	20,444	43,200	48.4
1971	12,388	34,700	35.7
1972	28,788	54,312	53.0
1973	15,275	43,237	35.3
1974	33,977	93,973	26.2
1975	40,318	99,101	40.7
1976[b]	64,342	115,925	55.5
1977[b]	74,226	152,920	48.5
1978[b]	23,539	101,402	23.2

SOURCE: C. Jabara: Agricultural Comparative Advantage Under Uncertainty: The Case of Senegal, p. 9.

[a]Includes peanuts, peanut oil (refined-unrefined) and cake.

[b]Completed from B.C.E.A.O., No. 288, Nov. 1980.

TABLE 3

Evolution of Income from Cotton Credited to the Account of "Price Stabilization Funds"[a]

YEAR	BENEFITS
1968/69	20,839,157 CFA
1969/70	73,029,715 CFA
1970/71	69,838,653 CFA
1971/72	366,737,189 CFA
1972/73	327,900,592 CFA
1973/74	1,192,554,514 CFA
1974/75	188,868,129 CFA
1975/76	5,230,126 CFA
1976/77	1,147,916,471 CFA
1977/78	(-760,000,000)CFA
1978/79	N.A.

SOURCE: SODEFITEX, mimeo, March 1980.

[a]"Caisse de Péréquation et de stabilization des Prix."

2. Food Import Substitution

Diversification of food crops may also reduce the amount of imported foodstuffs. The Fifth Development Plan (1977-1981) stated that "for many reasons, the government is better off promoting actions towards cereals import substitution." C. Jabara (1979) notes that the "greatest source of international price uncertainty for Senegal is the price of peanut products and in the import price of rice." The Banque Centrale des Etats de l'Afrique de l'Ouest (BCEAO, 1980) reports that import and export price indices varied widely from 1967 to 1977. Over the same period, the export price index was rarely higher than the import price index (see Table 4). The need for import substitutions becomes apparent when it is observed that the annual cereal deficit is about 300,000 T, two-thirds of which is rice. Furthermore, over 50 percent of the foreign exchange derived from the sale of peanuts is used to import cereals, mainly rice. The need for import substitutions is supported by the findings of C. Jabara (1979), who points out that Senegal's comparative advantage in exporting peanut products in exchange for cereals may not hold when price uncertainty is taken into account.

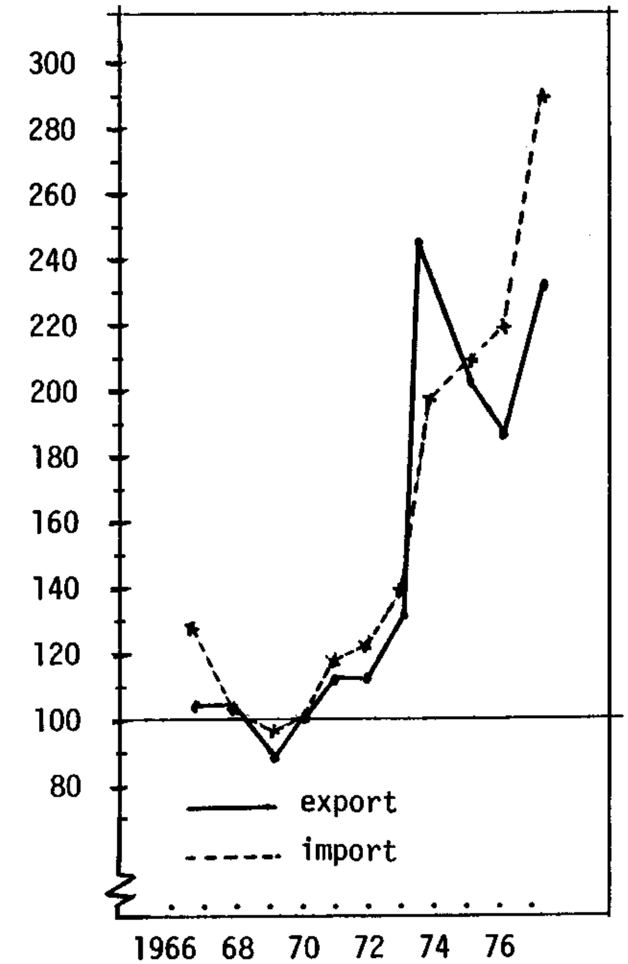
B. Problems at the Farm Level of Crop Diversification

So far we have concentrated on the major advantages of diversification for a country like Senegal. But how will this strategy affect farmers? It should be understood first that the small farmer has practiced diversification long before it became a national policy. Dalrymple (1970), Norman et al. (1979) have described indigenous mixed cropping systems undertaken by small farmers as risk-minimizing strategies.

TABLE 4

Senegal - Export and Import Price Indices

YEARS	EXPORT	IMPORT
	Base 100:	Year 1970
1967	104.8	130.1
1968	104.0	100.2
1969	89.6	98.2
1970	100.0	100.0
1971	110.9	117.0
1972	108.4	121.1
1973	128.5	138.1
1974	244.3	197.5
1975	206.6	209.2
1976	192.3	223.8
1977	231.9	291.2



SOURCE: B.C.E.A.O., No. 285, July 1980.

Therefore, one might expect some problems to arise at the farm level when new crops such as cotton or soybeans are introduced and pushed heavily.

1. Seasonal Distribution of Labor Among Competing Crops

Diversification of crops in Eastern Senegal and Upper Casamance may face labor constraints. Although Eastern Senegal and Upper Casamance cover approximately 30 percent of the land area of the country, they contain only 20 percent of the population. In Upper Casamance the population density is 18 inhabitants per square kilometer, and in Eastern Senegal it is only 5 inhabitants per square kilometer. These very low population densities are bound to have a significant influence on the future course of agricultural development. Many authors have pointed out that labor availability is frequently a greater constraint to increasing agriculture production than the availability of land. "As a result" writes U. Lele (1975), "technological innovations which require intense labor input, often may not result in the full realization of the potential production increases." This is particularly true for cotton, as indicated by numerous examples around the world. J.H. Cleave (1974) describes the heavy labor demand among cotton farmers in Sukumaland, Tanzania, during the weeding and harvesting periods for other crops. Norman et al. (1979) discuss the same problems of allocating labor between weeding food crops and cotton in Northern Nigeria. In his paper "analyse des constraintes qui limitent le rendement du cotonnier en culture paysanne en Haute

Casamance, Sénégal," A. Ange (ISRA, 1981) notes that cotton is planted and weeded after the food crops (millet/sorghum), reflecting the same labor seasonability and time allocation problems.

T.W. Schultz (1964) has characterized the small farmer in LDC's as "poor but efficient." Given the available labor and capital, he cannot produce more than he is currently producing, assuming a fixed technology; thus, he finds himself in a "technical and economical trap" (Stevens, 1977). A crop diversification policy, by introducing possible competition for labor between the different crops, can upset this equilibrium. The farmer, who is the ultimate decision-maker, will be forced to put into his "allocative equation" a new set of constraints. He will have to come up with a new set of solutions, sometimes in conflict with recommendations from the research station and extension services.

A multi-disciplinary team in Northern Nigeria compared traditional cotton farming practices yielding 200 kilograms per hectare with a new package capable of producing over 1,500 kilograms per hectare and found that the new cotton package was not accepted because it involved a major (and it would seem unacceptable) change in the farmer's cropping system (Norman et al., 1974 and 1975).

The evidence provided by these and other studies suggests that a national policy of diversification in Senegal may upset the small farmer's traditional equilibrium by introducing competition for his limited supply of labor.

2. Export and Food Crop Interactions

Some theoretical issues in export food crop interactions have been raised by H. Myint, who argues that an expansion of cash crops could take place where there is a "surplus of land and surplus labour over and above minimum subsistence requirements [of the peasant farmers]. With this margin of productive capacity, the peasants could take to the production of cash crops for the export market without reducing their subsistence output" (Myint, 1973). He also notes that in some cases like rice in the Southeast Asian countries, where this crop [rice] was at the same time a subsistence and an export crop, the question of reducing subsistence output did not arise.

However, when land or labor is not in surplus, problems can be expected, particularly when the "peasants are only partially committed to the production of cash crops, and the larger proportion of their resources is still used to for their subsistence production" (Myint, 1973). One possible problem in Senegal may be the decrease of food grain production as a result of export-food crop interactions at the farm level.

Uma Lele (1975) addresses this issue in the context of West Africa. She notes that "reviews indicate how promotion of export crops in the absence of a more profitable food technology may reduce the [food] supplies available for domestic consumption...". She adds:

> Anderson, like Collinson, in his review of the CFDT cotton development scheme in Fana, Mali, also observed an adverse effect of export crop specialization on food availability in the program area and the consequent readjustment of the farming system to ensure domestic food supplies. As a

> result of cotton promotion, the ratio of food area to cotton area was less than 2:1 in 1971. With the failure in rainfall during the 1971/72 season, food crop production declined considerably. In the period 1972/73 the ratio of the food crop to cotton area increased to 3:1.

A decrease in food grain production might also be the result of unbalanced pricing incentives. Farmgate prices are set every year by the Senegalese government, which is the sole purchaser of the main cash crops (peanuts and cotton) through public or semi-public agencies (see Table 5). A very low percentage of food crop production (6 to 10 percent) is sold at harvest at the official market price; a substantial portion is sold later at higher prices in local markets. Pricing incentives favoring cash crops may lead to a decrease in the allocation of land and labor to food crop production. This may lead to an increase in imported foodstuffs, not only for the urban areas, but also for the rural areas. (A second order effect, however, might be an increase in food prices in the rural areas and eventually a substantial shift away from cash crops back into food crops.)

C. Need for a Better Understanding of the Farming System

Sara Berry (1980) is certainly correct in pointing out that "diversification pays". The question is, what type of diversification, and how much does it pay? Norman et al. (1974) emphasize the need for a new crop to fit into the existing farming system. However, over-emphasis on a single crop might lead to imbalances at the farm level,

TABLE 5

Evolution of Producer Prices
in Senegal in F CFA/Kg

Years	Peanuts	Cotton	Millet	Maize	Rice Paddy
1964-65 (64)	19.54	33	16	14	21
1965-66 (65)	20.20	33	16	14	21
1966-67 (66)	19.77	33	17.5	15	21
1967-68 (67)	16.60	33	17.5	15	21
1968-69 (68)	16.60	28	17.5	15	21
1969-70 (69)	15.59	28	17.5	16	21
1970-71 (70)	17.60	30	17.5	16	21
1971-72 (71)	23.10	30	17.5	16	21
1972-73 (72)	23.10	31	17.5	16	21
1973-74 (73)	25.50	34	25	20	30
1974-75 (74)	35.50	42	30	22	41.5
1975-76 (75)	41.5	47	30	25	41.5
1976-77 (76)	41.5	49	35	35	41.5
1977-78 (77)	41.5	49	40	37	41.5
1978-79 (78)	41.5	49	40	37	41.5
1979-80 (79)	45.5	55	40	37	41.5
1980-81 (80)	50	60	40	37	41.5
1981-82 (81)	60	68	50	47	51.5

SOURCE: Direction generale de la Production agricole, SODEFITEX, CILSS, Marchés tropicaux, 1981.

TABLE 6

Evolution of Relative Prices with Respect to Millet/Sorghum for the Period 1970-1980

YEAR	PG/PM	PC/PM	PG/PC	PMZ/PM	PR/PM
1970-71 (70)	1.00	1.71	.58	.91	1.20
1971-72 (71)	1.32	1.71	.77	.91	1.20
1972-73 (72)	1.32	1.77	.74	.91	1.20
1973-74 (73)	1.02	1.36	.75	.80	1.20
1974-75 (74)	1.18	1.4	.84	.73	1.38
1975-76 (75)	1.38	1.56	.88	.83	1.38
1976-77 (76)	1.18	1.4	.84	1.0	1.18
1977-78 (77)	1.03	1.22	.84	.92	1.03
1978-79 (78)	1.03	1.22	.84	.92	1.03
1979-80 (79)	1.13	1.37	.82	.92	1.03
1980-81 (80)	1.25	1.5	.88	.92	1.03
1981-82 (81)	1.20	1.36	.88	.94	1.03

PG = Price of Groundnuts
PM = Price of Millet
PC = Price of Cotton
PMZ= Price of Maize
PR = Price of Rice

which might easily spread to the macro level, particularly in a country like Senegal, where the small farmer is basically the "engine of growth." There is a need for better understanding of the traditional farming system to enable development planners better to anticipate the impact of macro-level policies, at the farm level.

The purpose of this paper is to analyze crop diversification at the farm level using a linear programming approach. The analysis will maximize revenues above variable costs, subject to the satisfaction of an adequate level of family food consumption. However, the reader is warned that dealing with all the issues related to crop diversification is beyond the scope of this paper. The author hopes that the preliminary results from this study, handled with the appropriate caution, might enhance policy-making and suggest directions for further studies in this area of Senegal.

CHAPTER III

CHOICE OF A METHODOLOGY AND SOURCES OF DATA

Many analytical tools are now available for farm management studies in LDC's. C.K. Eicher and D.C. Baker (1982) provide a review of different analytical techniques used in smallholder studies in Africa. Regression analysis, for example, has been used for farm production functions and determinants of resource use by Norman, Pryor and Gibbs in 1979 in Nigeria, and for supply responses by Norman et al. (1975) in Nigeria, and A. Ange (1981) in Upper Casamance (Senegal). Norman, Pryor and Gibbs showed that "farmers were in general allocating resources to crop production in a manner consistent with the goal of profit maximization," with dependent variable being the value of production derived from crop production and the independent variables being cultivated area, family labor, hired labor, fixed and variable costs, and dummy variables to take account of differences in location. They showed mainly the relationship between farm income and the different variables and the determinants of resource use. A. Ange in Upper Casamance (Senegal) showed the relationship between cotton yield and sowing date, soil ph, amounts of clay and silt, and organic matters, concluding that cotton farmers "lose in average 46 kg/ha for every late sowing date—sowing date with respect to the first useful rain." Despite many specification problems, such as choice of a functional form, measurement and aggregation of input and output, regression analysis remain a valuable analytical tool. But it is inappropriate for decision-making with respect to how much of what resource ought to be used on a given farm.

Budgeting is another analytical tool available for assessing the performance of a farm. Budgeting was used by J.P. Rigoulot (1980) to assess the profitability of rice cultivation in the Casamance region of Senegal. Despite numerous methodological issues[1] budgeting remains a valuable analytical technique which can be used to examine one enterprice at a time in farm analysis. Budgeting usually is used to compare two or three alternative farm organizational plans. It would be very time consuming and costly to use budgeting to determine which of 20 or 30 different organizational plans would be most profitable under a crop diversification policy.

Linear programming is a powerful tool of analysis which can be used to look at several budgets of a farm at a time and depict the optimal enterprises in a profit-maximization or cost-minimization context. Linear programming has been used in Africa from the early 60's (Clayton, 1961; Heyer, 1966) and its use for farm analysis in the Sahel region is underway (Richard, Fall, Attonaty, 1977; Niang, 1980; Kamuanga, 1981). We have chosen a linear programming approach since we want to identify a set of recommendations for the regional development agency in charge of integrated agricultural development in this region of Senegal.

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[1]See C.K. Eicher and D.C. Baker, Research on the Rural Economies of Sub-Saharan Africa—A Critical Survey, MSU, p. 80.

Linear programming can be criticized because of its basic assumptions (linearity, additivity, divisibility, parameters known with certainty). It can also be criticized because of the assumed objective of profit maximization (which is not always appropriate), because of the lack of adjustment which occurs when the program focuses only on a one-year period (Palmer-Jones, 1977); and because of the aggregation bias that may occur when the analyst infers "region —or country-wide policy implications from the results of individual farms" (C.K. Eicher, D.C. Baker, 1982).[1] Despite all these criticisms, linear programming remains one of the most valuable tools of analysis available for the problem posed in this study. A.R.C. Low (1978) warns about the danger of falling into the trap that Forrester (1961) cautioned against:

> There is a general misunderstanding to the effect that a model cannot be undertaken until every constant is known to a high degree of accuracy. This often leads to the omission of highly significant factors, sometimes termed intangibles, because they are "unmeasurable". To omit such variables is equivalent to saying that they have a zero effect—probably the only value that is known to be wrong.

A.R.C. Low (1978) concludes that: "...despite the data problem, appropriately specified linear programming models can make a significant contribution to the understanding and development of peasant farming systems."

Sources of Data

Secondary data have been used in this paper. The diversity of sources reflects the difficulty of getting reliable data. The SONED

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[1]See also Palmer-Jones (1979): "Linear Programming Analysis of Peasant Farming: Rejoinder," Journal of Agricultural Economics 30(2), pp. 199-203.

study (Projet de developpement rural au Sénégal oriental et en Haute Casamance) and the SODEFITEX annual reports 1979/80, 1980/81 provided the majority of the data. The SONED study defined the representative farm households used, based on "the interpretation of data from a random sample of 88 farm households" in the counties [départements] of Tambacounda and Bakel (SONED, 1980). In the counties of Velingara and Kolda, the representative farms have been defined by the SONED study based on information from the office of agricultural production and SODEFITEX.

The same SONED study provided information about the input-output coefficients per crop, the resource availability [land and labor] in the different representative farm households, and yields under a higher level of technology, such as the use of animal-powered plowing, seeder and weeder. The SODEFITEX annual reports 1979/80, 1980/81 provided the estimates of yields under the first level of technology in the different representative farms. An earlier SONED study (Etude sur la commercialisation et le stockage des cereales, 1977) provided the estimates of rural annual consumption per capita of different products used in the paper as constraints of family consumption. For the cost estimates, information from various sources has been used, such as SODEVA (Société de Développement et de Vulgarisation Africole, 1981), Sargeant et al. (1981); I. Sène (1980); J.P. Rigoulot (1980). The producer prices used in the analysis came from Marches Tropicaux (1981). Estimates of buying prices for different commodities come from personal communications.

CHAPTER IV

THE LINEAR PROGRAMMING MODEL

The standard linear programming model is in the form:

$$\text{Max } Z = \Sigma\, C_j\, X_j$$

subject to:

$$\Sigma\, a_{ij}\, X_j \leq bi$$

$$(X_j \geq 0)$$

where Z = gross returns (total revenues above variable costs)

X_j = the different activities (or decision variables), which cannot be negative ($X_j \geq 0$)

C_j = cost of production or returns of the activities per unit of land or product

a_{ij} = input-output coefficients for the different activities

b_i = amounts of factor available, or constraints.

The linear programming tableau appears at the end of the chapter. This chapter presents a brief description of the location and description of households and of the different components of the tableau such as, objective function, activities, constraints, labor periods, underlying assumptions and relative prices.

Location and Description of Households

For this paper we will use five representative cotton-producing farm households previously identified by SONED (see Table 7). The three cotton farm households in the Tambacounda county are associated with:

- The natural zone B4, including the SODEFITEX areas of intervention: Dialacoto, Tamba SO and Missirah (I).

- The natural zone D, including the SODEFITEX area of intervention: Boundou (II).

- The natural zones A1, B1, B3, B5, including the SODEFITEX areas of intervention: Tamba NE, Koussanar, Dianké, Maka and Kothiary (III).

The two cotton farm households in the counties of Velingara and Kolda are associated with

- The natural zone F2, including the SODEFITEX areas of intervention: Pakour, Linkering and Kounkané (IV).

- The natural zones F2/F1,[1] including the SODEFITEX areas of intervention: Velingara-ouest, Kolda Sud, Dabo and Velingara Centre (V).

The Objective Function

The objective function is set to maximize revenue above variable costs, subject to the satisfaction of a minimum level of food supplies, which is assumed to be the top priority of the household. It is in general consistent with the goal of profit maximization (Norman et al., 1979) and with the goal of food self-sufficiency.

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[1]Here there is an overlapping of two administrative counties, Kolda and Velingara.

TABLE 7

Characteristics of the Different Households, 1980

Characteristics	NATURAL ZONES				
	B_4 I	D II	A_1 B_1 B_3 B_5 III	F_2 IV	F_2/F_1 V
Number of people	9.5	9.5	9.5	11.8	11.8
Number of active persons	4.6	4.6	4.6	5.7	5.7
Man-day equivalent	1080	1080	1080	1332	1332
Peanuts (ha)	1.14	1.14	1.14	2.05	2.05
Millet/Sorghum (ha)	2.88	2.88	2.88	1.80	1.80
Maize (ha)	.42	.42	.42	.50	.50
Rice (ha)	.03	.03	.03	.45	.45
Cotton (ha)	2.05	1.22	1.12	2.11	1.08
Total Acreage (ha)	6.52	5.69	5.59	6.91	5.88

SOURCE: SONED (1980).

Activities

Production activities are defined for peanuts, millet/sorghum, cotton, rainfed maize and rice. Family consumption activities are defined for millet/sorghum, maize, rice, and peanuts. For family consumption requirements, it is assumed that the rural person annually consumes on average 195 kilos of cereal in Eastern Senegal and 239 kilos in Upper Casamance (SONED, 1977). See Table 8. This discrepancy may seem puzzling, but it is based on the best available data. The researcher judges that the figures reflect 80 to 90 percent of the food self-sufficiency level in Eastern Senegal and Upper Casamance. These conservative approximations are based on the estimates of the Fifth Development Plan (1977-1981) that "adults cover generally about 90 percent of their consumption requirements, but about 5 to 15 percent of them do not cover 70 percent" (Fifth Development Plan, 1977). More detailed information about food self-sufficiency levels is contained in Table 9. The estimated level of peanut consumption is based on a figure of 15 kilograms per person (Sargent et al., 1981).

Selling and buying activities are defined for millet/sorghum, maize and rice. For peanuts, a selling activity is added to family consumption. For cotton, there is only a selling activity.

Agricultural production is assumed to be sold at the official market price at harvest. The selling prices were set at 60 CFA/kg for

TABLE 8

Estimated Annual Cereal Consumption
(Kg of Products/Year/Person)

REGION	RURAL POPULATION				URBAN POPULATION				
	Millet/ Sorghum	Paddy	Maize	Total	Millet/ Sorghum	Paddy	Maize	Wheat	Total
Eastern Senegal	151	16	28	195	60	119	16	50	245
Casamance	127	93	19	239	14	192	5	39	250

SOURCE: SONED, 1977.

TABLE 9

Actual and Assumed Increase in Cereal Consumption

REGION	Millet/Sorghum Quantity Kg	Millet/Sorghum Flour equiv. .6	Maize Quantity Kg	Maize Flour equiv. .85	Rice Quantity Kg	Rice Flour equiv. .62	Total Quantity Kg	Total Flour equiv. Kg[b]
Eastern Senegal 80%[a]	151	90.6	28	23.8	16	9.92	195	124.3
90%	169	101.4	31	26.35	18	11.16	218	138.9
Upper Casamance 90%[a]	127	76.2	19	16.15	93	57.66	239	150.0
95%	134	80.4	20	17	98	60.76	252	158.16

SOURCE: SONED (1977).

[a]Casamance region is in general better naturally endowed than Eastern Senegal, therefore we assume the actual level of food self-sufficiency at 80% for Eastern Senegal and 90% for Upper Casamance. The increased level of self-sufficiency is assumed to 90% for Eastern Senegal and 95% for Upper Casamance.

[b]The rural people consume in general 100-124 kg of flour equivalent per year and per capita, whereas the urban consume 159-168 kg of flour equivalent/year/capita (SONED, 1977). An increase of 5-10% of the actual food level consumption would pull the rural cereal consumption from 150 to 158.16 kg of flour equivalent/year/capita in Upper Casamance and from 124.3 to 138.9 kg of flour equivalent/year/capita in Eastern Senegal.

peanuts, 68 CFA/kg for cotton, 50 CFA/kg for millet/sorghum, 47 CFA/kg for maize, and 51.5 CFA/kg for rice. These figures reflect the 1981 producer prices (Marchés Tropicaux, 1981). Buying prices[1] change frequently and vary from region to region. The average buying prices are assumed to be 60 CFA/kg for millet/sorghum and 50 CFA/kg for maize. The price of rice varies from 85 CFA/kg in the county of Tambacounda to 90 CFA for the counties of Velingara and Kolda, due mostly to differences in transportation costs.

Consumption activities are assumed to have zero value. Hiring-in activities for labor are assumed to reflect seasonal labor demands during four different peak labor periods, which will be specified below. The cost of labor is assumed to be 500 CFA during the second labor period (which corresponds generally to the weeding of most crops, when demand for labor is generally high), and 300 CFA during the three other periods.

Constraints

Resource restrictions are defined for land, family labor and hired labor. Operating capital (or operating costs) reflecting the costs of production of peanuts, millet/sorghum, maize, cotton and rice in the household is also assumed, as is a minimum level of family consumption. The land constraint is set at 6.52, 5.69, 5.59 ha for the three households in Tambacounda county, and 6.91, 5.88 ha respectively for the two households in Velingara and Kolda counties. These figures are taken from the 1980 SONED study (see Table 7).

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[1] The buying prices assumptions are based on personal communications and judgement.

Family labor varies from county to county. It is assumed to be provided by 4.6 active persons[1] in the three households of Tambacounda representing a total of 1,080 man-days. In the counties of Velingara and Kolda, it is provided by 5.7 active persons, representing a total amount of 1,332 man-days. There are on average 9.5 persons in the first three households, and 11.8 persons in the last two households (see Table 10).

It is assumed that each household can hire one seasonal laborer, who will be provided housing, land and food in exchange for part of his labor, evaluated at 16 man-days per month (SONED, 1980). The wage rates specified above are assumed to include these costs.

Family food consumption are calculated as follows (see Table 9):

TABLE 10

Estimated Food Requirements Per Household at the Two Assumed Levels of Self-Sufficiency

Regions		Millet/Sorghum (kg)	Rice (kg)	Maize (kg)	Peanuts (kg)
Eastern Senegal	80%	1434.5	152	266	142.5
	90%	1605.5	171	294.5	142.5
Upper Casamance	90%	1498.6	1097.4	224.2	177
	95%	1581.2	1156.4	236	177

SOURCE: Tables 7 and 8.

Labor Periods

The agricultural production season has been divided into four labor periods reflecting peak labor periods during the growing season (see Figure 1 and Appendices 1-5):

	I (2.5 months)	II (1 month)	III (1.5 month)	IV (4 months)
	May – June – July	July – August	August – September	October – November – December – January
Peanuts:	preparation & planting	weeding	weeding	harvest stacking threshing & winnowing
Millet/ Sorghum:	preparation & planting weeding & thinning	weeding		harvest threshing & winnowing
Cotton:	preparation & planting	weeding thinning spraying	weeding spraying	harvest tearing off and burning of cotton plants
Maize:	preparation & planting	weeding thinning	harvest	shelling
Rice:	preparation & planting	weeding thinning	weeding	harvest threshing & winnowing

FIGURE 1

Labor Periods During the Cropping Season in Eastern Senegal and Upper Casamance

1. Labor Period I (May 1 to July 15)

This period reflects land preparation and planting for all crops: millet/sorghum, cotton, peanuts, maize and rice. Additional activities for millet/sorghum, such as weeding, thinning and fertilizing, also take place in this first labor period.

2. Labor Period II (July 15 to August 15)

This period reflects fertilizing, thinning and first weeding for cotton, peanuts, maize and rice, as well as the second weeding and fertilizing for millet/sorghum. It also includes cotton pesticide spraying.

3. Labor Period III (Aúgust 15 to September 30)

This period reflects the second weeding, fertilizing and pesticide spraying for cotton, second weeding for peanuts, second weeding and harvesting for maize, second weeding and fertilizing for rice. For millet/sorghum, there are usually no activities in this period.

4. Labor Period IV (October 1 to January 30)

This period reflects harvesting, threshing and winnowing of all other crops (see Appendices 1-5).

Underlying Assumptions

Two levels of animal traction technology will be tested.[1]

1. The first level (I), reflects actual conditions and includes the use of animal traction mainly for plowing cotton, rice and maize, as well as the use of improved seeds and fertilizer for the present crops. These seem to be reasonable assumptions, since the extension

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[1] In the region of interest, there is approximately one pair of oxen and one plow for every two households (see Table 11).

service is promoting the use of fertilizer and the substitution of high-yielding varieties for local varieties.

2. The second level of animal traction technology (II) adds animal-powered planting and weeding on cotton, peanuts, millet/sorghum and maize. However, adapted animal-powered planting and weeding equipment is not yet available for rice cultivation.[1]

Costs of production for the different crops are estimated under both levels of technology. Cattle-entrusting practices reported by C.L. Delgado (1980) in Upper Volta are consistent with this region of Senegal, so we can assume that oxen normally grazed with the general cattle herd are taken away only when needed on the fields. We also assume that, for the first labor period where grazing possibilities are nonexistent, the farmer purchases peanut hay and grain-mineral supplement for one pair of oxen. After the first period, it is assumed that grazing becomes possible. The formula for estimating the cost of oxen feed during this period was developed by I. Sene (1980):

Kg/head/day x days of labor period I		x	Price x 2 head	
for peanut hay	8 x 75	x	5 CFA/kg x 2	= 6000
for grain mineral-supplement	15 x 75	x	20 CFA/kg x 2	= 4500
			Total	10500 CFA

[1]Because loans for animal traction equipment have been suspended for five years beginning in 1980, the first level of animal traction seems more realistic. However, it would still be interesting to test the second level of technology as described above.

TABLE 11

Animal Traction and Agricultural Equipment Per Household in the SODEFITEX Area

ITEMS	COUNTY		
	Tambacounda Bakel	Kedougou	Velingara Kolda
Pair of Oxen	.59	.48	.57
Horses	.19	-	.09
Donkeys	.17	-	.17
Plows	.55	.48	.61
Animal-Powered Hoes	.28	.01	.20
Peanut Seeders	.21	.02	.15
Cotton Seeders	.03	-	.01
Carts	.18	.05	.22

SOURCE: SONED (1980)

Under the first level of technology the costs of production per hectare are estimated as follows: Assuming that plowing is done on maize, rice and cotton in the five households, the average plowed area per household is estimated to 2.166 ha. This is computed by dividing the sum of crop areas on which plowing is assumed to be done in all households (maize, rice and cotton: 10.83 ha) by the number of households (5). See Table 7.

The estimated average feed cost per hectare is accordingly:

10,500 CFA/2.166 = 4547.6 CFA/ha

= 4848 CFA/ha

The cost of equipment is estimated based on 1977 prices (see J.P. Rigoulot, 1980).[1]

The average cost per hectare of maintenance and repair of the equipment is estimated at 10 percent of equipment cost. The estimated average repair and maintenance cost of equipment (plow) is:

(22218 x .1)/2.166 = 1025.7 CFA/ha

= 1026 CFA/ha

A lump sum of 69 CFA/ha will be allowed to reflect cost of drugs and veterinary services per hectare, based on Sargent et al. estimate (1981): 150/2.166 = 69.0 CFA/ha.

Operating capital (operating costs) is estimated for each household as the sum of the cost of production of each crop times its respective acreage. This computation gives the following estimates of

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[1] UCF plow: 22,218 CFA
Super Eco seeder: 27,381 CFA
Sine hoe weeder: 17,520 CFA

TABLE 12

Variable Costs of Production Per Hectare Under the First Level of Technology

Input Categories	Millet/Sorghum			Peanuts			Maize			Rice			Cotton[b]		
	Q	P	C	Q	P	C	Q	P	C	Q	P	C	Q	P	C
Seeds[a]	4-5		619	100		7335	20	80	1600	100	65	6500	45		--
Fertilizer															
NPK	150	25	3750	150	25	3750	100	25	2500	100	25	2500	150	25	--
Urea	150	25	3750	--	--	--	100	25	2500	100	25	2500	50	25	--
KCL													50	25	--
Hand Tools			300			300			300			300			300
Maintenance & Repairs of equipment (10%)	--	--	--	--	--	--			1026			1026			1026
Draft Animal Feed	--	--	--	--	--	--			4848			4848			4848
Drugs	--	--	--	--	--	--			69			69			69
TOTAL	8419			11385			12843			17743			6243		

Q = Quantity (kg)
P = Unit Price (CFA/kg)
C = Costs (CFA)

[a]For peanuts, millet/sorghum, SODEVA figures have been used (SODEVA, 1981).

[b]For cotton, seeds, fertilizer and spraying materials are not charged. The producer price is a net of these inputs.

operating capital per household under the first level of technology:

Household I = 55,950 CFA

Household II = 50,768 CFA

Household III = 50,144 CFA

Household IV = 64,804 CFA

Household V = 58,374 CFA

The yields of the different crops in the different household types comes from SODEFITEX annual report 1979/80, reflecting climatic conditions of the year 1979, which was relatively dry (see Appendix 9). The choice of 1979 yields was based on two reasons: 1) complete data were available and 2) the researcher thought that it would be better to select slightly conservative rather than overly generous figures.

Costs of production have also been estimated under the second level of technology which adds animal-powered planting and weeding equipment for peanuts, millet/sorghum, maize and cotton. Cotton is planted with the Super Eco Seeder (SODEFITEX, 1981). The use of the seeder means that operations can now be performed more timely during the first labor period—i.e. not only plowing, but also seeding and some weeding (millet/sorghum). Since feed purchases during this period are assumed fixed, the greater use of oxen effectively reduces feed cost per unit area. The average area on which the pair of oxen works in labor period I increases to 4.614 ha. This is computed by dividing the sum of the total area on which animal traction is used under the first labor period (millet/sorghum, peanuts, maize, rice and cotton) in all households (23.07 ha) by the number of households (5). See Table 7. The estimated average feed cost per hectare becomes: 10,500 CFA/4.614 = 2276 CFA/ha.

Repairs and maintenance costs are estimated for the seeding and weeding equipment, which is used in labor periods I to III. The average area per household on which the seeder and weeder are used (5.92 ha) is computed by dividing the total area on which this equipment is used (millet/sorghum, maize, peanuts and cotton) in all households (29.6 ha) by the number of households (5). The estimated average repairs and maintenance cost per hectare becomes:

seeder: (27,381 x .1)/5.92 = 462 CFA/ha

weeder: (17,520 x .1)/5.92 = 296 CFA/ha

A lump sum of 25 CFA/ha will be allowed to reflect the cost of drugs and veterinary services, computed as before: 150 CFA/5.92 = 25 CFA/ha.

The operating capital (operating costs) under the second level of technology is estimated by the same procedure used earlier, in this case:

Household I = 60,985 CFA

Household II = 57,345 CFA

Household III = 59,907 CFA

Household IV = 67,157 CFA

Household V = 62,640 CFA

TABLE 13

Variable Costs of Production Under
the Second Level of Technology

Input Categories	Millet/ Sorghum	Peanuts	Maize I	Rice I	Cotton[b/]
Seeds[a/]	619	7335	1600	6500	----
Fertilizer					
NPK	3750	3750	2500	2500	----
Urea	3750	----	2500	2500	----
Kcl	----	----	----	----	----
Hand Tools	300	300	300	300	300
Maintenance & Repairs (10%)					
Plow	----	----	1026	1026	1026
Seeder	462	462	462	----	462
Weeder	296	296	296	----	296
Draft Animal Feeds	2276	----	2276	2276	2276
Drugs	25	25	25	25	25
TOTAL	11478	12168	10985	15127	4385

[a]For peanuts, millet/sorghum, SODEVA figures have been used (SODEVA, 1981).

[b]For cotton, seeds, fertilizer and spraying materials are not charged. The producer price is a net of these inputs.

Relative Prices

Two sets of relative commodity prices are used to test the effect of a change in relative prices. Half of the runs use the relative prices which prevailed in 1981/82. A new set of relative prices was calculated by projecting the recent five-year trend; however, this set turned out to be identical to the 1981/82 relative prices (see Tables 14 and 6). Since the idea was to determine the effect of a relative price in favor of cotton, a new set of relative prices was constructed based on prices which actually prevailed in 1970/71 and 1981/82.

The two sets of relative prices are as follows:

	PG/PM	PC/PM	PG/PC	PR/PM	PMZ/PM
Recent relative prices (1981/82)	1.20	1.35	.88	1.03	.94
Changed relative prices (1970/71 and 1981/82)	1.0	1.71	.58	1.03	.94

Assuming a base of 70 CFA/kg for millet/sorghum, the following prices were calculated:

millet/sorghum	70	CFA/kg	(PM)
peanuts (groundnuts)	71	"	(PG)
cotton	119.7	"	(PC)
rice	72.1	"	(PR)
maize	65.8	"	(PMZ)

Assuming that the difference between producer prices and buying prices for millet/sorghum and maize constant at 1981/82 level, the buying prices are estimated as follows: millet/sorghum, 80 CFA/kg;

TABLE 14

Projection of New Producer Prices From the Last Five-Year Trend

Years	Producer Prices				
	Cotton	Peanuts	Millet/Sorghum	Maize	Rice
1977/78	49	41.5	35	37	41.5
1978/79	49	41.5	40	37	41.5
1979/80	55	45.5	40	37	41.5
1980/81	60	50	40	37	41.5
1981/82	68	60	50	47	51.5
Average Change in the Last Five Years	3.8	3.7	3	2	2
Projected Producer Prices (1982/83)	71.8	63.7	53	49	53.5

PG/PM = 1.20; PC/PM = 1.35; PG/PC = .88; PM/PM = .94; PR/PM = 1.03

maize, 68.8 CFA/kg. Because of the government's strong commitment to keeping price of rice down, it is considered unlikely that the price of rice will be allowed to increase as much as projected (105.6 CFA/kg). Therefore a buying price for rice of 90 CFA/kg is assumed in the county of Tambacounda and 95 CFA/kg in the counties of Velingara and Kolda, due to differences in transport costs.

The Linear Programming Tableau

A single linear programming tableau was prepared. The different households can be reflected by changes in the coefficients on farm size, yields, family labor and consumption constraints. The tableau for household I is presented as an illustration (see Table 15).

TABLE 15

The L. P. Tableau for Representative Farm I Under the First Level of Technology

Constraints \ Activities X_j	Peanuts ha 1	Millet/Sorghum ha 2	Maize ha 3	Rice ha 4	Cotton ha 5	Sell Peanuts Kg 6	Millet/Sorghum Sell Kg 7	Millet/Sorghum Buy Kg 8	Millet/Sorghum Cons Kg 9	Maize Sell Kg 10	Maize Buy Kg 11	Maize Cons Kg 12	Rice Sell Kg 13	Rice Buy Kg 14	Rice Cons. Kg 15	Sell Cotton Kg 16	Hire in Labor for all Crops L_I m.d. 17	L_{II} m.d. 18	L_{III} m.d. 19	L_{IV} m.d. 20	Consume Peanuts m.d. 21	Restriction Levels (bi)
Objective function (FCFA)	-11385	-8419	-12039	-16939	-5439	60	50	-60	0	47	-50	0	51.5	-85	0	68	-300	-500	-300	-300	0	
1. Land (ha)	1	1	1	1	1																	≤ 6.52
2. Labor Period 1 (m.d.) (May 1-July 15 = 2.5 months)	36	69	18	27	27												-1					≤ 300 (370)
3. Labor Period 2 (m.d.) (July 15-Aug. 15 = 1 month)	21	21	21	17	46.5													-1				≤ 120 (148)
4. Labor Period 3 (m.d.) Aug. 15-Sept. 30 = 1.5 months)	20	-	36	16	21														-1			≤ 180 (222)
5. Labor Period 4 (m.d.) (Oct. 1-Jan. 30 = 4 months)	56	76	20	68	52															-1		≤ 480 (592)
6. Produce Peanuts (Kg)	-1000					1															1	≤ 0
7. " Millet/S (Kg)		-1013					1	-1	1													≤ 0
8. " Maize (Kg)			-1614							1	-1	1										≤ 0
9. " Rice (Kg)				-1300									1	-1	1							≤ 0
10. " Cotton (Kg)					-800											1						≥ 1434.5
11. Family Millet/S (Kg)									1													≥ 266
12. " Maize (Kg)												1										≥ 152
13. " Rice (Kg)															1							≤ 40
14. Upper Bound L_I (m.d.)																	1					≤ 16
15. " " L_{II} (m.d.)																		1				≤ 24
16. " " L_{III} (m.d.)																			1			≤ 64
17. " " L_{IV} (m.d.)																				1		≤ 55950
18. Operating Capital (CFA)	11385	8419	12039	16939	5439	-60	-50	60	0	-47	50	0	-51.5	85	0	-68	300	500	300	300		≥ 142.5
19. Family Peanut (Kg)																					1	

CHAPTER V

ANALYSIS OF THE RESULTS

Presentation and discussion of the results are made difficult by their complexity. The analysis in this paper is based on eighty separate runs of the basic model, exploring the behavior of cropping patterns under different technological and economic constraints for five representative farms. This chapter includes two sections. First, the organizational framework used to present the results is described. Secondly, the results of the runs are presented and discussed.

The R. Black and S. Harsh package (1975) has been used for the different runs. The output provided the objective value of the model, the optimal combination of activities in solution and their respective levels, the shadow prices of resources, the cost of forcing in non-optimal activities and the price range over which the activity holds.

A. Organizational Framework

The organizational framework is depicted in Figure 2. The eighty runs actually consist of four series of twenty runs reflecting four different sets of assumptions concerning level of technology and prices: 1) first level of technology and recent relative prices; 2) second level of technology and recent relative prices; 3) first level of technology and changed relative prices; and 4) second level of technology and changed relative prices.

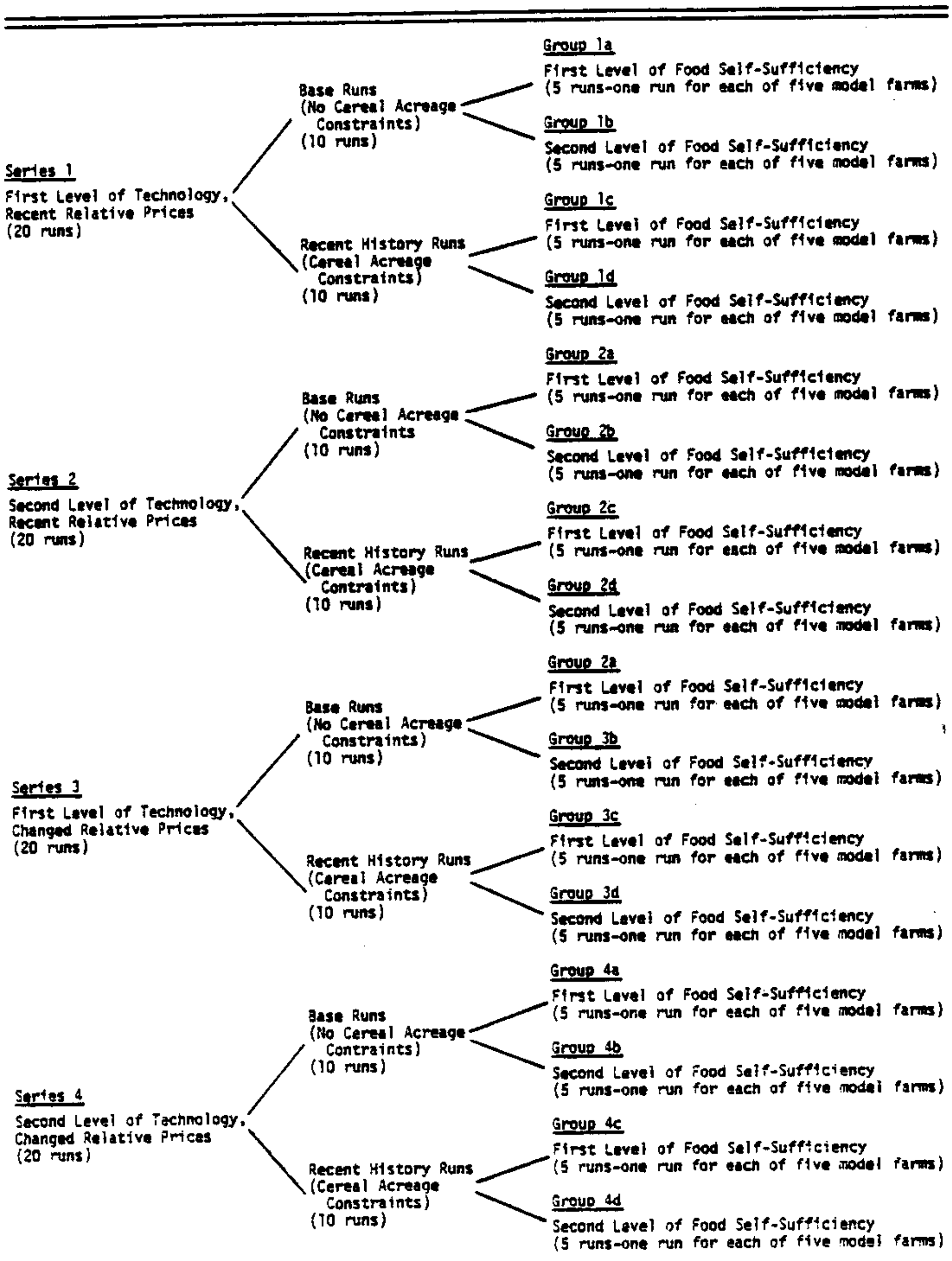

FIGURE 2

Organization of the Research

These four variables are defined as follows:

First level of technology — Animal traction plowing for rice, maize, cotton, and use of fertilizer.

Second level of technology — Additional use of animal-powered seeder and weeder for peanuts, millet/sorghum, maize, and cotton.

Recent relative prices — 1981 producer prices and buying prices (see Chapter IV).

Changed relative prices — producer price of cotton increased relative to food crops.[1]

The four main series of twenty runs are subdivided into two sets of ten runs each. The base runs were made with no specific cereal acreage constraints. The recent history runs on the other hand, incorporated specific cereal acreage constraints[2] under the assumption that farmers will generally plant a minimum acreage to cereal crops to secure food supplies.

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[1]The following relative price changes were introduced. (These relative prices are based on prices which prevailed several years ago. Their choice is somewhat arbitrary. What we are most interested in is the effect of an increase in the price of cotton relative to the price of the major staple (millet/sorghum). In effect, this constitutes a form of sensitivity analysis). Peanuts/millet/sorghum = 1.01; cotton/millet/sorghum = 1.71; peanut/cotton = .58; rice/millet/sorghum = 1.03; maize/millet/sorghum = .94. Assuming a base of 70 CFA/kg for millet/sorghum, the other prices were derived as the following: peanuts = 71 CFA/kg; cotton = 119.7 CFA/kg; rice = 72.1 CFA/kg and maize = 65.8 CFA/kg. The buying prices for cereals were assumed to reflect the 1981 difference between producer and consumer prices except for rice, which is less likely to change very much: millet/sorghum = 80 CFA/kg; maize = 68.8 CFA/kg; rice = 90 CFA/kg for the county of Tambacounda where the first three representative farms belong and 95 CFA/kg for the counties of Velingara and Kolda where the two last representative farms belong.

[2]The following cereal acreage constraints were introduced: millet/sorghum = 2.88-1.80 ha; maize = .42-.50 ha; rice = .03-.45 ha respectively for Eastern Senegal (areas I, II, III) and Upper Casamance (areas IV and V). (See Table 10.) Under the second level

Each set of base runs and recent history runs consists of two groups differentiated by food constraint level (see Chapter IV). These groups contain one run for each of the five representative farms.

To sum up: the eighty total runs are categorized into sixteen groups of five runs according to the level of technology and prices, cereal acreage constraints, and food constraint level. This disaggregation of the results makes possible an analysis of cropping patterns under different sets of possible circumstances.

B. Discussion of Results

The results of the runs are classified into four categories of economic activity to facilitate systematic analysis: 1) land allocation; 2) consumption activities (including buying and selling of food commodities); 3) shadow prices of land and labor and cost of forcing in non-optimal solutions; and 4) income (revenues above variable costs). The discussion of results will be carried out with respect to these categories. The tables (16 through 35) present the actual results of the runs and are displayed at the end of this chapter.

1. First Level of Technology and Recent Relative Prices

a. Base Runs

Beginning first with land allocation, maize generally dominated the plan in all five areas in the base runs. The share of available

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of technology, they were changed respectively to: millet/sorghum = 250-1.50 ha; maize = .50 ha for both regions. A .45 ha rice acreage constraint is kept only for the Casamance region to reflect the greater rice consumption in this region.

land allocated to maize varied from 74 percent in representative farm I to 95 percent in representative farm II. The share of maize amounted to 86 percent in area III, 76 percent in areas IV and V. This is more than expected (and more than is actually planted) and consequently raises the question whether or not the costs and yields of maize are under- or overemphasized. Nevertheless the costs and yields have been generated realistically from the available sources of data. In areas I and III of Tambacounda county, maize is generally followed by millet/sorghum with respectively 20 and 8 percent of the land. Millet/sorghum has not been suggested by the base runs in the areas II, IV and V. In the first three areas of Tambacounda and area V of Upper Casamance, the base run did not suggest cotton in the optimal plans. Cotton appeared only in area IV of Upper Casamance with 4.3 percent of the land (see Tables 16 through 20).

Regarding consumption activities, the results suggest that in areas II, IV and V, the total family millet/sorghum consumption requirement be purchased. This, of course, is unlikely to happen. In areas I and III, the results suggest that part of the requirement be grown and part purchased. Just enough peanuts for family consumption should be grown in all five areas. The same applies to rice in all areas, except in area I, where a slight surplus for sale is allowed by the base run.

The shadow prices, reflecting the rate of change of the objective function associated with one unit change of a given resource and the scarcity of a resource, provided useful information (see Appendix 9). Land generally showed what might be considered a high shadow price, ranging from 10,943 CFA/ha in area I to 62,827 CFA/ha in area V. Since land is not generally a constraint in these areas, expansion of acreage might be profitable. The shadow price of labor which could be expected to be high for all five areas, because of the low population density, was high only for area I (1972 CFA) in the labor period II corresponding to the weeding of most crops (see annex 9). This is not consistent with the prevailing practices, which generally keep hired seasonal labor in the farm household during the whole cropping season. The generally low shadow prices of labor seem to suggest that we may have been too generous with regard to the family labor availability. It may also arise from the fact that other activities (off-farm activities) have not been considered in the model, due to the non-availability of reliable input-output coefficients.

The Black and Harsh package also calculates the cost of forcing non-optimal solutions. The program indicated a cost of forcing cotton in the county of Tambacounda (area I, II, III) ranging from 329 CFA in area II to 60,712 in area I (see Appendix 10). For area III, it was 10,205 CFA. The program did not indicate a cost of forcing cotton in the areas IV and V of Upper Casamance in the base runs. The existence of this cost of forcing cotton might explain the general decline of cotton in Eastern Senegal. The program did not indicate a cost of forcing in for millet/sorghum in areas I and III in the base runs, but there was a substantial cost ranging from 1621 CFA to 5246 CFA for areas II, IV and V (see Appendix 10).

The main source of income in the five areas was the sale of the large maize excess over family requirements. For area IV, the sale of cotton also provided income to the farm but to a lesser extent.

The runs were then repeated at the second level of food self-sufficiency (16) specified in the previous chapter. The higher level of minimum family food supply did not drastically affect the land allocation to crops, as can be seen in Tables 16 through 20. A slight reduction occurred generally in the sale level of maize and eventually of rice (Table 16). The purchase of millet/sorghum increased generally by the difference between the two levels of food requirements. However, the objective function (revenues above variable costs) decreased generally by about 5 to 7 percent.

b. Recent History Runs

The results of the base runs suggested a pattern of land use quite different from actual land allocation (see Table 10). The optimal solution of the base runs was not expected to reflect actual practices but to provide an insight into what should be done in order to maximize the revenues above variable costs, provided the technical coefficients and prices are known with certainty. As is well known, farmers may have goals other than revenue maximization (Kamuanga, 1982). Also it is very difficult with limited resources and data to accurately model farmers' decision-making processes. Nevertheless, attempts to introduce more realism into the model are shown below.

Runs were made with cereal acreages constrained to recent acreage allocation history, i.e. millet/sorghum = 2.88-1.80 ha, maize = .42-.50 ha, rice = .03-.45 ha, respectively in the regions of Tambacounda and Upper Casamance (SONED, 1980). (See Table 10.) The results appear in Tables 16 through 20. It can be seen, generally more peanuts come into solution, occupying 40 to 56 percent of the available land. Cotton appeared substantially only in area IV (.81 ha or 11 percent of the available land) compared to the negligible amount of .02 ha, or less than one percent in area II. In the other areas, cotton did not appear in the solution, and the program did not indicate a cost of forcing in for cotton, suggesting that cotton might be allowed into the solution under the recent relative prices if more land were available. The generally high shadow price associated with land (except in area I) supported this idea. However there was generally a "cost" paid to keep a millet/sorghum acreage at the recent level, reflected by a negative shadow price[1] ranging from about 4,400 to 16,000 CFA (see Appendix 9). Whether this cost is high with respect to what farmers are willing to pay for securing their own food remains a question. This is the likely reason why the objective functions (revenues above variable costs) with respect to the base runs showed a sharp decrease in monetary terms, generally by 30 percent in the five areas, when the analysis was constrained by recent history acreages (see Tables 16 through 20). This could be considered as the price for risk discount.

The source of income in areas I, II, III and V is provided mainly by the sale of peanuts, millet/sorghum and maize. In areas IV the sale of cotton provides an additional income.

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[1]In fact this should be interpreted as a cost of forcing in a non-optimal solution. It occurs when the direct costs plus the inputed are greater than the revenues from the use of one additional unit of land for a given activity. This was generally consistent with the formula:

$$SP = Y \cdot P - (\Sigma aij\ SPi + Cj)$$

where Y = Yield (millet/sorghum)
P = Producer Price (millet/sorghum)
aij·SPi = inputed costs
aij = technical coefficient of resource used (here labor)
SPi = shadow price of a given resource in a given period
cj = direct cost of production of a given crop (millet/sorghum)

There is evidence, however, that the farmers sell a small amount of their product at the official market price (2 to 6 percent—CILSS, Aug. 1977, Vol. II). The rest is likely to be sold in the black market at a higher price (thus generating a greater income), and/or used for traditional ceremonies such as birth, death, etc., which unfortunately are not well-documented. When the runs were repeated at the second level of food self-sufficiency the results did not show a drastic change in land allocation and there was a drop in the objective function (revenues above variable costs) by 5 percent.

2. Second Level of Technology and Recent Relative Prices

The assumption underlying the second level of technology is that the introduction of animal-powered seeders and weeders would allow more timely field operations for all crops, particularly for cotton which generally lags behind in field care (see Tables 21 through 25).

a. Base Runs

The base runs under the second level of technology and recent relative prices still showed maize dominating the optimal plan in Eastern Senegal (areas I, II, III) with 80.95 percent of the share of land. However, this was not the case in Upper Casamance (areas IV and V) where maize covered only 20 to 45 percent of the land. Cotton occupied 50 to 70 percent of the land in this region and only about 14 percent in area I of Eastern Senegal (see Tables 21 through 25). There was generally no millet/sorghum in the optimal plans of the base runs for all five areas. This suggests that farmers buy all their cereal consumption requirements in all five areas, which of course is unlikely. In the base runs at the second level of technology, consumption activities, the shadow price of land and the objective function all behaved roughly the same as at the first level of technology. The shadow price of labor for all labor periods is generally low, as might have been expected since the second level of technology has a lower labor requirement. However an exception occurs in labor period III in Eastern Senegal (areas I, II, III), when a substantial hiring-in of labor is suggested by the results, probably due to the maize harvest.

b. Recent History Runs

Since we did not expect the base runs optimal solutions to be reflected in actual practice (because of the possibility of goals other than profit maximization in monetary terms), we again introduced a minimum acreage constraint of 2.50 ha for millet/sorghum and .50 ha for maize in Eastern Senegal. The constraint of .50 ha of maize reflects the present shortage of hybrid maize seed. For the Casamance areas (IV, V), an additional constraint of a minimum .45 ha of rice was added to the 1.50 ha of millet/sorghum and .50 ha of maize acreage constraints to reflect the greater rice consumption pattern in this region. Under these acreage constraints, cotton comes into solution in areas I and II at the expense of peanuts in Eastern Senegal. The cotton share in these two areas (I and II) ranges from 40 to 50 percent. For area III of Eastern Senegal, cotton is not in solution, but the results did not show a cost of forcing in. Thus cotton could be expected to come into solution if more land were available. If cotton does not appear in the solution, approximately 45 percent of the land can be expected to be occupied by peanuts.

For Upper Casamance, the share of land to cotton ranged from 55 percent in area V to 62 percent in area IV, the increases coming at the expense of peanuts. In both regions, except for area III in Eastern Senegal, peanut production for family consumption only was indicated. Hired labor was not in solution except for a negligible amount (.69 man-days) in area IV. This was to be expected, since the higher level of technology implies a reduction in labor requirements. However, the introduction of labor-saving equipment, associated with the generally high shadow price of land, could eventually bring in more land use and therefore more hiring-in activities.

The introduction of cereal acreage constraints generally decreased the objective functions (revenues above variable costs). The sharp reduction (20 to 30 percent as compared to the base runs) probably represents the "cost" to be paid for setting acreage constraints as reflected by the negative shadow prices[1] (see Appendix 9). When the recent history runs were repeated at the second level of food self-sufficiency, the results again changed very little. Once again, there was no drastic change in land allocation to crops and a drop of about 5 percent occurred in the objective function.

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[1]See footnote on page 55.

3. First Level of Technology and Changed Relative Prices

Changed relative prices were introduced next. The main purpose was to explore the behavior of cropping patterns under different price circumstances (see Tables 25 through 30).

a. Base Runs

Under the first level of technology and changed relative prices, the results generally showed the base runs still dominated by maize. Surprisingly, cotton did not dominate the optimal plans, as might have been expected. This again raises the question whether or not the costs and yields of maize are under or overemphasized.

The share of land allocated to maize ranged from 80 to 93 percent. Cotton occupied only about 12 percent in area II, 2 percent in area III, 10 percent in area IV and 16 percent in area V (see Tables 25 through 30). However, it is surprising that in Eastern Senegal cotton appeared in area III, although in a negligible amount, and not in area I which in the year of reference had a higher cotton yield (800 kg/ha) than area III (752 kg/ha). Either the model did not accurately reflect the input-output coefficients, or under more land scarcity (5.59 ha in representative farm III vs 6.52 ha in representative farm I) the program allocated land to the crop with the higher MVP, ceteris paribus, in order to maximize revenues. The same pattern was noticed in Upper Casamance (IV, V) where in area V more land was allocated to cotton: .96 ha in V vs .74 ha in IV, although cotton yield was higher in area IV (1,018 kg/ha vs 920 kg/ha in area IV). There was no millet/sorghum in the optimal plans, except in area I. In this area (I), millet/sorghum occupied about 10 percent of the land and covered only partially the family millet/sorghum consumption requirements. The results suggest that part of the family millet/sorghum consumption requirement be purchased in this area I and all of it be purchased in four other areas. Again, just enough peanuts for family consumption is suggested.

The shadow price of land is generally high, as in the other runs. The shadow price of labor is not consistently high in all labor periods, as might have been expected. There is however a substantial hiring-in activity in labor periods two and three in almost all five areas, except in area V.

Sales of maize and rice provided the source of income in area I. In the other areas, the sale of cotton provided an additional income. When the runs were repeated at the second level of food self-sufficiency. The results were similar to those of the base runs of the first level of technology and recent relative prices: no drastic change in land allocation, increase in purchases of millet/sorghum by the difference between the two levels of food self-sufficiency and a drop in the objective function by about 5 percent.

b. Recent History Runs

When more realism was introduced into the model by constraining cereal acreages to recent levels, peanuts tended to occupy the largest share of land, ranging from 25 in area V to 48 percent in area IV. In areas I, II, III, peanuts occupied respectively 48, 29 and 27 percent of the land.

Cotton occupied about 11 percent of areas II and IV, 13 percent of area III, and 28 percent of area V. Cotton did not appear in area I. However cotton did not indicate a cost of forcing-in in area I, suggesting that cotton would be allowed into solution if more land were available. The shadow price of labor was consistently high for all five areas only in labor period two, corresponding to the weeding of most crops. Only in area I was there hiring-in activity, for labor period one.

Income was provided by the sale of peanuts, millet/sorghum, maize and eventually of cotton.

When the runs were repeated at a higher level of food self-sufficiency, drastic changes did not occur.

4. Second Level of Technology and Changed Relative Prices

A combination of the second level of technology and changed relative prices was also introduced to explore the behavior of cropping patterns under the new price circumstances and improved technology. The results are displayed in Tables 31 through 35.

a. Base Runs

The combination of the second level of technology and changed relative prices generally brought cotton into solution, ranging from 33 percent in area I to 95 percent in area V. In area II, cotton occupied 49 percent of the land and 65 percent in area IV. In area III cotton was not suggested, but did not indicate a cost of forcing-in. Maize dominated the plan only in areas I and III, covering 64 percent and 95 percent of the land. In areas II, IV, and V, maize occupied respectively 48 percent, 32 percent and 6 percent of the land. There was no millet/sorghum in solution in all five areas, implying that total family millet/sorghum consumption requirements would be purchased.

Just enough peanuts for family consumption was suggested by the results. The shadow price of land remained high in general. The shadow price of labor was zero for all labor periods in areas I and II, where there was no hiring-in activity. In area III, the results suggested a hiring-in labor of 15 man-days in labor period three, probably for the harvest of maize. In areas IV and V, the shadow price of labor was high only for the labor period two, corresponding again to the weeding of most crops. This suggests that additional labor would be profitable in this period. Income is generally provided by the sale of maize and cotton, except in area III, where there was no cotton suggested. When the runs were repeated at the second level of food self-sufficiency, the results were as expected: there were no big changes in land allocation to crops, purchases of millet/sorghum for family consumption increased by the difference between the two food self-sufficiency levels, and the revenues above variable costs decreased by about 5 percent .

b. Recent History Runs

When minimum cereal acreage constraints were again introduced, cotton still occupied a substantial share of land, ranging from 42 percent in area III to 62 percent in area IV. Cotton occupied 52 percent, 45 percent and 58 percent respectively in areas I, II and V. Cotton did dominate the plans generally, except in area III, where the plan was dominated by the constrained millet/sorghum. Cotton domination occurred, generally, at the expense of peanuts, which was suggested only for family consumption. The shadow price of land remained high. The shadow price of labor was generally zero, suggesting no hiring-in activities. Cotton became the main source of income.

As in earlier cases, there is still a "cost" to be paid[1] for setting a minimum cereal acreage constraint (see Appendix 10). But to what extent this cost is high remains to be assessed. This "cost" to be paid is probably the reason for the 10 to 20 percent decrease of the objective function (revenues above variable costs) with respect to the base runs.

When the recent history runs were repeated at the second level of food self-sufficiency, the results again changed very little: there was no drastic change in land allocation and a decrease in the revenues above variable costs by about 3 to 5 percent.

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[1]See footnote on page 55.

TABLE 16

Summary Table for Representative Farm I Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and Recent Relative Prices

ACTIVITY		Base Run		Recent Cereal Acreages	
		Food Level one (1a I)	Food Level two (1b I)	Food Level one (1c I)	Food Level two (1d I)
Peanuts	(ha)	.1425	.1425	3.1519	3.1519
Millet/Sorghum	(ha)	1.3289	1.3289	2.88	2.88
Maize	(ha)	4.8186	4.8186	.42	.42
Rice	(ha)	.23	.23	.03	.03
Cotton	(ha)	---	0.0	0.0	---
Sell Peanuts	(kg)	---	---	3009.4	3009
Sell Millet/S.	(kg)	---	---	1482.9	1311.9
Buy Millet/S.	(kg)	88.3	259.3	---	---
Consume Millet/S.	(kg)	1434.5	1605.5	1434.5	1605.5
Sell Maize	(kg)	7511.2	7482.7	411.8	383.3
Consume Maize	(kg)	266	294.5	266	294.5
Sell rice	(kg)	147	128	---	---
Buy Rice	(kg)	---	---	113	132
Consume rice	(kg)	152	171	152	171
Sell Cotton	(kg)	---	---	---	---
Hire in Labor period 1	(m.d.)	---	---	20.5	20.5
Hire in Labor period 2	(m.d.)	16.0	16.0	16.0	16.0
Consume peanuts (kg)	(kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)		268,522	255,944	184,239	172,735

TABLE 17

Summary Table for Representative Farm II Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and Recent Relative Prices

ACTIVITY	Base Runs		Recent Cereal Averages	
	Food Level one (1a II)	Food Level two (1b II)	Food Level one (1c II)	Food Level two (1d II)
Peanuts (ha)	.1425	.1425	2.3353	2.3353
Millet/Sorghum (ha)	---	---	2.8800	2.8800
Maize (ha)	5.4306	5.4160	.4200	.4200
Rice (ha)	.1169	.1315	.0300	.0300
Cotton (ha)	---	---	.0247	.0247
Sell Peanuts (kg)	---	---	2192.7	2192.7
Sell Millet/Sorghum (kg)	---	---	1445.5	1274.5
Buy Millet/Sorghum (kg)	1434.5	1605.5	---	---
Consume Millet/Sorghum (kg)	1434.5	1605.5	1434.5	1605.5
Sell Maize (kg)	8612.9	8560.5	420.7	392.2
Consume maize (kg)	266	294.5	266	294.5
Buy Rice (kg)	---	---	113	132
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	---	---	23.7	23.7
Hire in labor period 3 (m.d.)	20.2	19.2	---	---
Consume peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	239,232	226,526	158,712	147,207

TABLE 18

Summary Table for Representative Farm III Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and Recent Relative Prices

ACTIVITY		Base Run		Recent Cereal Acreages	
		Food Level one (1a III)	Food Level two (1b III)	Food Level one (1c III)	Food Level two (1d III)
Peanuts	(ha)	.1425	.1425	2.2600	2.2600
Millet/Sorghum	(ha)	.4617	.4536	2.8800	2.8800
Maize	(ha)	4.8689	4.8624	.4200	.4200
Rice	(ha)	.1169	.1315	.0300	.0300
Cotton	(ha)	---	0.0	0.0	0.0
Sell Peanuts	(kg)	---	---	2117.5	2117.5
Sell Millet/Sorghum	(kg)	---	---	1379.2	1208.2
Buy Millet/sorghum	(kg)	983.4	1162.3	---	---
Consume Millet/Sorghum	(kg)	1434.5	1605.3	1434.5	1605.5
Sell Maize	(kg)	7134.5	7096.3	372.4	343.9
Consume Maize	(kg)	266	294.5	266	294.5
Sell Rice	(kg)	---	---	---	---
Buy Rice	(kg)	---	---	113	132
Consume Rice	(kg)	152	171	152	171
Sell Cotton	(kg)	---	---	---	---
Consume Peanuts	(kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)		206.210	193,563	148,007	136,503

TABLE 19

Summary Table for Representative Farm IV Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and Recent Relative Prices

ACTIVITY		Base Runs		Recent Cereal Acreages	
		Food Level one (1a IV)	Food Level two (1b IV)	Food Level one (1c IV)	Food Level two (1d IV)
Peanuts	(ha)	.1779	.1779	3.3486	3.3486
Millet/Sorghum	(ha)	---	---	1.80	1.80
Maize	(ha)	5.2963	5.2252	.50	.50
Rice	(ha)	1.1431	1.2046	.45	.45
Cotton	(ha)	.2925	.3023	.8114	.8114
Sell Peanuts	(kg)	---	---	3154.8	3154.8
Sell Millet/Sorghum	(kg)	---	---	382.4	299.8
Buy Millet/Sorghum	(kg)	1498.6	1581.2	---	---
Consume Millet/Sorghum	(kg)	1498.6	1581.2	1498.6	1581.2
Sell Maize	(kg)	8038.0	7915.3	555.8	544.0
Consume Maize	(kg)	224.2	236.0	224.2	236.0
Sell Rice	(kg)	---	---	---	---
Buy Rice	(kg)	---	---	665.4	724.4
Consume Rice	(kg)	1097.4	1156.4	1097.4	1156.4
Sell Cotton	(ha)	297.9	307.7	825.9	825.9
Hire in Labor period 2	(m.d.)	---	---	16.0	16.0
Consume Peanuts	(kg)	177	177	177	177
Objective Function (CFA)		215,976	205,682	150,066	140,071

TABLE 20

Summary Table for Representative Farm V Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and Recent Relative Prices

ACTIVITY		Base Runs		Recent Cereal Acreages	
		Food Level one (1a V)	Food Level two (1b V)	Food Level one (1c V)	Food Level two (1d V)
Peanuts	(ha)	.1487	.1487	3.1300	3.1300
Millet/Sorghum	(ha)	---	---	1.80	1.80
Maize	(ha)	4.5119	4.4464	.50	.50
Rice	(ha)	1.2193	1.2849	.45	.45
Cotton	(ha)	0.0	0.0	0.0	0.0
Sell Peanuts	(kg)	---	---	3547.7	3547.7
Sell Millet/S.	(kg)	---	---	481.4	398.8
Buy Millet/S	(kg)	1498.6	1581.2	---	---
Consume Millet/S	(kg)	1498.6	1581.2	1498.6	1581.2
Sell Maize	(kg)	7040.0	6922.6	580.8	569.0
Consume Maize	(kg)	224.2	236	224.2	236
Buy Rice	(kg)	---	---	692.4	751.4
Consume Rice	(kg)	1097.4	1156.4	1097.4	1156.4
Sell Cotton	(kg)	---	---	---	---
Consume Peanuts	(kg)	177	177	177	177
Objective Function (CFA)		159,689	148,897	136,718	126,723

TABLE 21

Summary Table for Representative Farm I Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with Second Level of Technology and Recent Relative Prices

ACTIVITY		Base Runs		Millet/S acreage = 2.50 ha Maize = .50 ha	
		Food Level one (2a I)	Food Level two (2b I)	Food Level one (2c I)	Food Level two (2d I)
Peanuts	(ha)	.1188	.1188	.1188	.1188
Millet/S.	(ha)	---	---	2.50	2.50
Maize	(ha)	5.3563	5.3525	.50	.50
Rice	(ha)	.1169	.1315	.1169	.1315
Cotton	(ha)	.9280	.9172	3.2843	3.2697
Sell Peanuts	(kg)	---	---	---	---
Sell Millet/S.	(kg)	---	---	1315.5	1144.5
Buy Millet/S.	(kg)	1434.5	1605.5	---	---
Consume Millet/S.	(kg)	1434.5	1605.5	1430.5	1605.5
Sell Maize	(kg.	9375.3	9340.0	634.0	605.5
Consume Maize	(kg)	266	294.5	266	294.5
Consume Rice	(kg)	152	171	152	171
Sell Cotton	(kg)	951.2	940.1	3366.4	3351.4
Hire in Labor period 3	(m.d.)	24.0	24.0	---	---
Consume peanuts	(kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)		345,932	33,126	272,687	261,622

TABLE 22

Summary Table for Representative Farm II Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with Second Level of Technology and Recent Relative Prices

Activity	Base Runs		Millet/Sorghum acreage = 2.50 ha; maize = .50 ha	
	Food Level One (2a II)	Food Level Two (2b II)	Food Level One (2c II)	Food Level Two (2d II)
Peanuts (ha)	.1188	.1188	.1188	.1188
Millet/Sorghum (ha)	-	-	2.50	2.50
Maize (ha)	5.4543	5.4397	.50	.50
Rice (ha)	.1169	.1315	.1169	.1315
Cotton (ha)	0.0	-	2.4543	2.4397
Sell Peanuts (kg)	-	-	-	-
Sell Millet/Sorghum (kg)	-	-	1,315.5	1,144.5
Buy Millet/Sorghum (kg)	1,434.5	1,605.5	-	-
Consume Millet/Sorghum (kg)	1,434.5	1,605.5	1,434.5	1,605.5
Sell Maize (kg)	9,551.7	9,496.9	634.5	605.5
Consume Maize (kg)	266	294.5	266	294.5
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	-	-	2,454.3	2,439.7
Hire in Labor Period 3 (m.d.)	19.1	18.8	-	-
Consume Peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	293,981	281,173	214,303	203,263

TABLE 23

Summary Table for Representative Farm III Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with Second Level of Technology and Recent Relative Prices

Activity	Base Runs		Millet/Sorghum acreage = 2.50 ha; maize = .50 ha	
	Food Level One (2a III)	Food Level Two (2b III)	Food Level One (2c III)	Food Level Two (2d III)
Peanuts (ha)	.1188	.1188	2.4731	2.4585
Millet/Sorghum (ha)	-	-	2.50	2.50
Maize (ha)	5.3543	5.3397	.50	.50
Rice (ha)	.1169	.1315	.1169	.1315
Cotton (ha)	0.0	0.0	0.0	0.0
Sell Peanuts (kg)	-	-	2,825.1	2,807.6
Sell Millet/Sorghum (kg)	-	-	1,315.5	1,144.5
Buy Millet/Sorghum (kg)	1,434.5	1,605.5	-	-
Consume Millet/Sorghum (kg)	1,434.5	1,605.5	1,434.5	1,605.5
Sell Maize (kg)	9,371.7	9,316.9	634.0	605.5
Consume Maize (kg)	266	294.5	266	294.5
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	-	-	-	-
Hire in Labor Period 3 (m.d.)	15.7	15.2	-	-
Consume Peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	287,700	274,891	199,035	188,050

TABLE 24

Summary Table for Representative Farm IV Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with Second Level of Technology and Recent Relative Prices

Activity	Base Runs		Millet/Sorghum: acreage = 1.50 ha maize = .50; rice = .45 ha	
	Food Level One (2a IV)	Food Level Two (2b IV)	Food Level One (2c IV)	Food Level Two (2d IV)
Peanuts (ha)	.1475	.1475	.1475	.1475
Millet/Sorghum (ha)	-	-	1.50	1.50
Maize (ha)	3.2013	3.2013	.50	.50
Rice (ha)	-	-	.45	.45
Cotton (ha)	3.5612	3.5612	4.3125	4.3125
Sell Peanuts (kg)	-	-	-	-
Sell Millet/Sorghum (kg)	-	-	151.4	68.8
Buy Millet/Sorghum (kg)	1,498.6	1,581.2	-	-
Consume Millet/Sorghum (hg)	1,498.6	1,581.2	1,498.6	1,581.6
Sell Maize (kg)	5,538.1	5,526.3	675.8	664.0
Consume Maize (kg)	224.2	236.0	224.2	236
Buy Rice (kg)	1,097.4	1,156.4	665.4	724.4
Consume Rice (kg)	1,097.4	1,156.4	1,097.4	1,156.4
Sell Cotton (kg)	4,451.5	4,451.5	5,390.6	5,390.6
Hire in Labor Period 2 (m.d.)	-	-	.69	.69
Consume Peanuts (kg)	177	177	177	177
Objective Function (CFA)	321,735	310,915	295,439	285,444

TABLE 25

Summary Table for Representative Farm V Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with Second Level of Technology and Recent Relative Prices

Activity	Base Runs		Millet/Sorghum: acreage = 1.50 ha maize = .50; rice = .45 ha	
	Food Level One (2a V)	Food Level Two (2b V)	Food Level One (2c V)	Food Level Two (2d V)
Peanuts (ha)	.1475	.1475	.1475	.1475
Millet/Sorghum (ha)	-	-	1.50	1.50
Maize (ha)	1.3598	1.3598	.50	.50
Rice (ha)	-	-	.45	.45
Cotton (ha)	4.3727	4.3727	3.2825	3.2825
Sell Peanuts (kg)	-	-	-	-
Sell Millet/Sorghum (kg)	-	-	151.4	68.8
Buy Millet/Sorghum (kg)	1,498.6	1,581.2	-	-
Consume Millet/Sorghum (kg)	1,498.6	1,581.2	1,498.6	1,581.6
Sell Maize (kg)	2,223.3	2,211.5	675.8	664.0
Consume Maize (kg)	224.2	236.0	224.2	236.0
Buy Rice (kg)	1,097.4	1,156.4	692.4	751.4
Consume Rice (kg)	1,097.4	1,156.4	1,097.4	1,156.4
Sell Cotton (kg)	5,028.6	5,028.6	3,774.8	3,774.8
Consume Peanuts (kg)	177	177	177	177
Objective Function (CFA)	221,858	211,037	188,022	178,008

TABLE 26

Summary Table for Representative Farm I Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Recent Cereal Acreages	
	Food Level One (3a I)	Food Level Two (3b I)	Food Level One (3c I)	Food Level Two (3d I)
Peanuts (ha)	.1425	.1425	3.1519	3.1519
Millet/Sorghum (ha)	.6622	.6622	2.8800	2.8800
Maize (ha)	5.4853	5.4853	.4200	.4200
Rice (ha)	.2300	.2300	.0300	.0300
Cotton (ha)	0.0	0.0	0.0	-
Sell Peanuts (kg)	-	-	3,009.4	3.009.4
Sell Millet/Sorghum (kg)	-	-	1,482.9	1,311.9
Buy Millet/Sorghum (kg)	736.6	934.6	-	-
Consume Millet/Sorghum (kg)	1,434.5	1,605.5	1,434.5	1,605.5
Sell Maize (kg)	8,587.2	8,558.7	411.8	383.3
Consume Maize (kg)	266	294.5	266	294.5
Sell Rice (kg)	147	128	-	-
Buy Rice (kg)	-	-	113	132
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	-	-	-	-
Hire in Labor Period 1 (m.d.)	-	-	20.5	20.5
Hire in Labor Period 2 (m.d.)	16	16	16.0	16.0
Hire in Labor Period 3 (m.d.)	24	24	-	-
Consume Peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	417,619	400,694	254,180	238,625

TABLE 27

Summary Table for Representative Farm II Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Recent Cereal Acreages	
	Food Level One (3a II)	Food Level Two (3a II)	Food Level One (3c II)	Food Level Two (3d II)
Peanuts (ha)	.1425	.1425	1.7078	1.7078
Millet/Sorghum (ha)	-	-	2.88	2.88
Maize (ha)	4.7648	4.7479	.42	.42
Rice (ha)	.1169	.1315	.03	.03
Cotton (ha)	.6658	.6681	.6522	.6522
Sell Peanuts (kg)	-	-	1,565.3	1,565.3
Sell Millet/Sorghum (kg)	-	-	1,445.5	1,274.5
Buy Millet/Sorghum (kg)	1,434.5	1,605.5	-	-
Consume Millet/Sorghum (kg)	1,434.5	1,605.5	1,434.5	1,605.5
Sell Maize (kg)	7,524.4	7,468.2	420.7	392.2
Consume Maize (kg)	266	294.5	266	294.5
Buy Rice (kg)	-	-	113	132
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	640.4	642.6	627.3	627.3
Hire in Labor Period 1 (m.d.)	-	-	-	-
Hire in Labor Period 2 (m.d.)	16.0	16.0	16.0	16.0
Hire in Labor Period 3 (m.d.)	10.2	9.9	-	-
Consume Peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	376,896	359,827	243,244	227,689

TABLE 28

Summary Table for Representative Farm III Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Recent Cereal Acreages	
	Food Level One (3a III)	Food Level Two (3b III)	Food Level One (3c III)	Food Level Two (3d III)
Peanuts (ha)	.1425	.1425	1.5255	1.5255
Millet/Sorghum (ha)	-	-	2.88	2.88
Maize (ha)	5.2099	5.1930	.42	.42
Rice (ha)	.1169	.1315	.03	.03
Cotton (ha)	.1207	.1230	.7345	.7345
Sell Peanuts (kg)	-	-	1,382.9	1,382.9
Sell Millet/Sorghum (kg)	-	-	1,379.2	1,208.2
Buy Millet/Sorghum (kg)	1,434.5	1,605.5	-	-
Consume Millet/Sorghum (kg)	1,434.5	1,605.5	1,434.5	1,605.5
Sell Maize (kg)	7,653.0	7,598.8	372.4	343.9
Consume Maize (kg)	266	294.5	266	294.5
Sell Rice (kg)	-	-	-	-
Buy Rice (kg)	-	-	113	132
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	90.7	92.4	552.3	552.3
Hire in Labor Period 2 (m.d.)	-	-	16.0	16.0
Hire in Labor Period 3 (m.d.)	14.8	14.4	-	-
Consume Peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	323,869	306,870	215,064	199,509

TABLE 29

Summary Table for Representative Farm IV Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Recent Cereal Acreages	
	Food Level One (3a IV)	Food Level Two (3b IV)	Food Level One (3c IV)	Food Level Two (3d IV)
Peanuts (ha)	.1779	.1779	3.3486	3.3486
Millet/Sorghum (ha)	-	-	1.80	1.80
Maize (ha)	5.9913	5.9913	.50	.50
Rice (ha)	-	-	.45	.45
Cotton (ha)	.7408	.7408	.8114	.8114
Sell Peanuts (kg)	-	-	3,154.8	3,154.8
Sell Millet/Sorghum (kg)	-	-	382.4	299.8
Buy Millet/Sorghum (kg)	1,498.6	1,581.2	-	-
Consume Millet/Sorghum (kg)	1,498.6	1,581.2	1,498.6	1,581.2
Sell Maize (kg)	9,122.2	9,110.4	555.8	544.0
Consume Maize (kg)	244.2	236	244.2	236
Sell Rice (kg)	-	-	-	-
Buy Rice (kg)	1,097.4	1,156.4	665.4	724.4
Consume Rice (kg)	1,097.4	1,156.4	1,097.4	1,156.4
Sell Cotton (kg)	754.1	754.1	825.9	825.9
Hire in Labor Period 2 (m.d.)	16.0	16.0	16.0	16.0
Hire in Labor Period 3 (m.d.)	12.8	12.8	-	-
Consume Peanuts (kg)	177	177	177	177
Objective Function (CFA)	370,935	357,945	242,243	230,079

TABLE 30

Summary Table for Representative Farm V Under Two Subsistence Food Levels and Constrained by Recent Cereal Acreages with First Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Recent Cereal Acreages	
	Food Level One (3a V)	Food Level Two (3b V)	Food Level One (3c V)	Food Level Two (3d V)
Peanuts (ha)	.1487	.1487	1.4704	1.4704
Millet/Sorghum (ha)	-	-	1.80	1.80
Maize (ha)	4.7697	4.7697	.50	.50
Rice (ha)	-	-	.45	.45
Cotton (ha)	.9616	.9616	1.6596	1.6596
Sell Peanuts (kg)	-	-	1,572.7	1,572.7
Sell Millet/Sorghum (kg)	-	-	481.4	398.8
Buy Millet/Sorghum (kg)	1,498.6	1,581.2	-	-
Consume Millet/Sorghum (kg)	1,498.6	1,581.2	1,498.6	1,581.2
Sell Maize (kg)	7,455.0	7,443.2	580.8	569.0
Consume Maize (kg)	224.2	236	224.2	236.0
Buy Rice (kg)	1,097.4	1,156.4	692.4	751.4
Consume Rice (kg)	1,097.4	1,156.4	1,097.4	1,156.4
Sell Cotton (kg)	884.6	884.6	1,526.8	1,526.8
Hire in Labor Period 2 (m.d.)	-	-	16.0	16.0
Consume Peanuts (kg)	177	177	177	177
Objective Function (CFA)	303,336	290,346	235,904	223,740

TABLE 31

Summary Table for Representative Farm I Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with the Combination of Second Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Millet/Sorghum acreage = 2.50 ha; maize = .50 ha	
	Food Level One (4a I)	Food Level Two (4b I)	Food Level One (4c I)	Food Level Two (4d I)
Peanuts (ha)	.1188	.1188	.1188	.1188
Millet/Sorghum (ha)	-	-	2.50	2.50
Maize (ha)	4.2367	4.2367	.50	.50
Rice (ha)	-	-	-	-
Cotton (ha)	2.1645	2.1645	3.4013	3.4013
Sell Millet/Sorghum (kg)	-	-	1,315.5	1,144.5
Buy Millet/Sorghum (kg)	1,434.5	1,605.5	-	-
Consume Millet/Sorghum (kg)	1,434.5	1,605.5	1,434.5	1,605.5
Sell Maize (kg)	7,360	7,331.5	634.0	605.5
Consume Maize (kg)	266	294.5	266	294.5
Buy Rice (kg)	152	171	152	171
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	2,218.6	2,218.6	3,486.2	3,486.2
Consume Peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	543,981	526,716	486,883	471,327

TABLE 32

Summary Table for Representative Farm II Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with the Combination of Second Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Millet/Sorghum acreage = 2.50 ha; maize = .50 ha	
	Food Level One (4a II)	Food Level Two (4b II)	Food Level One (4c II)	Food Level Two (4d II)
Peanuts (ha)	.1188	.1188	.1188	.1188
Millet/Sorghum (ha)	-	-	2.50	2.50
Maize (ha)	2.7528	2.7528	.50	.50
Rice (ha)	-	-	-	-
Cotton (ha)	2.8185	2.8185	2.5713	2.5713
Sell Millet/Sorghum (kg)	-	-	1,315.5	1,144.5
Buy Millet/Sorghum (kg)	1,434.5	1,605.5	-	-
Consume Millet/Sorghum (kg)	1,434.5	1,605.5	1,434.5	1,605.5
Sell Maize (kg)	4,688.9	4,660.4	634.0	605.5
Consume Maize (kg)	266	294.5	266	294.5
Buy Rice (kg)	152	171	152	171
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	2,818.4	2,818.4	2,571.25	2,571.25
Consume Peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	473,424	456,159	380,993	365,438

TABLE 33

Summary Table for Representative Farm III Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with the Combination of Second Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Millet/Sorghum acreage = 2.50 ha; maize = .50 ha	
	Food Level One (4a III)	Food Level Two (4b III)	Food Level One (4c III)	Food Level Two (4d III)
Peanuts (ha)	.1188	.1188	.1188	.1188
Millet/Sorghum (ha)	-	-	2.50	2.50
Maize (ha)	5.3543	5.3397	.50	.50
Rice (ha)	.1169	.1315	.1169	.1315
Cotton (ha)	0.0	0.0	2.3543	2.3397
Sell Millet/Sorghum (kg)	-	-	1,315.5	1,144.5
Buy Millet/Sorghum (kg)	1,434.5	1,605.5	-	-
Consume Millet/Sorghum (kg)	1,434.5	1,605.5	1,434.5	1,605.5
Sell Maize (kg)	9,371.7	9,316.9	634.0	605.5
Consume Maize (kg)	266	294.5	266	294.5
Buy Rice (kg)	-	-	152	171
Consume Rice (kg)	152	171	152	171
Sell Cotton (kg)	-	-	-	-
Hire in Labor Period 3 (m.d.)	15.	15.2	-	-
Consume Peanuts (kg)	142.5	142.5	142.5	142.5
Objective Function (CFA)	435,199	417,940	311,527	296,125

TABLE 34

Summary Table for Representative Farm IV Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with the Combination of Second Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Millet/Sorghum: acrbage = 1.50 ha maize = .50; rice = .45 ha	
	Food Level One (4a IV)	Food Level Two (4b IV)	Food Level One (4c IV)	Food Level Two (4d IV)
Peanuts (ha)	.1475	.1475	.1475	.1475
Millet/Sorghum (ha)	-	-	1.50	1.50
Maize (ha)	2.2316	2.2316	.50	.50
Rice (ha)	-	-	.45	.45
Cotton (ha)	4.5309	4.5309	4.3125	4.3215
Sell Peanuts (kg)	-	-	-	-
Sell Millet/Sorghum (kg)	-	-	151.4	68.8
Buy Millet/Sorghum (kg)	1,498.6	1,581.2	-	-
Consume Millet/Sorghum (kg)	1,498.6	1,581.2	1,498.6	1,581.2
Sell Maize (kg)	3,792.6	3,780.8	675.8	664.0
Consume Maize (kg)	224.2	236	224.2	236
Buy Rice (kg)	1,097.4	1,156.4	665.4	724.4
Consume Rice (kg)	1,097.4	1,156.4	1,097.4	1,156.4
Sell Cotton (kg)	5,663.6	5,663.6	5,390.6	5,390.6
Hire in Labor Period 2 (m.d.)	16.0	16.0	.69	.69
Consume Peanuts (kg)	177	177	177	177
Objective Function (CFA)	649,176	636,187	586,540	574,377

TABLE 35

Summary Table for Representative Farm V Under Two Subsistence Food Levels and Constrained by Assumed Cereal Acreages with the Combination of Second Level of Technology and a Change in the Relative Prices

Activity	Base Runs		Millet/Sorghum: acreage = 1.50 ha maize = .50; rice = .45 ha	
	Food Level One (4a V)	Food Level Two (4b V)	Food Level One (4c V)	Food Level Two (4d V)
Peanuts (ha)	.1475	.1475	.1475	.1475
Millet/Sorghum (ha)	-	-	1.50	1.50
Maize (ha)	.3901	.3901	.50	.50
Rice (ha)	-	-	.45	.45
Cotton (ha)	5.3424	5.3424	3.2825	3.2825
Sell Peanuts (kg)	-	-	-	-
Sell Millet/Sorghum (kg)	-	-	151.4	68.8
Buy Millet/Sorghum (kg)	1,498.6	1,581.2	-	-
Consume Millet/Sorghum (kg)	1,498.6	1,581.2	1,498.6	1,581.2
Sell Maize (kg)	477.9	466.1	675.8	664.0
Consume Maize (kg)	224.2	236	224.2	236
Buy Rice (kg)	1,097.4	1,156.4	692.4	751.4
Consume Rice (kg)	1,097.4	1,156.4	1,097.4	1,156.4
Sell Cotton (kg)	6,143.7	6,143.7	3,774.8	3,774.8
Hire in Labor Period 2 (m.d.)	16.0	16.0	-	-
Consume Peanuts (kg)	177	177	177	177
Objective Function (CFA)	505,212	492,222	395,434	383,271

CHAPTER VI

SUMMARY, CONCLUSIONS, POLICY IMPLICATIONS AND SUGGESTIONS FOR FURTHER RESEARCH

A. Summary

The purpose of this paper was to analyze some effects of export and food-crop strategies on farm income and food self-sufficiency at the farm level in Eastern Senegal and Upper Casamance. A linear programming analysis was carried out in order to assess the impact of alternative government policies. These included examination of changes in relative prices to increase cotton production, of increased levels of food self-sufficiency and technological change. The major strategies examined were price policy and the introduction of improved maize, cotton, peanuts and millet/sorghum technology.

The main agricultural policy objectives of the government of Senegal are increased domestic food production and increased foreign exchange earnings from export crops. A review of literature indicated that increased crop diversification could reduce the fluctutation in foreign exchange earnings and possibly increase food availability. Our main concern was to find out how increased crop diversification could be implemented without any reduction in farm income.

A linear programming approach was used to trace the effects of alternative policies and technical packages on small farmers. The base model incorporated an improved level of agricultural practices, including the use of fertilizer, animal traction mainly for plowing purposes on maize, rice and cotton, and a constraint to secure at least 80 percent or more food availability at the farm level. The effects of a change in the relative prices, the use of animal-powered seeders and weeders, and the effects of a higher level of food self-sufficiency, have been explored. Attention was focused on the effects of the changes on export production, food availability and farm income.

The data were obtained mainly from SONED and SODEFITEX throughout the paper. The areas on which the analysis was focused were identified initially by SONED and described in Chapter IV. The results are summarized below.

Under the first level of technology (which included the use of fertilizer and animal-powered plowing on maize, rice and cotton) and recent relative prices (series 1), the base runs showed a surprising dominance of maize. Since these results may have been caused by the narrow definition of the objective function (maximization of the revenues above variable costs), cereal acreage constraints were added to reflect actual practices (giving generally the priority to cereal cultivation), based on SONED estimates. The addition of the cereal acreage constraints brought a small amount of cotton into solution only in two of the five representative areas (II and IV). Under the cereal acreage constraints, peanuts had a substantial acreage share in all five areas ranging from 40 to 56 percent. Sensitivity analysis revealed that a change of 5 to 10 percent in the level of food self-sufficiency had very little influence on optimal land allocation, but decreased income by about 5 percent.

Under the second level of technology (adding to the first level the use of animal-powered seeders and weeders) and recent relative prices (series 2), the base runs showed a dominance of maize in Eastern Senegal and of cotton in Upper Casamance. There was generally no millet/sorghum in the base runs in the five areas, suggesting that farmers buy all their millet/sorghum consumption. Since this is unlikely to happen, cereal acreages constraints were again introduced to reflect the priority generally given to the cereal cultivation. Under these additional constraints, cotton generally came into solution, but at the expense of peanuts. Increasing the level of family food self-sufficiency had little effect, as in the earlier series.

Under the first level of technology and changed relative prices (series 3), cotton did not dominate the optimal plans of the base runs as might have been expected. Maize still dominated, surprisingly. Cotton did appear, however, but to a lesser extent, ranging from 2 to 16 percent. Upper Casamance showed generally a larger cotton share of land relative to Eastern Senegal.

When cereal acreage constraints were introduced, cotton did come into solution but generally received less acreage than the constrained millet/sorghum and peanuts.

Under the combination of the second level of technology and changed relative prices (series 4), cotton generally came into solution, but at the expense of millet/sorghum and peanuts. When cereal acreage constraints were added to introduce more realism, cotton still kept a substantial share of land (45 to 75 percent), but at the expense of peanuts. A higher level of food self-sufficiency changed very little the land allocation to crops and farm income.

B. Conclusions

The model showed that maize could be expected to occupy the largest share of land in all five areas, given adequate supplies of hybrid maize seed.

In all cases, there was a "cost" to keeping millet/sorghum in solution. Whether or not this cost is high with respect to what the farmer is willing to pay to secure an adequate food subsistence level is difficult to assess. The millet/sorghum acreage constraint was probably the major reason for the sharp decrease in income (in monetary terms—by 30 percent) observed between the base runs and the runs with cereal acreage constraints. Again whether or not there is a decrease in actual income terms is difficult to assess.

Surprisingly, an increase in the constraint of the family food supply beyond 80 percent of food self-sufficiency did not introduce major changes in income and crop acreage allocation. Since the analysis indicated that a moderate increase in the relative price of cotton did not make cotton the dominate enterprise, it would appear that increased cotton yield and/or reduced input costs will be required to stabilize or increase cotton production.

C. Policy Implications

Maize production could become a major means of increasing farmers' income, a means of improving nutrition in rural areas, and a savings in foreign exchange. But there are prerequisites to be tackled first. First, the existing hybrid maize seed shortage will have to be overcome.

Second, a large market outlet for maize would have to be provided in order to avoid overproduction and accumulation of unsold stocks. Third, the I.T.A. (Institut de technologie alimentaire) would have to develop the broken "maize-rice" product as a substitute (or at least a complement) for rice and perhaps millet/sorghum to the extent that it can be produced commercially.

rice and perhaps millet/sorghum to the extent that it can be produced commercially.

Cotton production has been suggested as a means of diversifying foreign exchange earnings and raising farmers' income. Despite great efforts to increase cotton cultivation, production has not increased as anticipated.[1] This analysis showed that the introduction of labor-saving equipment (such as animal-powered seeders and weeders) appeared to be a profitable way to implement increased cotton production in this area of Senegal. The main tool used to date on most crops, including cotton, has been price policy. This analysis showed that price policy above might not have a large effect on cotton if yields remain low and/or input costs high.

The objective of the paper was to analyze some effects of macro policies (export, food crop strategies) at the farm level (income, food self-sufficiency). It should be recognized that as practices change at the farm level, there will be a flow of effects, sometimes unpredictable, eventually back to the macro level. Our analysis indicated a trade-off between cotton and millet/sorghum (cash vs food

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[1]The anticipated cotton production was about 60,000 T. The maximum cotton production has been reached in the cropping season 1976/77 with 45,000 T, but the production was steadily declining since down to 20,600 T in 1980/81.

crops). If farmers increase cotton, thereby decreasing millet/sorghum in their farming system, to such an extent that overall production of millet/sorghum decreases significantly, the increase in cotton will indirectly conflict with another government policy objective, namely increasing millet/sorghum production to reduce the wheat imports used in bread production.[1] A similar trade-off might eventually occur between the potentially profitable maize and cash crops (peanuts and cotton). Many other macro level policy conflicts exist, and these will have to be considered by policy-makers. However, they remain beyond the scope of this paper.

D. Need for Further Research

The uncertainty about the quality of the data used in this paper makes it necessary to call for more research to extend the results of this preliminary analysis. A possible area for further research might be the study of relative prices, along with the appropriate technical changes, which might ease the trade-offs observed above. Additional research could be directed to the questions of labor availability (current situation and projections), improved empirical estimates of family consumption requirements, and empirical estimates of supply responses for the major crops.

Finally, it would be interesting to examine the actual practices of farmers in future years to see if the assumptions used in developing the model are validated empirically.

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[1]There is a new policy to gradually substitute domestic millet for wheat in the bread production.

APPENDICES

APPENDIX I

LABOR REQUIREMENT[1] FOR COTTON PER HECTARE IN MAN-DAYS

Labor Period	Type of Activity	Crop Technology I	Crop Technology II
I	Plowing	17	17
	Mechanical Planting	-	4
	Manual Planting	10	-
		27	21
II	Fertilizer Spreading (NPK Urea)	2	2
	First Mechanical Weeding	-	3
	First Manual Weeding	20	-
	Thinning and Weeding	24	24
	Spraying	.5	.5
		46.5	29.5
III	Second Weeding	20	8
	Spraying	1	1
		21	9
IV	Harvest	32	48
	Tearing Off and burning of Cotton Plants	20	20
		52	68
	TOTAL	146.5	127.5

SOURCE: SONED (1980).

[1]The coefficients have been adjusted to reflect the different assumed labor periods.

APPENDIX 2

LABOR REQUIREMENT[1] FOR PEANUTS PER HECTARE IN MAN-DAYS

Labor Period	Type of Activity	Crop Technology I	Crop Technology II
I	Shelling and Sorting	16	16
	Land Clearing	14	14
	Mechanical Planting	-	4
	Manual Planting	6	-
		36	34
II	First Mechanical Weeding	-	8
	First Manual Weeding	20	-
	Fertilizing (NPK)	1	1
		21	9
III	Second Mechanical Weeding	-	8
	Second Manual Weeding	20	-
		20	8
IV	Harvest	12	12
	Stacking	14	14
	Threshing and Winnowing	30	30
		56	56
	TOTAL	133	107

SOURCE: SONED (1980).

[1]The coefficients have been adjusted to reflect the different assumed labor periods.

APPENDIX 3

LABOR REQUIREMENTS[1] FOR MILLET/SORGHUM PER HECTARE IN MAN-DAYS

Labor Period	Type of Activity	Crop Technology I	Crop Technology II
I	Field Clearing	14	14
	Mechanical Planting	-	5
	Manual Planting	10	-
	First Mechanical Weeding	-	3
	First Manual Weeding	20	-
	Thinning	24	24
	Fertilizing (NPK)	1	1
		69	47
II	Second Mechanical Weeding	-	3
	Second Manual Weeding	20	-
	Fertilizing (urea)	1	1
		21	4
IV	Harvest	36	36
	Threshing and Winnowing	40	40
		76	76
	TOTAL	166	127

SOURCE: SONED (1980).

[1]The coefficients have been adjusted to reflect the different assumed labor periods.

APPENDIX 4

LABOR REQUIREMENT[1] FOR MAIZE PER HECTARE IN MAN-DAYS

Labor Period	Type of Activity	Crop Technology I	Crop Technology II
I	Plowing	12	12
	Mechanical Planting	-	4
	Manual Planting and NPK	6	-
		18	16
II	First Mechanical Weeding	-	8
	First Manual Weeding	20	-
	Thinning	-	4
	Urea	1	1
		21	13
III	Harvest	36	36
		36	36
IV	Shelling	20	20
		20	20
	TOTAL	95	85

SOURCE: SONED (1980).

[1]The coefficients have been adjusted to reflect the different assumed labor periods.

APPENDIX 5

LABOR REQUIREMENT[1] FOR RAINFED RICE PER HECTARE IN MAN-DAYS

Labor Period	Type of Activity	Crop Technology I
I	Plowing	17
	Row Planting and NPK	10
		27
II	First Weeding	16
	Fertilizing (urea)	1
		17
III	Second Weeding	16
		16
IV	Harvest	52
	Threshing and Winnowing	16
		68
	TOTAL	128

SOURCE: SONED (1980).

[1]The coefficients have been adjusted to reflect the different assumed labor periods.

APPENDIX 6

RAINFALL IN THE REGION

YEARS		Eastern Senegal			Upper Casamance		
		Koussanar	Tamba	Dialacoto	Velingara	Linkering	Kolda
1970	mm	492.5	481.7	667.5	781	872.3	
	days	35	44	40	53	58	n.a.
1971	mm	859.2	923.8	915.5	859	948.3	n.a.
	days	45	37	44	61	53	n.a.
1972	mm	456	639.3	858.4	646	754.9	n.a.
	days	32	40	41	46	46	n.a.
1973	mm	645.6	618.1	672.4	909.5	911	n.a.
	days	31	36	40	53	49	n.a.
1974	mm	905	900.8	650.2	772.2	770.9	546
	days	44	61	42	55	58	51
1975	mm	858	896.9	743.7	1141.6	1182.3	1206.4
	days	43	68	68	72	62	73
1976	mm	434.2	634.1	825.1	734.7	824.4	1124
	days	39	60	57	52	55	64
1977	mm	581.8	591.6	1009.4	668.3	787.3	672.1
	days	29	47	46	50	44	50
1978	mm	799.3	769.7	1084.1	1051.7	1067.7	769
	days	47	55	59	66	52	58
1979	mm	648.5	733.1	754.3	750	653.5	795
	days	51	55	37	56	40	54
1980	mm	518.1	469.5	577	719.2	907	523.1
	days	34	39	33	41	29	54
Mean 1961-1970	mm	809	833	802	1022	n.a.	n.a.
Mean 1971-1980		670.6	717.7	809	825	880.7	n.a.

SOURCE: SODEFITEX.

APPENDIX 7

ASSUMED YIELDS UNDER TECHNOLOGY LEVEL I

	Millet/Sorghum	Peanuts	Maize	Rice	Cotton
Household I	1013*	1000	1614	1300	800
Household II	1000	1000	1635	1300	962
Household III	977	1000	1520	1300	752
Household IV	1045	995	1560	960	1018
Household V	1100	1190	1610	900	920

SOURCE: SODEFITEX, Annual Report 1979/80.

*Corrected.

APPENDIX 8

ASSUMED YIELDS UNDER TECHNOLOGY LEVEL II

	Millet/Sorghum	Peanuts	Maize	Rice[1]	Cotton
Household I	1100	1200	1800	1300	1025
Household II	1100	1200	1800	1300	1000*
Household III	1100	1200	1800	1300	800
Household IV	1100	1200	1800	960	1400
Household V	1100	1200	1800	900	1150

SOURCE: SONED (1980).

[1]Rice assumed not yet reached by the technological improvement (use of seeder and weeder).

*Corrected.

APPENDIX 9

SHADOW PRICES AND COST OF FORCING IN NONOPTIMAL SOLUTIONS
UNDER THE RUNS 1a, 1c, 2c AND 4c IN THE FIVE AREAS

Constraints	I	II	III	IV	V
Land (1a)	10,943	53,202	50,201	58,414	62,827
Labor period 1 (1a)	--	--	--	--	--
Labor period 2 (1a)	1,972	--	--	98	--
Labor period 3 (1a)	295	300	233	--	--
Labor period 4 (1a)	--	--	--	--	--
Land (1c)	(excess .0381) 0	39,920	48,615	36,237	60,015
Millet/Sorghum acreage constraint (1c)	-16,284	-7,034	-8,184	-4,484	-13,434
Maize acreage constraint (1c)	19,800	15,387	9,982	12,162	2,812
Rice acreage constraint (1c)	54,044	45,798	44,142	22,642	3,242
Land (2c)	65,315	63,615	59,832	65,865	73,815
Millet/S. acreage constraint (2c)	-21,793	-20,093	-16,310	-24,343	-30,293
Maize acreage constraint (2c)	8,300	10,000	13,783	1,250	-200
Rice acreage constraint (2c)	--	--	--	-3,092	-7,942
Land (4c)	118,307	115,315	91,375	130,490	133,270
Millet/S. acreage constraint (4c)	-52,785	-49,793	-25,853	-66,968	-67,748
Maize acreage constraint (4c)	-10,852	-7,860	16,080	-29,535	-25,815
Rice acreage constraint (4c)	--	--	--	-62,917	-62,897

APPENDIX 10

COST OF FORCING IN NONOPTIMAL ACTIVITIES FOR RUNS 1a, 1c FOR FIVE AREAS

ACTIVITY	I	II	III	IV	V
Run "1a"					
Millet/sorghum	--	1621.0	--	6196.0	5246.0
Cotton	60711.9	329.0	10205.6	--	--
Sell peanuts	9.6	10.5	6.25	12.2	2.3
Sell millet/s	10.0	10.0	10.0	10.0	10.0
Buy maize	3.0	3.0	3.0	3.0	3.0
Sell rice	--	6.7	3.6	29.5	38.0
Buy rice	33.5	26.7	29.8	8.9	.4
Hire in labor period 1	300	300	300	300	300
Hire in labor period 2	--	500	500	401.8	500
Hire in labor period 3	4.05	--	66.7	300	300
Hire in labor period 4	300	300	300	300	300
Run "1c"					
Cotton	--	--	--	--	--
Sell peanuts	--	--	--	--	--
Buy millet/sorghum	10.0	10.0	10.0	10.0	10.0
Buy maize	3.0	3.0	3.0	3.0	3.0
Sell rice	33.5	33.5	33.5	38.5	38.5
Sell cotton	54.5	--	4.9	--	4.01
Hire in labor period 1	--	300	300	300	300
Hire in labor period 2	--	85.9	500	--	500
Hire in labor period 3	300	300	300	300	300
Hire in labor period 4	300	300	300	300	300

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