FOOD SECURITY AND COMPARATIVE ADVANTAGE IN SENEGAL: A MICRO-MACRO APPROACH

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FREDERIC MARTIN

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A MICRO-MACRO APPROACH

By

Frederic Martin

A DISSERTATION

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ABSTRACT

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By

Frederic Martin

This research analyzes food security and comparative advantage in Senegal, from both a micro and macro perspective. The subject was chosen because of the continuing debate about whether poor countries with important food deficits such as Senegal should follow comparative advantage and import food financed by export earnings, or instead support local food production to increase self-sufficiency.

The research objectives were:

1) to develop a conceptual framework for analyzing food security and comparative advantage at the farm and national levels;
2) to conduct an empirical analysis of: (a) Senegal's current and projected comparative advantage; (b) the costs associated with higher levels of cereals self-sufficiency; and (c) the key variables which stimulate or constrain cereals production.

The research methodology recognized the need for consistency

between the farmers' strategies and the government's food strategy. First, the national food supply/demand situation was analyzed. Then farm-level costs and returns were analyzed by preparing 181 crop budgets, used as the basis for 13 typical farm models. These LP models represented major production regions and incorporated micro food security constraints.

Regional cereals supply curves were estimated assuming 20%-100% increases in financial cereals producer prices. These supply curves were incorporated into an agricultural sector model, which used separable programming techniques to identify the combination of local production and trade which minimized the cost of achieving given levels of cereals self-sufficiency.

The results showed limited cereals supply response to price increases. Land for rice production is limited, and millet/sorghum remains less profitable than peanuts. Maize output increases substantially, which might create a surplus given the small demand for that cereal. Output increases more significantly when expansion of irrigated area is assumed, but irrigation development and higher producer prices are costly to government and consumers.

Raising the rice price alone (e.g., by establishing a protected regional market) has negligible effects on production, but would impose substantial costs on consumers. Aligning producer prices with economic prices would produce benefits from Senegal's current comparative advantage in peanut production, but may not be a viable long-run strategy.

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LIST OF ABBREVIATIONS

BAME	Bureau d'Analyses Macro-Economiques (part of ISRA).
CSS	Cereals self-sufficiency.
CFAF	CFA Franc (currency in Senegal).
CILSS	Comité Inter-Etats de Lutte contre la Sécheresse au Sahel.
FAO	Food and Agriculture Organization of the United Nations.
IMF	International Monetary Fund.
ISRA	Institut Sénégalais de Recherches Agricoles.
LP	Linear programming.
OECD	Organization for Economic Cooperation and Development.
SAED	Société d'Aménagement et d'Exploitation des Terres du Delta du Fleuve Sénégal et des Vallées du Fleuve Sénégal et de la Falémé.
SODEFITEX	Société pour le Développement des Fibres Textiles.
USAID	United States Agency for International Development.
WARDA	West African Rice Development Association.

CHAPTER 1

INTRODUCTION

The research presented in this thesis is an analysis of food security and comparative advantage in Senegal using both a micro perspective and a macro perspective. This topic was chosen for two reasons. First, from a disciplinary point of view, efforts have been expended in the last fifteen years to incorporate uncertainty in the analysis of comparative advantage. Since much of this work has been theoretical in nature, there is a widespread need for more empirical research. This research tries to make a contribution in this area with its attempt to add a food security perspective both at micro and macro levels to the standard comparative advantage analysis.

Second, from a policy-making point of view, there has been and still is much debate about the desirable agricultural development strategy for poor countries with important food deficits. Senegal is a good example of such a country with the government and donors relying more on ideological grounds and short term financial and political concerns than on scientific analysis to decide on the desirable strategy that Senegal should follow. This research provides policy-makers in Senegal with a better estimation of the long run costs associated with different levels of self-sufficiency and hence hopes to contribute to a better policy dialogue.

This research had the following objectives:

- To provide a conceptual framework for analyzing the interactions between food security and comparative advantage at the micro level and at the macro level;
- To elaborate a methodology for empirical analysis of the same topic;
- To illustrate the potential of this methodology by applying it to the case of Senegal, making it possible to:
  - i) determine Senegal's comparative advantage in agricultural products;
  - ii) estimate the costs associated with different levels of cereals self-sufficiency;
  - iii) provide some insights about the relative importance of key agricultural variables on several food system performance indicators;
- To draw some implications for food strategy and food policies in Senegal.

The thesis includes seven chapters, including this brief introductory chapter. Chapter 2 presents the conceptual framework developed, the review of literature and a theoretical model of food security and comparative advantage with a micro-macro approach.

Chapter 3 analyzes the food situation in Senegal mainly from a macro perspective. The evolution of cereal balances over the period 1974 to 1985 is described first, followed by an analysis of several projections of these balances made until the end of the century.

Chapter 4 switches to a micro perspective with the presentation of the crop budgets elaborated for Senegal and an analysis of the financial margins for the major crops. This provides insights on the profitability of different crops from the producer's perspective under current prices.

Chapter 5 presents the methodology used in the empirical modelling exercise. This exercise starts with a micro perspective, but ends with a macro perspective. To incorporate food security considerations at the micro level and look at their interactions with the profit objective, a number of typical farm models were built. These models were run with several output price vectors to derive cereal supply curves. These supply curves served as an interface between the micro farm models and the macro agricultural sector model. The latter model considered the trade-offs between the benefits of comparative advantage and food security.

Chapter 6 presents the results of applying this methodology to the case of Senegal. First, some interesting microeconomic results coming from the farm models are presented on the possible cereals self-sufficiency rates, the financial profitability of agriculture in various zones, and the most binding constraints. Second, the implications of three price policies on several performance indicators are analyzed: a general cereals prices increase policy, an increase in rice and wheat prices, and an economic price policy. Finally, some key policy variables affecting food system performance are identified.

The concluding chapter 7 includes a summary of findings and an analysis of several implications for food strategy and food policies in Senegal.

CHAPTER 2

CONCEPTUAL FRAMEWORK AND REVIEW OF THE LITERATURE

This research is concerned with two key concepts: food security and comparative advantage.

2.1 - The concept of food security

Food security is a vague concept which can be defined in several ways. Reutlinger and Knapp (1980) defined it as "the assurance of a minimally adequate level of food consumption" (p. 1). Alternatively, they defined food insecurity as "the probability of per capita food consumption falling below a specified level" (p. 2). Another definition given by one of the authors is that food security is "the access to a sufficient and continuous food source at all times" (Reutlinger 1984 p. 2).

Valdes (1981) defined food security as "the ability of food deficit countries, or regions or households within these countries, to meet target consumption levels on a year-to-year basis" (p. 2). Staatz (1984) defined it as "the ability of a country or a region to assure, on a continuous, long-term basis that its total population has access to a timely and reliable supply of food adequate to meet minimum nutritional needs" (p. 2). From these definitions, it is clear that food security involves three key dimensions: the time horizon, the level of aggregation and the specification of the consumption level.

2.1.1 - The time horizon

Food security can be seen as a short-run or transitory problem whereby some groups of people cannot satisfy their nutritional requirements on a temporary basis. It can also be looked at as a long-run or chronic problem when some people cannot meet their food needs on a permanent basis (Reutlinger 1984 p. 2)

The number and variety of policy instruments that the government can use to reduce food insecurity depend on the time horizon considered. In the short-run, the policy options are limited since many variables such as technology, inputs availability or food needs cannot be changed. Short-term food security policy is therefore mainly concerned with the provision of adequate storage, commercial imports and food aid.

In the long run, the range of available policy options expands. For example, the government might want to increase the average level of local food production by starting irrigation projects, or limit population growth by encouraging birth control programs. These policies aim at solving a chronic food security problem.

Most of the research conducted so far on food security has looked at short-term food security. There is an extensive literature on optimal storage policies and more recently on optimal trade policies (see Valdes (1981), Chisolm et al. (1982), Bigman (1985) for a general discussion and McIntire (1981) for a study of the Sahelian case; see

Newbery et al. (1981) and Schmitz (1984) on price stabilization stocks).

The general conclusion to be drawn from these studies is that keeping national food security stocks is rather expensive compared to trade. However, encouraging stocks at the producer level can contribute significantly to rural food security. Using food stocks to stabilize prices does not seem desirable since there are in theory alternative less expensive policy options such as insurance schemes and trading on futures markets. Price stabilization through the use of food stocks seems hardly feasible, in particular on international markets.

There has also been some research on the impact of alternative pricing policies on different performance indicators including production and consumption of important crops, foreign exchange and government budget. Two models have been built to analyze this issue in the case of Senegal: the SONED/SEMA model (SONED/SEMA 1979, 1980, 1981) and Braverman's model (Braverman et al. 1983). Even though these studies were not made in a food security perspective, they offer insights on the impact of pricing policies on short-run food security and on the suitability of different methodologies used for agricultural sector modelling.

The SONED/SEMA model was designed as a decision tool to help the government in setting the level of official producer prices for each agricultural campaign and in estimating the consequences of such prices on the public budget. The model contained two separate components: a set of producer models and a public budget model.

Senegal was divided in 15 zones and a linear programming model of production was built for each zone. The producer had to decide on the area planted in the major crops cultivated according to several possible technical modules.

Technical modules were defined as alternative input/output combinations based on different levels of input use for a given crop. Given a set of input and output prices offered by the state, the producer was assumed to maximize profits under a set of resource constraints.

The public budget model was an algebraic model which calculated the net effect on the public budget of choosing a particular price vector. Optimal food imports were calculated by subtracting the sum of the regional optimal food outputs from estimated food consumption levels.

Unit subsidies or taxes were calculated at each stage of the marketing of each product by calculating the difference between the real cost of production and the set of prices used to run the production models in each zone. Total subsidies and taxes were then calculated by multiplying the unit subsidy by the relevant optimal quantity produced or traded.

Using the model involved picking a set of producer prices, running the regional linear programming models using these prices to obtain an optimal pattern of production from the farmer's point of view, estimating the impact on the public budget and then starting again with a different set of prices until one was satisfied with the pattern of production and trade as well as with the effect on the public budget.

The SONED/SEMA model presented a number of interesting features:

- It tried to address an important issue in the eyes of the government, namely at which level should official prices be fixed, by looking at the probable implications of different sets of prices on production, trade and public finance.
- It was disaggregated at the regional level and considered explicitly the producer's interest.

However, this model had a number of limitations:

- The allocation of production between official marketing channels, the parallel market and home consumption seems to be exogenous, which restricts the value of the model;
- It was concerned exclusively with financial prices and did not consider economic prices that reflected the estimated opportunity costs of a resource or of a product;
- Farmers are not simple profit maximizers as was assumed by the model. Their other important objective is food security;
- The partition made of Senegal into 15 zones as well as the contents of some technical modules in the producer's models have been criticized by a number of ISRA researchers as being an inaccurate representation of Senegalese agriculture in the mid-eighties;
- To date, the model has not been operationalized and used by the Senegalese government.

The other model dealing indirectly with short-term food security issues has been developed by a team of economists from the World Bank headed by Braverman (Braverman et al. 1983). The objective of the model was to assess the effects of agricultural pricing policies in

Senegal on the government budget, foreign exchange, real income disaggregated by region, and the production and consumption of important crops.

The model was based on the multimarket analysis framework, which simulates the behavior of several key markets and their interactions. This approach has been advocated by Braverman and his colleagues as a good compromise between overly simplistic partial equilibrium models and very complex general equilibrium models.

The model for Senegal divided the country in four regions and included the markets for major food and cash crops. Each region was endowed with a fixed supply of land and labor while other agricultural inputs had an elastic supply. Domestic crop production was modelled using translog restricted profit functions as in Lau (1976). The demand side was modelled using an Almost Ideal Demand System as in Deaton et al. (1980).

Braverman et al. analyzed the effects of several changes in official prices of major agricultural inputs and outputs on several policy objectives. In particular, they looked at the trade-offs between several policy objectives, e.g., between increased government net revenues and lower food consumption by the poor as a result of an increase in the consumer price of rice. They also incorporated uncertainty in yields and producer prices and showed the well-known trade-off between the level and the variability of producer's income.

Their approach presented a number of advantages:

- A good representation of key market interactions;
- A quantification of the trade-offs between different policy

objectives;

- A model based on microeconomic foundations with profit-maximizing producers and utility-maximizing consumers;
- The attempt to incorporate uncertainty.

This model had also a number of limitations:

- A number of its results and hence policy conclusions could have been at least roughly estimated;
- The policy contribution of the model was primarily its quantification of important trade-offs between several government objectives. However, the lack of adequate data in Senegal, in particular on the demand side, raises questions about the validity of the parameters used in the rather sophisticated demand and supply functions. Thus, the precise quantification of trade-offs among policy objectives must be interpreted cautiously;
- The level of regional and technological aggregation was too high, which led to questionable conclusions. For example, the model predicted that an increase in the producer price of rice would result in a decrease in the production of cotton. This conclusion came partly from the lumping together of Casamance and Eastern Senegal.[1]

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[1]In fact, the only regions where rice and cotton are both cultivated are the Upper and the Middle Casamance. Cotton is not grown in Lower Casamance and rice is not grown in Eastern Senegal, except as a marginal crop. Even in the zones where both crops are grown, the possibilities of substitution between these two crops are very limited. Cotton is grown on the plateau as a rainfed crop while rice is mainly grown on lowland. Cotton cannot be grown on lowland. There is some rainfed rice grown on the plateau, but it is usually grown on land recently cleared from trees and bushes. Rainfed rice is a risky crop and the producer is not likely to expand much its production. The lumping together of all types of land resulted in making the

Another assumption, i.e., that the supply of agricultural inputs such as seeds, fertilizers, agricultural equipment is elastic, might be questioned, given the breakdown of the public input procurement system in 1980.

Very little has been said about the role of long-run structural changes in supply and demand in increasing food security. Labonne et al. (1978) looked at a small part of this issue for the FAO when they analyzed the input requirements of meeting the Senegalese government's objectives for rainfed agricultural production in 1980-81 and 1984-85.

They built an agricultural sector linear programming model for Senegal including five regions and several technical modules for each major crop. The objective function maximized was the gross revenue over all modules, crops and regions. Resource constraints were defined at the regional and national levels. Production objectives were considered as constraints at the regional level.

They found that the government's objectives were too optimistic, since the model had no feasible solution. This model was useful for estimating the feasibility of certain production objectives and for identifying the binding constraints to production growth.

This model also had some limitations:

- The level of aggregation was too high. All rainfed cereals were lumped together. There were only five regions which, furthermore, were administrative regions, i.e., heterogeneous zones from a physical, human and agricultural points of view;

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substitutability between the two crops appear higher than it really is.

- The optimal national pattern of production identified by the model was not necessarily consistent with the optima of the producers in each region;
- Uncertainty was not taken into account.

From a more general perspective, this model would not be very useful in analyzing the broader issue of the impact of structural changes in supply and demand on food security in the long run since it does not include irrigated crop activities and import/export activities.

Sarris (1983) is apparently the first to have tackled this issue, in his research on Egypt. He started from a general welfare optimization problem under conditions of international price and domestic production uncertainty. To reflect a food security perspective, he set the consumption bundle to be obtained either through domestic production or trade at its current level.

Assuming the country's welfare function was an exponential utility function of the net foreign exchange gains, he derived an objective function in terms of the expected value and the variance of this variable. This objective function was a quadratic function which was maximized under the standard resource constraints after dividing Egypt in three producing regions. Sarris concluded that the current pattern of production was suboptimal, and that the current area controls had a high efficiency cost.

He showed that the area of different crops should be increased depending on the level of the national aversion to foreign exchange risk. Crops that were socially profitable at low levels of risk aversion (mainly cash crops) became quite unattractive at high levels of risk aversion and gave place to subsistence crops. He also concluded that food self-sufficiency was impossible, although domestic reallocation of resources could yield substantial improvements in food security.

Some aspects of Sarris' methodology can be criticized:

- Some of his assumptions seem arbitrary, for example his use of net foreign exchange gains to approximate social welfare;
- Using actual levels of consumption as nutritional norms for food security seems too rigid and too optimistic;
- His refusal to submit his model to an empirical verification through a simulation of the current pattern of production and trade because his model was normative seems questionable and raises doubts about the validity of his conclusion that the current pattern was inefficient;
- Even if the model provided the optimal pattern of production and trade from a national point of view, it remains quite uncertain whether such a pattern was also optimal for the producers.

In spite of these criticisms, Sarris' approach to the food security issue through changes in the pattern of production and trade seems a promising one. Our research uses the same approach and focuses on identifying the variables that most affect the cost of reaching food security.

2.1.2 - The level of aggregation

The analysis can be conducted at various levels of aggregation. One can look at food security at the international, national, regional, village, household and eventually individual levels. Food security for a given group does not necessarily imply that food security is obtained for all subgroups within that group. This raises the issue of income distribution among subgroups, e.g., between urban and rural groups. It implies that a food security analysis should be as disaggregated as possible.

Most of the research so far, in particular the optimal storage literature already mentioned, has been conducted at the international and national levels. An important literature connected to the food security issue at the international level is the literature on uncertainty in international trade, although its theoretical orientation makes it less relevant for our policy-oriented research (see Helpman and Razin (1978) and Pomeroy (1979) for a review of this literature).

Our research is concerned with food security at two levels: the government level and the farmer level.

2.1.2.1 - <u>Food security for the government</u>

From a macro perspective, at least four aspects of food security are likely to be important to a government in a typical developing country:

i) The government does not want to depend on other countries to feed its population. This political objective of national independence favors a high level of food self-sufficiency. No country in the world is totally food self-sufficient, but many try to keep a high level of food self-sufficiency. This objective is a valid one. At the same time, it is useful to evaluate the economic costs associated with different levels of food self-sufficiency.

ii) The government in a typical developing country must take into account the importance of agriculture as a source of employment and of income. Agricultural activities play a critical role in food security through the production of food crops which are mainly consumed on the farm and through cash crops that generate rural income used partly to buy extra food. Even if agriculture is not very competitive on the world market, the government may foster its growth to assure the food security of a large part of the population.

iii) The government may implement a regional land management policy. Even if cultivation is not economically efficient in a region, it may feel that investment in agriculture in that region is justified by the social and political necessity of assuring food security in that part of the country, as well as contributing to national food security.

iv) The government may want to minimize fluctuations in the cost of the food bill. These fluctuations are caused by price variations and quantity variations. World prices of agricultural commodities fluctuate widely over time. Domestic prices of nontraded or little-traded agricultural products fluctuate also within a given year as a result of supply variations. Regarding quantities, the main source of uncertainty comes from domestic crop yields that fluctuate from year to year mainly as a result of variations in rainfall quantity and distribution.

In reducing the impact of this uncertainty, the government faces a dilemma in terms of food policy: variations in world prices and in yields of export crops argue for a greater level of food self-sufficiency, yet variations in cereals yields argue for a lower level of self-sufficiency. The relative importance of the price variations and the yield variations will vary by country and by crop and must be empirically estimated.

2.1.2.2 - Food security for the farmer

From the farmer's perspective, food security is likely to involve questions analogous to those at the macro level concerning the appropriate degree of self-sufficiency in production.

i) The farmer will try to produce enough cereals to meet a large share of his family needs. He will therefore plant each year a sizeable part of his land with food crops.

ii) The farmer also wants a minimum income to be able to finance purchases of complementary food and basic consumption goods. He will therefore also allocate a minimum share of his land to cash crops. This second objective may explain that a poor farmer with limited land might still grow some cash crops even though this means reduced acreage for food crops.

iii) The farmer may also want to minimize the fluctuations in the quantity of food produced and in his income. The implications of an income stabilization objective for the desired food self-sufficiency level are not clear. An often-heard argument is that the farmer would favor cash crops if their prices were effectively guaranteed by the state, as is often the government's desire in developing countries. The farmer would not cultivate cereals for sale because their price on the market fluctuates too much.

This argument is debatable. In fact, in an uncertain climatic environment in which yields fluctuate from year to year, maintaining a fixed price directly transforms yield variations into income variations. In contrast, fluctuating prices contribute to stabilizing income by counterbalancing yield fluctuations. Hence, given our current knowledge about farmer behavior, it is not clear whether the farmer will favor industrial crops or cereal crops to minimize his income variations.

Our research is disaggregated at the regional level. Thirteen zones in Senegal were identified according to physical, human and agricultural criteria. Of these thirteen zones, eleven are agricultural, one is for livestock grazing and one is urban. In each agricultural zone, a typical farm is modelled, including household food security objectives. Then an agricultural sector model is constructed, incorporating the results of the farm models, and reflecting national food security considerations.

There are several important advantages to this multilevel approach:

- *It* reconciles the micro and the macro levels of analysis. It is based on the recognition of two key economic agents with different perspectives: the farmer and the government. The key characteristics of each level of analysis in our research are presented in Table 1;

TABLE 1

MAJOR CHARACTERISTICS OF THE MICRO AND MACRO LEVELS OF ANALYSIS IN THIS RESEARCH APPLIED TO SENEGAL

Level of analysis	Economic agent	Objective function	Exogenous variables	Endogenous variables	Uncertain variables
Micro	Farmer	Maximize profits under food security constraints and resource constraints	.Producer prices .Technologies available .Input availability .Farm yields	.Hectarage for each crop .Food purchases .Food crop and cash crop sales .Choice of technology	.Domestic prices of millet, maize, cowpeas .Farm yields
Macro	Policy-maker	Minimize cost of satisfying population food needs minus the value of exports	.World prices .Short-run regional supply curves	.Producer prices .Input imports .Food imports .Level of food self-sufficiency desired	.World prices .Regional yields

NB: The proposed classification of variables as exogenous, endogenous or uncertain is only valid for the modelling exercise conducted as part of this research.

- The approach adopted provides good micro-foundations and a national optimum that is consistent with the producers' optima;
- Coefficients in the farm models are based on the technical expertise of many ISRA researchers, thus increasing the quality of the data;
- The model can be validated at the regional level by comparing the regional model's optimum pattern of production based on past prices with the observed pattern of production;
- The implications of a given policy can be examined for each region.

2.1.3 - The specification of the consumption level

In the food security literature, the consumption level used as an acceptable nutrition standard has either been the observed average consumption level or a norm defined in terms of nutritional elements. A widely used norm in the literature is the FAO norm defined in terms of calories per capita. This individual norm varies depending on the age, sex and physical activity of the person (FAO 1973 and WHO 1985).

FAO calculates an average individual norm for each country by weighting the individual norms by the relative importance of each category of population disaggregated by age, sex and physical activity. This national norm is 2380 calories for Senegal (FAO 1977).

There has been some discussion in the literature about the adequacy of defining a nutritional norm exclusively in terms of caloric needs, i.e., disregarding protein and vitamin needs. The consensus now is that a cereal diet which is adequate in terms of calories will probably also be adequate in general in terms of proteins. However, this diet might imply deficiencies in terms of vitamin A, iodine and iron (Sukhatme 1970 and Reutlinger et al. 1976).

Since we are interested in the most important components of an adequate diet for the Senegalese population, the FAO caloric norm for Senegal is adopted. Moreover, the consumption of each product is constrained to remain in an acceptable bracket to reflect food habits.

A programming approach seems appropriate for our research, both at micro and macro levels, since we are analyzing how the farmer and the government can allocate scarce resources in the most cost-effective way to achieve food security goals, in particular this nutritional norm.

This research focuses on the supply side of the food security issue, namely on the provision of a nutritionally adequate quantity of food at the minimum cost. It does not examine whether the real income of urban consumers is sufficient for them to afford a nutritionally adequate quantity of food. However, our research does consider the demand side of the food security issue at the farm level by setting appropriate constraints in the farm models:

i) Farm households must satisfy their total food needs either by producing their food or by purchasing it;

ii) Farm households must satisfy a given and significant percentage of their food needs through production of food crops.

2.2 - The concept of comparative advantage

The second key concept of this research is comparative advantage. Food security is not necessarily synonymous with a high level of food self-sufficiency. Food security can be achieved through a combination of local production and trade. Pearson et al. (1986) distinguish three alternative strategies to satisfy food security: self-sufficiency, self-reliance and import dependency.

A self-sufficiency strategy favors a level of domestic food production far above the comparative advantage level. The self-reliance strategy favors a mix of production and trade that will correspond roughly to the comparative advantage of the country. The import dependency strategy favors the import of food at concessional terms to benefit urban consumers.

This research attempts to identify the self-reliance strategy for Senegal, namely the pattern of production and trade that minimizes the cost of meeting the population's food needs minus the value of exports. It also tries to estimate the opportunity cost of a self-sufficiency strategy, which would involve greater emphasis on local cereals production.

2.2.1 - The theory of comparative advantage

The concept of comparative advantage is quite old since it dates back to Ricardo (1821) and Torrens (1815 and 1958). Focusing on technology, Ricardian theory explains patterns of specialization and trade by means of relative productivity differentials among countries (Schydlowsky 1984). A distinction is made between absolute advantage and comparative advantage.

If Senegal can produce good X at a lower cost than the rest of the world, it has an absolute advantage in the production of X. In contrast, comparative advantage involves comoaring the opportunity cost of resources used in the production of several goods. Even if Senegal has an absolute disadvantage in producing X and Y, this country will be better off producing the good in which it is the more efficient, i.e., the good with the lower opportunity cost for the domestic resources used, and trading that for the other good.

The modern Heckscher-Ohlin theory explains international trade by means of differences in relative factor abundance. It assumes identical linear homogeneous technologies in all countries.

There are two versions of the Heckscher-Ohlin theory. The "weak" version states that a country will export the good whose production is relatively intensive in the relatively abundant factor of production of the country according to the value definition of abundance. Relative factor abundance is defined then in terms of pretrade relative factor prices. If the wage/rental ratio in autarky is higher in the foreign country than in the home country, the foreign country is said to be relatively capital abundant (Ohlin 1933).

According to the "strong" version of the Heckscher-Ohlin theory, if both countries have identical technologies and identical homothetic preferences, a country will export the good whose production is relatively intensive in the factor of production in which that country is relatively abundant under the quantity definition of relative abundance. Relative factor abundance is then defined in terms of relative factor endowments. If the endowed capital/labor ratio is higher in the home country than in the foreign country, then the home country is capital abundant (Jones 1956-57).

Both the Ricardian and the Heckscher-Ohlin theories of comparative advantage are macro-oriented, deterministic and static. The research on comparative advantage so far has been macro-oriented without explicit consideration of the individual strategies of the microeconomic agents. The main originality of this research is to consider both a micro and a macro perspective and to make sure that the two are consistent.

Farmers are the ones who make the essential decision of allocating land to different crops. This is a major determinant of the production pattern. The state can affect this decision indirectly by modifying the environment of the producer, particularly in Senegal by setting a number of input and product prices.

This research considers the objective functions and the constraints of typical farmers and of the Senegalese government. The consistency between the two levels is achieved by the derivation of supply curves for agricultural products.

There have been several efforts to incorporate uncertainty into the theory of international trade (see Helpman and Razin (1978) and Pomeroy (1979) for a review of this literature). The most relevant contribution in this domain for our research is Jabara's thesis (1979) on the comparative advantage of Senegal under international price uncertainty. This study is reviewed later in this chapter.

Uncertainty pervades the food system and more generally the whole economy in a developing country like Senegal. Therefore, it seems essential to incorporate it in an analysis of comparative advantage. The food security perspective adopted by our research reflects this concern.

Few studies appear to have been done on comparative advantage in a dynamic context. It is important to be clear about the use of the word dynamic. Comparative advantage is dynamic in the sense that it changes over time. The methodology used to study dynamic comparative advantage can be comparative statics, i.e., comparing a situation at two points of time. Or the methodology can be dynamic; i.e., looking at the process of change.

Most studies fall in the first category, namely a comparative statics study of dynamic comparative advantage. Several have looked ex post at the changing nature of comparative advantage in Japan and the newly industrialized countries, in particular the "gang of 4": South Korea, Taiwan, Singapore and Hong-Kong (Balassa 1977a, 1977b, Heller 1976, Whee Rhee et al. 1984).

The only research that presents a dynamic theory of comparative advantage appears to be a study by Klein (1973). Klein incorporates a learning factor of production in the traditional production function. This learning factor consists of scientists that learn about and improve the product's production process.

Some countries such as the United States have a "learning" advantage while other countries have a "static" advantage, i.e., a comparative advantage with regard to the other factors of the production function. The total comparative advantage in the production of a particular product shifts from the first category of countries to the other category when the production process for this product is completely known.

This research is a comparative statics study of dynamic comparative advantage. However, it differs from existing studies by its food security perspective and its ex ante approach to dynamic comparative advantage. It does not try to explain past changes in comparative advantage, but attempts to analyze how Senegal's comparative advantage situation is likely to change as a result of changes in key exogenous and endogenous variables.

Comparative advantage will change over time because of changes in exogenous variables which the Senegalese government does not control. The most important exogenous variables are the world prices of agricultural inputs and products traded by Senegal as well as the share of groundnuts in the fats and oils world market.

However, a basic hypothesis of this research is that comparative advantage is not something given to the government, but rather a situation that can be modified by appropriate policies. Our analysis tries to identify the key variables that determine Senegal's pattern of production and trade and the cost of reaching food security. This will give insights on the kind of policies that would result in the biggest reductions of the cost of meeting food needs.

There are four major policy areas where changes could result in a lower cost of food security: production, marketing, consumption and international trade. The major policies in each area are briefly reviewed hereafter.

2.2.1.1 - The role of production policies

There are two possible mechanisms through which production policies can reduce the cost of food security. One is an increase in the productivity of Senegalese agriculture which reduces unit costs of production, and the other is a reduction in the uncertainty faced by the producers which makes specialization possible.

The first mechanism, a productivity increase, implies the adoption of more intensive agricultural techniques. This in turn requires a certain number of conditions to be satisfied including:

- The availability of the right quantity of the right inputs at the right time in the right place. This concerns seeds, fertilizers and agricultural equipment, credit and irrigated land with single or double crop seasons.

  In part, this involves increasing the availability of inputs, e.g., through state efforts to promote a thriving private input supply system that can satisfy farmer's needs. The state can also provide inputs with public good characteristics such as certified seeds and irrigated land through public investment.

  Improved vertical coordination in the input marketing system is also necessary. This is discussed in the marketing policies section;
- The provision of adequate extension services to increase the producer's knowledge about more intensive technical practices. This concerns primarily crops that hold the biggest growth potential in the future: corn, cotton and irrigated crops. To be effective, extension must use a bottom-up approach in which extension agents try to advise farmers at their request;
- The attractiveness of more intensive practices in the eyes of the producers. Our analysis evaluates attractiveness in both financial (farm-level) and economic (national) terms.

One production policy the government can use to improve the attractiveness of the more intensive modules is to support agronomic research on higher yielding varieties and better cultivation practices. The government can also use marketing policies to reduce the cost of inputs and increase the price of products for the producer. This issue is discussed in the marketing policies section.

The second mechanism through which production policies can reduce the cost of food security is a reduction of the uncertainty faced by the producers. Reduced uncertainty makes it possible for producers to specialize more in the production of products where they are the most efficient. There are two major uncertain variables for the producer in Senegal: farm-level yields and output prices:

- Yield uncertainty can be reduced by state support for agronomic research on drought resistant varieties and for the development of irrigated agriculture in the Senegal River Basin;
- Price uncertainty varies depending on the crop. For cash crops and for rice, the official price is generally enforced. The relevant prices for millet/sorghum, maize and cowpeas are the market prices.

The uncertainty about the official price comes from the rather arbitrary price-fixing mechanism used and the announcing of these prices after the planting time. Government policies to reduce uncertainty about official prices could involve linking the official price level with the world price level and the domestic cost of production, and announcing the new official price level before the planting time.

The uncertainty about the market price comes from the producer's lack of knowledge at planting time about the price he will receive at harvest time for most food crops. This price depends principally on the levels of output of the crop and its close substitutes, which depend mainly on rainfall.

Government policy to reduce this uncertainty could involve announcing a floor price before planting time and stepping into the market as a last-resort buyer at harvest time to guarantee this price. However, there are serious questions about the cost and long run viability of such a price stabilization scheme in Senegal (see Martin (1986) and Ouedraogo and Ndoye (1986a and 1986b) for a review of this issue).

2.2.1.2 - The role of marketing policies

There are two mechanisms through which marketing policies can reduce the cost of food security. One is to increase the productivity of the Senegalese agricultural marketing system, thus reducing unit costs of marketing. The other is to reduce traders' uncertainty, which would reduce the risk premium incorporated in the marketing margin and foster specialization in agricultural production and marketing.

Greater productivity in the marketing system can be pursued by policies in three major areas: transportation, storage and processing. Transportation policies could involve:

- Improvements in the road infrastructure. The road network of Senegal is good compared to that of neighboring countries. However, repairs of existing roads and construction of new roads in more isolated regions such as Eastern Senegal could reduce the time of transportation and increase the lifetime of trucks. The construction of a bridge over the Gambia river would reduce considerably the transportation costs from Casamance to the northern part of Senegal;
- Public support to a competitive private transportation industry. The private sector is best suited to minimize transportation costs. Its profit-seeking nature makes it very cost-conscious and results in

maximum loading of trucks and two-way hauls. The role of the state should be to encourage this sector through the suppression of pan-territorial pricing to reflect true transportation costs, and the promotion of interregional trade to favor market integration.

These transportation policies might lead to reduced transportation costs. However, it is hard to predict a priori the consequences of a reduction in transportation costs on the comparative advantage of different regions. If we take for example the case of rice, locally produced rice would become more competitive in Dakar, but imported rice would also become more competitive in rice producing regions. What is clear, however, is that transportation costs could affect significantly the comparative advantage or disadvantage of different regions to produce rice (Stryker 1978).

Storage policies could involve:

- A partial transfer to the private sector of an extensive and largely underutilized public storage capacity;
- A suppression of official price fixity over time to recognize the economic need for the trader to cover his storage costs. This fixed level could be replaced by a large price band;
- An extension program to show farmers how to reduce storage losses at their level.

Processing policies could involve:

- A transfer of the rice milling industry to the private sector to make it more efficient (Morris 1986);
- The creation of a more competitive wheat and groundnut processing industries. Right now, wheat processing is done by two private firms

that are given wheat grain quotas in fixed proportions by the state. Groundnut processing is in the hands of two public companies that do not compete with one another.

The second mechanism through which marketing policies can reduce the cost of food security is a reduction of traders' uncertainty. Two kinds of policies can play a useful role here:

- Policies that clarify the rights and the responsibilities of the traders, i.e., who has the right to buy what, from whom, when, and where? The establishment of clear and durable trade legislation would reduce considerably the uncertainty of traders and thus the provisions they must make for possible fines, bribes or even seizure of their stocks;
- Policies that enhance coordination in the agricultural system. The state has a major role to play in promoting vertical and horizontal coordination through the provision of facilitating services. Examples of such services are:
  - The collection and dissemination of regional and international market information (in particular on prices and on marketing opportunities);
  - The promotion of standard grades and measures;
  - The promotion of contracts between producers and traders or between traders;
  - The provision of export insurance.

Whee-Rhee et al. (1984) showed that the public provision of facilitating services was a key factor in South Korea's impressive growth record.

2.2.1.3 - The role of consumption policies

There are two major mechanisms through which consumption policies can reduce the cost of food security. One is a change in food habits and the other is a reduction in population growth to curb the growth of food needs in the future.

A change of food habits will result in a lower food bill if the population reorients its consumption toward cheaper food products. Several policies can be used to modify food habits such as advertising and nutritional education campaigns, and adequate processing and packaging of the advertised products. In any case, food habits are slow to change and respond primarily to the relative price of each food product.

The second mechanism through which consumption policies can reduce the cost of food security is a reduction in population growth. The major policy in that area is the promotion of birth control. This can only be a very long-run endeavour because of the sociological and psychological resistances to birth control in Senegal. Even if accepted and put into effect, birth control would have an impact on the level of food needs only in the very long run because of demographic momentum. At an even longer time horizon, the reduction of the population will also reduce the size of the labor force.

2.2.1.4 - The role of international trade policies

Senegal is a small country and a price-taker on all world markets where it is present. It is directly subject to world price fluctuations on the import side and on the export side. Furthermore, this country belongs to the French Franc zone which means it has no control over the value of its currency, the CFA Franc being pegged to the French Franc. This increases even more the fluctuations of world prices expressed in domestic currency.

There are no futures markets in the products traded by Senegal which could be used to protect this country from uncertainty in world prices (see Gordon and Rausser (1984), Lewis and Fry (1984), Thompson and Bond (1987) for an analysis of this trade policy). However, the Senegalese government can try to reduce world price uncertainty by negotiating long-term contracts with major suppliers and customers.

The government also wants to protect the domestic market from too much price variation and has set up a parastatal in charge of absorbing the positive or negative differences between the world price and the domestic price. Too much isolation from world markets can lead to gross inefficiencies and a huge deficit for the parastatal, but too much variation in domestic prices is politically unacceptable and increases uncertainty for all economic agents.

To conclude this presentation of policies that can potentially change Senegal's comparative advantage and reduce the cost of food security, it seems clear that a number of these policies are related and must be consistent with one another to be effective. For example, it does not make sense to increase the productivity of a particular crop and thus probably its production if the marketing system is not ready to market the extra output and if there is no domestic or international demand for it.

2.2.2 - The empirical analysis of comparative advantage

A number of methods have been proposed to analyze comparative advantage. They fall into three broad groups: the Hecksher-Ohlin theory tests, the revealed comparative advantage methods and the comparative costs methods.

The Hecksher-Ohlin theory has been tested empirically by three different kind of studies (Leamer 1984). The first set of studies consists of factor content studies which take measures of trade and factor intensities and infer from them the factor abundance. The best known study in that category is by Leontieff (1953) who found that American imports were more capital intensive than American exports. He interpreted this result to mean that the United States was scarce in capital compared with labor. This famous Leontieff's paradox spawned an enormous literature.

The second kind of studies consists of cross-commodity studies of trade and input intensities. These studies also measure trade and factor intensities to infer factor abundance in the same way as the first set of studies, but they use regression of net exports on factor input intensities (Baldwin 1971, Branson et al. 1977, Harkness 1978).

The third kind of studies consists of cross-country studies of trade and resource endowments which use data on trade and endowments and infer trade intensities. They regress net exports across countries on measures of factor endowments (Leamer 1974, 1984, Chenery and Syrquin 1975).

The second group of methods used to analyze comparative advantage consists of the revealed comparative advantage methods. They attempt to determine comparative advantage on the basis of actual trade flows (Balassa 1977b, Vollrath 1985). A number of them use the export share measure of revealed comparative advantage that entails dividing the share of a country's exports in world trade of a given commodity by the country's share of the total world trade.

A basic problem with these methods is that a number of trade barriers affect trade flows, in particular tariffs, quotas, licences and subsidies. It has been suggested to work with export data, which have fewer distortions than import data (Hillman 1980).

The third group of methods consists of comparative costs methods. Two methods have been used. The first method is a partial equilibrium approach and uses concepts of net social profitability, resource cost ratio and domestic resource cost.

The net social profitability of an activity is the difference between the value of the outputs and the value of the inputs used. Both values are calculated using shadow prices expressed in terms of border prices.

The resource cost ratio of an activity is the ratio of the value of inputs used over the value added by the activity. Both values are calculated using shadow prices expressed in terms of border prices. The domestic cost ratio is the same as the resource cost ratio except that the value of inputs (the numerator) is calculated using shadow prices expressed in terms of local currency.

An activity is considered efficient, or alternatively a country is considered to have a comparative advantage in an activity, if one of the three conditions listed below is satisfied:

- Its net social profitability is greater than or equal to zero;
- Its resource cost ratio is smaller than or equal to one;
- Its resource cost ratio is smaller than or equal to the shadow exchange rate of its currency.

This methodology has been applied to the case of rice in Senegal by a Stanford/WARDA project. Tuluy (1978, 1979), Pearson et al. (1981) and Craven (1982) showed that rice production was inefficient in Senegal under the price and production conditions of the mid-seventies. However, some activities such as upland animal traction and improved manual swamp cultivation in the Casamance as well as manual irrigated production in the Senegal river basin would have entailed relatively small social losses. Moreover, some activities had a positive social profitability at the farm level.

The authors pointed out one major reason for this inefficiency in rice production, namely the remoteness of the producing areas (Casamance and the Senegal River Basin) from the most important consuming area (Dakar) which adds high transportation costs to the local costs of production. Rice production might still be considered desirable if other objectives are considered such as an increased security in food production and a better regional distribution of income.

The Stanford/WARDA study brought important empirical insights about the efficiency of rice production in the Senegal. However, the partial equilibrium methodology used does not provide the policy-maker with a global view of the interactions between major input and output markets. Also the study based its conclusions on data from the mid-seventies. Rice production conditions are changing considerably in the Senegal River Basin with:

- The restructuring of SAED (the parastatal involved in rice production and marketing in this region);
- The completion of two major dams on the Senegal river which make generalized double cropping technically possible;
- The increased experience of Senegalese farmers in rice production.

Thus, the study's conclusions need to be periodically reevaluated.

The second comparative costs method is to build a model of the agricultural sector to find the optimal pattern of production and trade. Jabara (1979) built such a model for Senegal using linear programming. Her objective was to look at the impact of the introduction of uncertainty on comparative advantage.

Her model incorporated production, processing, domestic and international trade and demand activities for six major products in six regions. Following Duloy et al. (1975), the model's objective function was to maximize the sum of consumer and producer surpluses to obtain competitive equilibrium prices. Moreover, the objective function included a penalty for trade risk, which was modelled following a MOTAD (Minimization Of Total Absolute Deviation) specification (see Hazell (1971) and Hazell et al. (1974) for a review of this specification).

Jabara found that under certainty conditions, Senegal had a comparative advantage in peanut production and a comparative disadvantage in cereals production. With uncertainty in international prices and in domestic export production, the production of cereals increased at the expense of peanuts. With risk in domestic production of import substitutes as well as the above mentioned sources of uncertainty, the pattern of comparative advantage was not clear and depended on the relative weights associated with the various sources of uncertainty.

Jabara's methodology presented a certain number of advantages:

- It took into account the interdependence of major agricultural input and output markets;
- It took into account the demand side and calculated competitive equilibrium prices;
- It tried to incorporate the effect of uncertainty on comparative advantage.

However, the model presented a certain number of limitations:

- Its results were not very conclusive. To conclude that uncertainty associated with international prices and domestic production of export crops favors domestic cereals production seems reasonable enough and might not require the elaboration of an agricultural sector model. Moreover, the design of the model seems to lead inevitably to the result obtained, given the penalty on uncertain trade activities in the objective function.

  The more interesting and realistic case is when all sources of uncertainty are acknowledged, including uncertainty in the domestic production of import substitutes. In this case, the model did not give a clear answer.
- Jabara considered production as an uncertain variable, which is true from the government's perspective, but not completely true from the producer's perspective. The level of production is a function of the

yield (an uncertain variable for the producer) and the area cultivated (a decision variable controlled by the farmer). One needs to distinguish between sources of uncertainty at the producer level and at the government level. Jabara also ignored the uncertainty for the government and for the producer about market prices;

- No farm survey data were available to build the model. Input/output coefficients were taken from various secondary sources. Available data on the demand side is limited and not very reliable in Senegal. No sensitivity analysis was conducted on the demand parameters, costs of production or international prices. This raises questions about the empirical validity of the optimal pattern of production and trade derived from the model.

Finally, since the analysis was based on data from the mid-seventies, it should be updated to take into account changes in the domestic and the international economies during the last ten years.

Out of all the methodologies which can be used to measure comparative advantage, the agricultural sector modelling methodology was selected since:

- It provides a global view of comparative advantage;
- It is suitable for the simulation of different policies.

There are some difficulties in estimating comparative advantage empirically using comparative costs methods. The theory assumes an accurate estimation of national costs of production and of the world price for the product under consideration. This is far from easy, however.

Rainfed cultivation in many developing countries, especially in

Africa, does not use purchased inputs and agricultural equipment intensively. The main factor of production is labor. As a result, the cost of production under rainfed conditions depends significantly on the value given to labor.

Agricultural wage labor is not extensively used in many countries. This reduces the validity of the agricultural wage as the basis for valuing labor. Another method is to value labor according to the average net margin per man-day of on-farm labor, calculated from crop budgets.[1] Still another method is to value labor at its shadow price estimated in a linear programming farm model. Whatever the method adopted, one must be cautious in the analysis of costs of production for rainfed agriculture.

The cost of production in irrigated agriculture is also hard to estimate. Should the initial investment required to create the irrigated infrastructure as well as the cost of foreign technical assistance be included in the cost of production? A priori, it seems reasonable to decide that past investments are sunk costs and, therefore, should not be counted as costs of production. However, future planned investments and recurrent costs on existing irrigated perimeters should be considered as costs.

Foreign technical assistance should not be counted if it is a gift to the country or if it is a very long-term loan with very little chance of being ever paid back. However, if the country is paying for some of the cost of living of the foreign experts such as housing,

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[1]After deduction of all other costs than family labor.

these expenses should probably be considered as part of the cost of production.

Whatever the method adopted, the inclusion or the exclusion of these costs will influence the total cost of production significantly, given their magnitude. Therefore, the cost of irrigated cultivation is also subject to alternative estimates.

One must also be cautious when selecting world prices for the analysis. First, these prices fluctuate over time and it is not always easy to know which reference level to use.

Second, the economic significance of world prices can sometimes be questioned, in particular for cereals. The United States and the European Community compete vigorously in the world cereals market, using direct and indirect subsidies to lure potential buyers. As a result, the export price falls well below the real cost of production in Europe or in the United States.

This benefits food deficit countries in the short run since it lowers the opportunity cost of obtaining cereals. However, a comparative advantage analysis should take a longer-run view, asking whether current world prices are likely to be maintained over a significant period. If this is not certain, then local production will be more attractive relative to imports.

In this regard, the world price of broken rice possesses some special characteristics. Only 4% of the world production of rice is traded in the world market.[1] Therefore, the world price of rice is

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[1]Siamwalla and Haykin (1983), p.13.

set in a residual market that does not necessarily reflect the costs of production in Asian countries.

This phenomena is all the more important since Senegal imports 100% broken rice, which is a by-product of paddy rice processing. The world market for broken rice is even narrower than the market for whole-grain rice.

2.3 - Other important aspects

Three other aspects are important in this research: food habits, the budgetary implications and the foreign exchange implications of alternative food strategies.

Food habits constrain food policy options in the short to the medium run. In the long run, one can expect food preferences to be open to change.

The budgetary implications of alternative food strategies are hard to estimate in detail. However, it is important to try to come up with an estimate of the rough impact of different strategies on the national budget. Most developing countries experience high budget deficits and try to limit their expenses.

Food strategies aiming at increasing the level of food self-sufficiency through increases of the producer prices of food crops imply corresponding increases in the consumer prices of food and/or subsidies from the state. It is interesting to estimate empirically the amount of subsidies corresponding to different levels of producer prices that would be required to avoid any increase in consumer prices.

A food strategy oriented toward more food self-sufficiency would also mean more investment. Estimating the amount of investment required to reach a certain level of food self-sufficiency is also a parameter of interest for the decision-maker.

Apart from the budget implications, the impact of different food strategies on foreign exchange needs to be considered. A strategy oriented toward more food self-sufficiency will probably result in reduced food imports. However, a higher rate of food self-sufficiency usually means less land allocated to export crops, a smaller production of export crops, and reduced export revenues. Also, higher food production might require the use of foreign exchange-intensive inputs such as chemicals, equipment, and fuel. The question of the net foreign exchange savings of a food self-sufficiency strategy is thus an empirical issue.

2.4 - A theoretical model of food security and comparative advantage

The theoretical model proposed consists of two models: a farmer model at the microeconomic level, and a policy-maker model at the macroeconomic level. Both models have a similar structure.

2.4.1 - The farmer model

2.4.1.1 - Graphical analysis

The farmer can produce two crops: one cash crop (X) and one food crop (Y). Let us make the following definitions:

F : Food needs of the farmer's household (in kilos).

N : Average level of food crop production desired by the farmer which covers a high share of the household's food needs.

M : Minimum level of food crop production desired by the farmer which covers a minimum share of the household's food needs.

P : Ratio of the cash crop price over the food crop price

(P_X/P_Y). P_X and P_Y are farm gate prices.

c : Consumption index.

p : Production index.

The farmer can adopt different strategies which correspond to different utility functions and to different shapes of indifference curves. Two strategies are considered here: an income maximization strategy and a food security strategy.

- The income maximization strategy

The income maximization strategy follows the standard neoclassical model of production and trade under certainty. The farmer's utility function has two arguments: $u = u(X_c, Y_c)$. The utility function is unique and continuous in the space defined by the three dimensions X, Y and u (see Figure 1). The corresponding indifference curves in the plane (X,Y) are continuous and monotonic, with the first two derivatives being negative.

If the farmer cares only about maximizing his income, his optimal strategy, given the production frontier ab and the price ratio P as drawn on Figure 2, is to specialize in the production of the cash crop X. The farmer produces X_3 and Y_1. Then he trades $X_3 - X_2$ to buy $Y_3 - Y_1$, so that he can consume X_2 and Y_3. The production point (B) and the consumption point (C) can be separated thanks to trade (see Figure 2).

Without the possibility of trade, the farmer is at A. He produces and consumes X_1 and Y_2. Point C is on a higher indifference curve (u_1) than point A (u_0) and so the farmer is better off when trade is possible.

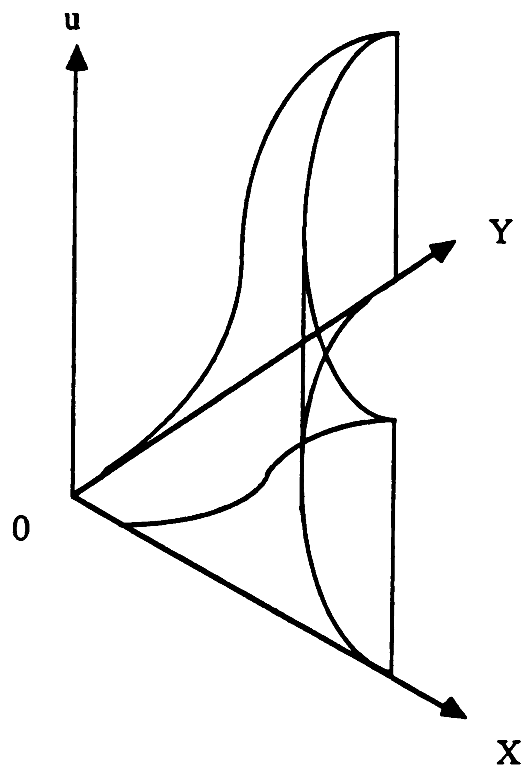

FIGURE 1

UTILITY FUNCTION FOR THE PROFIT MAXIMIZING FARMER

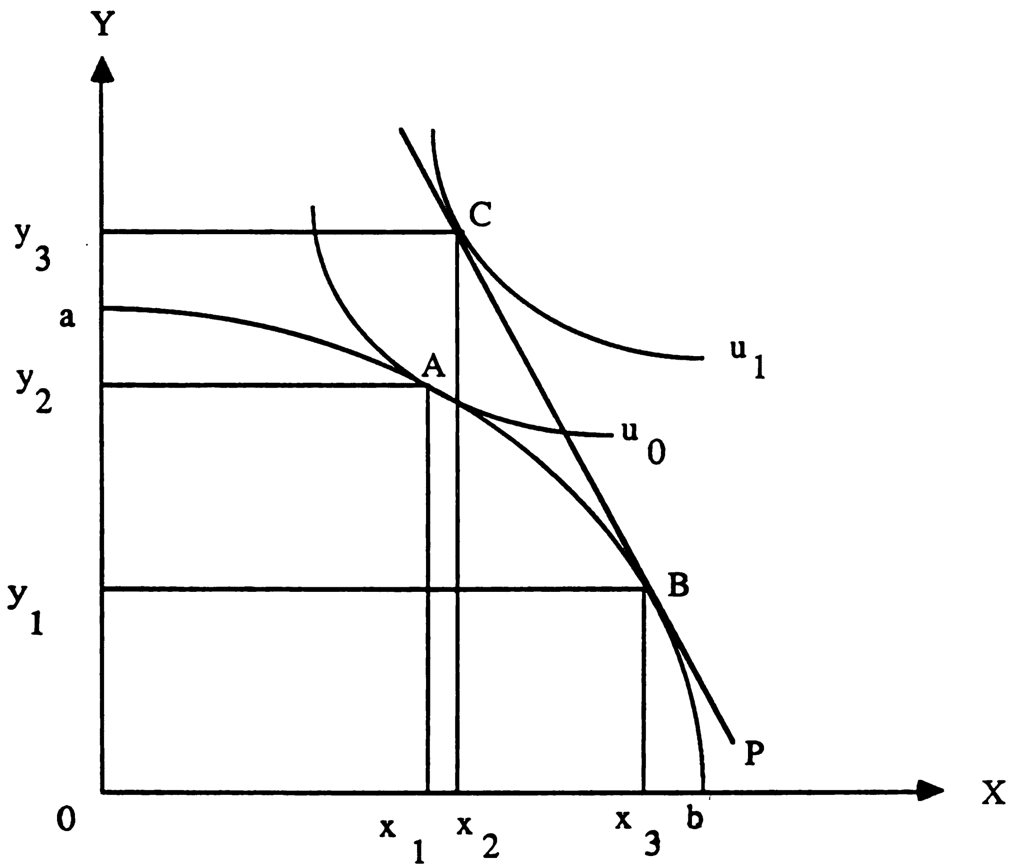

FIGURE 2

OPTIMUM PRODUCTION, CONSUMPTION AND TRADE

FOR THE PROFIT MAXIMIZING FARMER

- The food security strategy

The farmer's utility function has three arguments: $w = w(X_c,Y_c,Y_p)$. The utility function is different when $Y_p > N$ and when $Y_p \leq N$, which creates a discontinuity at $Y_p = N$. Indifference curves are also discontinuous at that level.

For $Y_p > N$, the utility function is as in the income maximization case: $w = u(X_c,Y_c)$. For $Y_p \leq N$, the utility function is $w = u(X_c,Y_c) * H(Y_p)$ where $H(Y_p)$ is a function as drawn in Figure 3.

The slope of the indifference curves are much flatter when $Y_p \leq N$, reflecting the very high value given to food production below N. The indifference curves are asymptotical to the M horizontal line, reflecting the fact that the farmer wants absolutely to produce a minimum M of product Y (see Figures 4 and 5).

The farmer can reach complete food self-sufficiency at E, which lies on the w_0 indifference curve (Figure 5). However, with the indifference curves as drawn in Figure 5, the highest indifference curve the farmer can reach, while staying on the production possibility curve, is w_1 at point G. It is worth pointing out that the production solution is invariant to any reasonable range of price ratio P as long as $Y_p \leq N$.

Then the farmer sells $X_6 - X_5$ to buy $Y_4 - N$. The farmer's household consumes at H on indifference curve w_2 and its food needs are satisfied since $Y_4 > F$.

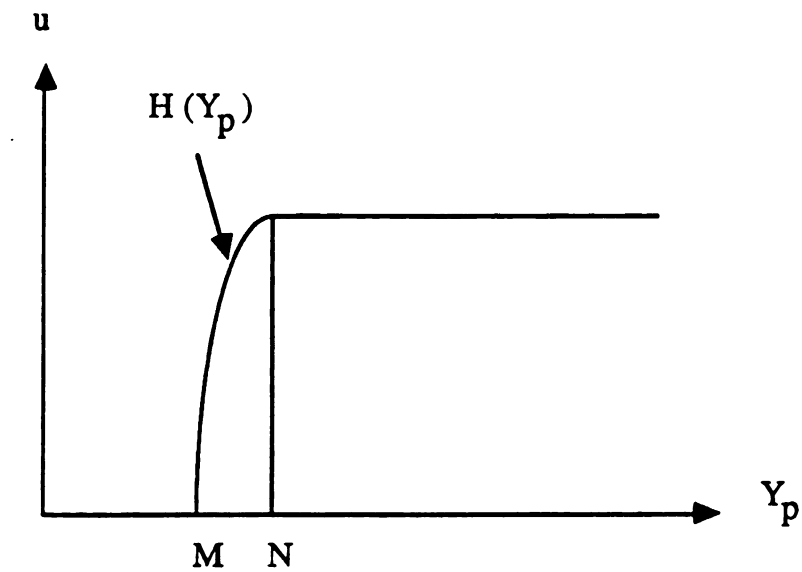

FIGURE 3

UTILITY FUNCTION AND LEVEL OF PRODUCTION OF THE FOOD PRODUCT

FOR THE FARMER CONCERNED WITH FOOD SECURITY

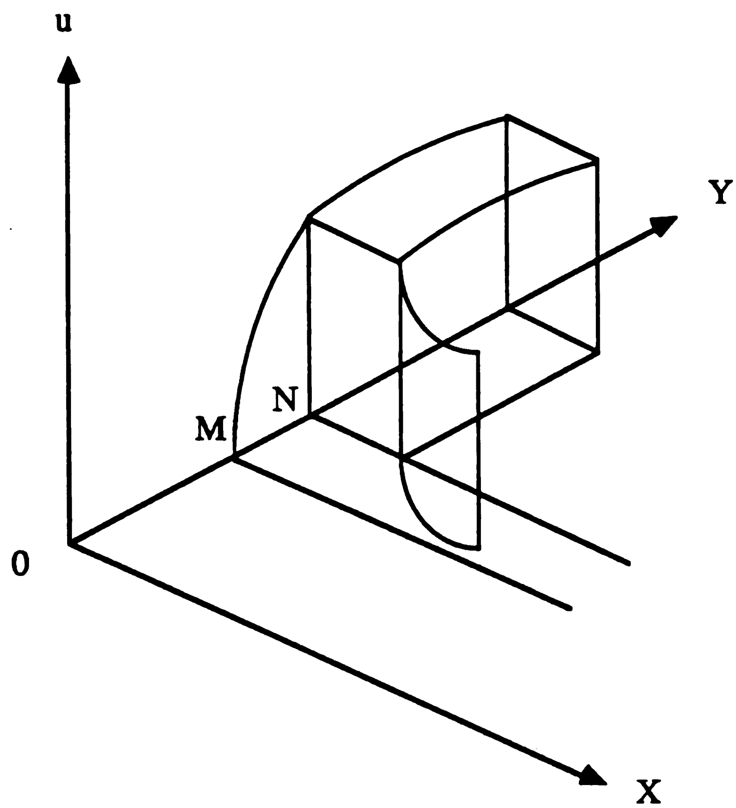

FIGURE 4

UTILITY FUNCTION FOR THE FARMER CONCERNED WITH FOOD SECURITY

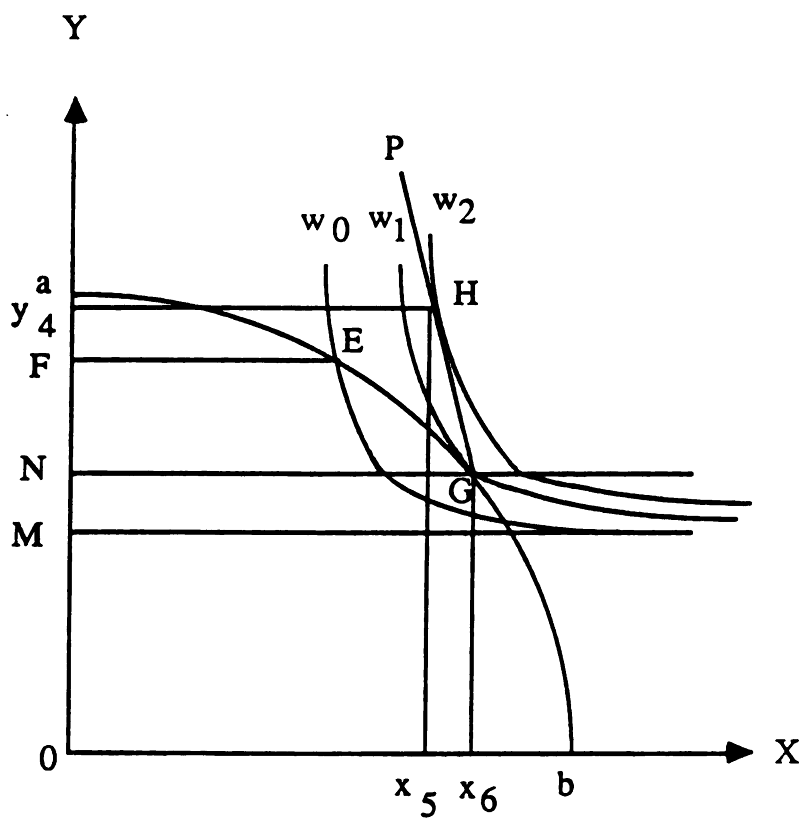

FIGURE 5

OPTIMUM PRODUCTION, CONSUMPTION AND TRADE

FOR THE FARMER CONCERNED WITH FOOD SECURITY

2.4.1.2 - Mathematical analysis

Let us describe successively the income maximization strategy and the food security strategy.

- The income maximization strategy

The formulation presented for this strategy is similar to the one used by Jabara (1979 pp. 23-26) for a national model of production and trade.

Let us make the following definitions:

X : One cash crop;

Y : One food crop;

$Y_p = f(X_p)$ production possibility curve with $f_1 < 0$ and $f_{11} < 0$;

c : Quantity consumed index;

p : Quantity produced index;

s : Quantity sold index;

P : Ratio of prices P_X / P_Y;

Then $X_c = X_p - X_s$

$Y_c = Y_p + P X_s$

$u = u(X_c, Y_c)$: Utility function of the farmer

"del" means partial derivative.

The unknowns are X_p and X_s.

The first-order conditions for utility maximization are:

$$(1) \quad \frac{\text{del } u}{\text{del } X_p} = \frac{\text{del } u}{\text{del } X_c} + \frac{\text{del } u}{\text{del } Y_c} \frac{\text{del } Y_p}{\text{del } X_p}$$

$$= u_1 + u_2 f_1$$

$$= 0$$

(2) $$\frac{\text{del } u}{\text{del } X_s} = \frac{\text{del } u}{\text{del } X_c}\frac{\text{del } X_c}{\text{del } X_s} + \frac{\text{del } u}{\text{del } Y_c}\frac{\text{del } Y_c}{\text{del } X_s}$$

$$= - u_1 + u_2 P$$

$$= 0$$

From (1), we obtain:

$$\frac{u_1}{u_2} = - f_1$$

From (2), we obtain:

$$\frac{u_1}{u_2} = P$$

$$=> P = - f_1$$

The marginal revenue of a unit of X is equal to the marginal cost of this unit. This solution corresponds to the graphical optimum at B on Figure 2.

- <u>The food security strategy</u>

The difference with the previous case is the specification of the utility function:

$$w (X_c,Y_c,Y_p) = u (X_c,Y_c) \text{ when } Y_p > N$$

$$= u (X_c,Y_c) * H(Y_p) \text{ when } Y_p \le N$$

where $H(Y_p) = - a Y_p^2 + b Y_p + c$

We want $H'(N) = 0$ and $H(M) = 0$ (see Figure 3)

So $- 2aN + b = 0 => b = 2aN$

and $c = aM^2 - bM = aM^2 - 2aNM$

Then $H(Y_p) = - aY_p^2 + 2aNY_p + aM^2 - 2aNM$

Without loss of generality, we can set a = 1.

Then $H(Y_p) = -Y_p^2 + 2NY_p + M^2 - 2NM$

When $Y_p > N$, we have the same solution as in the income maximization strategy. When $Y_p \le N$, W is maximized with respect to X_p, X_s and Y_p:

$$(1)\quad \frac{\text{del } w}{\text{del } X_p} = \frac{\text{del } u}{\text{del } X_c} H(Y_p) + \frac{\text{del } u}{\text{del } Y_c}\,\frac{\text{del } Y_p}{\text{del } X_p} H(Y_p) + \frac{\text{del } H(Y_p)}{\text{del } Y_p}\,\frac{\text{del } Y_p}{\text{del } X_p}\, u$$

$$= u_1\, H(Y_p) + u_2\, H(Y_p) + \frac{\text{del } H(Y_p)}{\text{del } Y_p} f_1\, u$$

$$= 0$$

$$(2)\quad \frac{\text{del } w}{\text{del } X_s} = \frac{\text{del } u}{\text{del } X_c}\,\frac{\text{del } X_c}{\text{del } X_s} H(Y_p) + \frac{\text{del } u}{\text{del } Y_c}\,\frac{\text{del } Y_c}{\text{del } X_s} H(Y_p)$$

$$+ \frac{\text{del } H(Y_p)}{\text{del } Y_p}\,\frac{\text{del } Y_p}{\text{del } X_s}\, u$$

$$= u_1\, H(y_p) + u_2\, P\, H(Y_p) + \frac{\text{del } H(Y_p)}{\text{del } Y_p} (-P)\, u$$

$$= 0$$

$$(3)\quad \frac{\text{del } w}{\text{del } Y_p} = u\,(-2Y_p + 2N)$$

$$= 0$$

From (3), we obtain:

$Y_p = N \Rightarrow H(Y_p) = 0$

Replacing in (1) and (2), we have

$$\frac{\text{del } w}{\text{del } X_p} = 0 \text{ and } \frac{\text{del } w}{\text{del } X_s} = 0$$

The farmer produces N of Y and $f^{-1}(N)$ of X which corresponds to point G on Figure 5.

2.4.2 - The policy-maker model

The policy-maker model is the farmer model transposed at the macro level. Therefore, we will only present the graphical model.

Let us make the following definitions:

X : One cash crop

Y : One food crop

AB : The production possibility curve of the country

T : The food needs of the country

P_w : Ratio of the cash crop price over the food crop price

P_{Xw} / P_{Yw}. P_{Xw} and P_{Yw} are border prices.

As in the farmer's case, we will consider two strategies: an income maximization strategy and a food security strategy.

- The income maximization strategy

This is the standard neoclassical model of production and trade under certainty. Given the production frontier AB and the world price ratio P_w as drawn on Figure 6, the decision-maker will transmit P_w to the producers so that the country produces X_3 and Y_1.

Then, $X_3 - X_2$ is exported to import $Y_3 - Y_1$. The country consumes at point E which puts it on indifference curve U_1. This solution is preferable to autarky (point C on indifference curve U_0).

- The food security strategy

If the decision-makers want to achieve a minimum rate of food self-sufficiency as part of a food security strategy, they would like the country to be at G on the production frontier (Figure 7). To reach

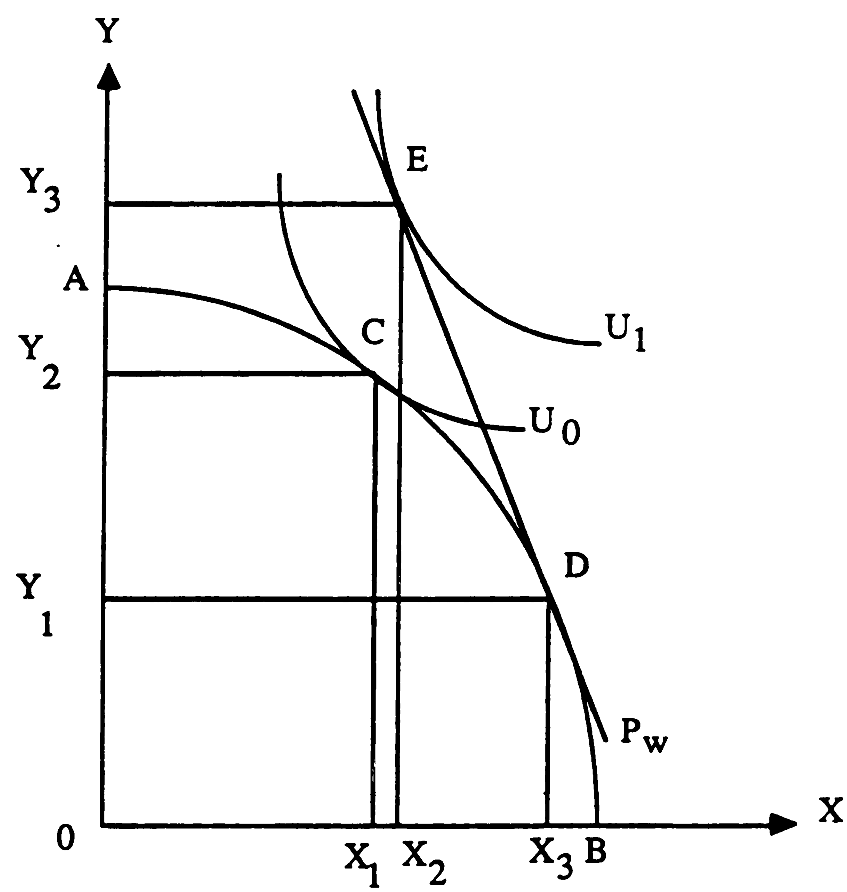

FIGURE 6

OPTIMUM PRODUCTION, CONSUMPTION AND TRADE FOR THE COUNTRY

WHOSE GOVERNMENT IS CONCERNED WITH INCOME MAXIMIZATION

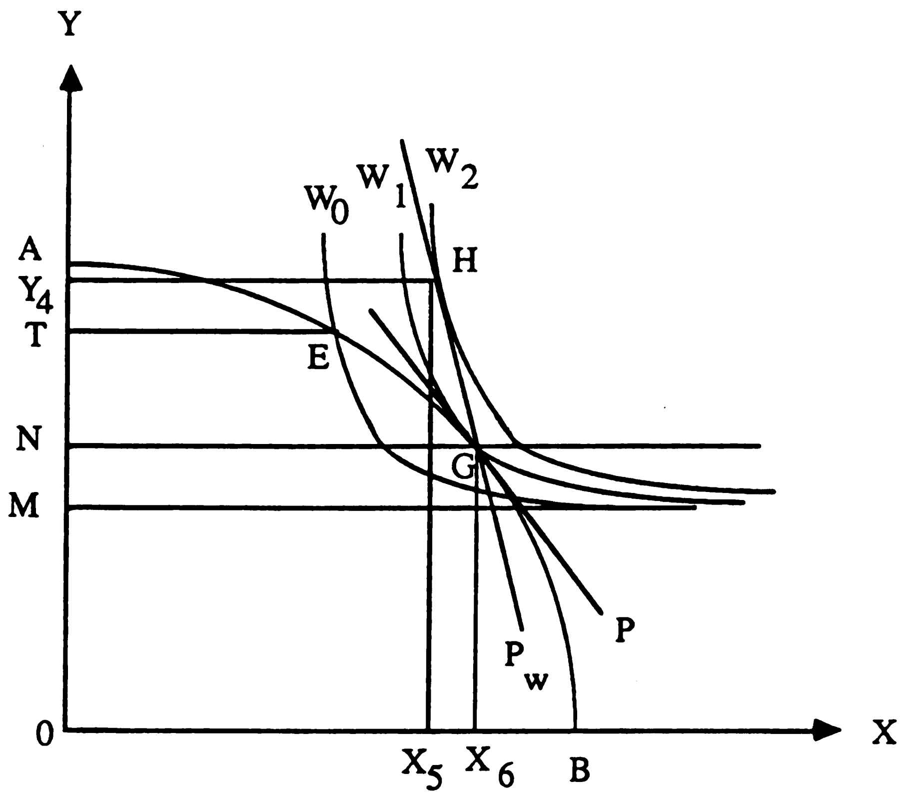

FIGURE 7

OPTIMUM PRODUCTION, CONSUMPTION AND TRADE FOR THE COUNTRY

WHOSE GOVERNMENT IS CONCERNED WITH FOOD SECURITY that objective, they have to offer P to the producer rather than P_w. P is smaller than P_w in absolute value, i.e., the relative price of the food product must be increased.

The country then exports $X_6 - X_5$ to import $Y_4 - M$. It consumes X_5 and Y_4 (point H). The decision-makers are sure there is enough food to meet the food needs of the population since $Y_4 > T$.

To review this chapter, a conceptual framework was proposed, based on a micro-macro approach to food security and comparative advantage. The relevant literature was reviewed at the same time. A theoretical model was presented to illustrate the relations between the key variables of the conceptual framework. The next chapters present the empirical part of the research. This starts with an analysis of the food situation in Senegal in Chapter 3.

CHAPTER 3

ANALYSIS OF THE FOOD SITUATION IN SENEGAL

The food situation in Senegal is analyzed using the five key concepts identified in the previous chapter: food security, comparative advantage, food habits, the budget implications and the foreign exchange implications. In this chapter, only secondary data are used. Their quality is sometimes less than desirable, in particular regarding consumption. Therefore, the general magnitudes of the data presented are more reliable than the specific numeric estimates.

3.1 - Food security

Food security in Senegal is analyzed, first, from the policy-maker's perspective and, secondly, from the farmer's perspective.

3.1.1 - Food security for the Senegalese government

As mentioned in the previous chapter, there are four aspects of food security likely to be important to the Senegalese government: the level of food self-sufficiency, the importance of the agricultural sector, the regional land management policy and the variations in the food bill.

3.1.1.1 - The level of cereals self-sufficiency

The position of the Senegalese government has changed recently regarding this issue. Since well before independence, Senegal has followed a strategy based on specialization in the production and the export of groundnut products, which pay for the import of Asian broken rice to feed its population. This strategy was questioned for the first time in 1977 in the Food Investment Plan published by the Ministry of Rural Development. This plan called for a voluntary policy of substitution of local cereals for imported cereals, but the policy was never put into effect.

More serious modification of the specialization strategy occurred in 1984 with the definition of a New Agricultural Policy, in 1985 with the publication of the Seventh Plan of Development, and in 1986 with the elaboration of a Cereals Plan (Ministère du Développement Rural 1986). In these documents, the government set a goal of 80% food self-sufficiency by the year 2000, implying a shift of priority from industrial crops to cereal crops.

It is not really clear what is meant by food self-sufficiency. We will interpret it as meaning cereals self-sufficiency, given the importance of cereals in Senegalese consumption.[1] We will also use data for milled quantities of cereals rather than for unmilled

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[1]According to surveys conducted by the "Organisme de Recherche sur l'Alimentation et la Nutrition en Afrique Noire" (ORANA), in 1978-81, annual per capita cereal consumption made up on average 57.8% of total calories consumed and 50.3% of total protein consumed in urban areas, and 60.3% of the calories and 49.4% of the protein consumed in rural areas (Secrétariat Chargé de la Décentralisation 1984 p. 278).

quantities to have a consistent measurement across cereals and across sources of supply.

In order to estimate the feasibility of the Senegalese government's new objective, the evolution of the cereals balance sheet from 1974 to 1985 is analyzed, followed by a study of the regional cereals balance sheets for 1983-85. Finally, several projections to the year 2000 of the national cereals balance sheet are presented.

3.1.1.1.1 - Evolution of the national cereals balance sheet from 1974 to 1985

The national cereals balance sheets expressed in tons of milled product are presented first for all cereals combined and second for each cereal. The total cereals supply increases 29% from 845,170 tons in 1974-76 to 1,093,070 in 1983-85 (see Figure 8).[1] National cereals production decreases 17% from 513,640 tons in 1974-76 to 428,100 tons in 1983-85. Moreover, the share of national production in the total supply of cereals, i.e., the self-sufficiency level, decreases from 61% in 1974-76 to 39% in 1983-85.[2]

The absolute value and the share of the national production fluctuate a lot from year to year in response to rainfall (see Figure 9).[3] This reflects the predominance of rainfed agriculture in Senegal.

Commercial imports of cereals increase 75% from 294,110 tons in

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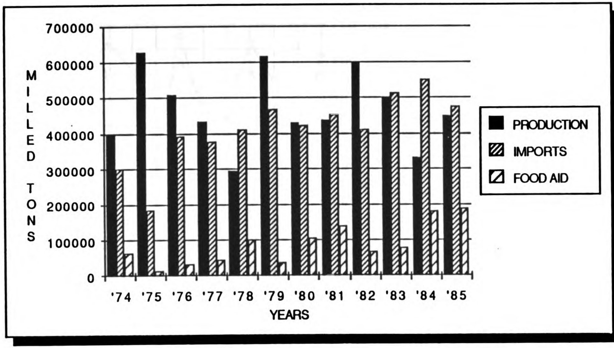
[1]See also Table 39 in Appendix A.

[2]See Table 40 in Appendix A.

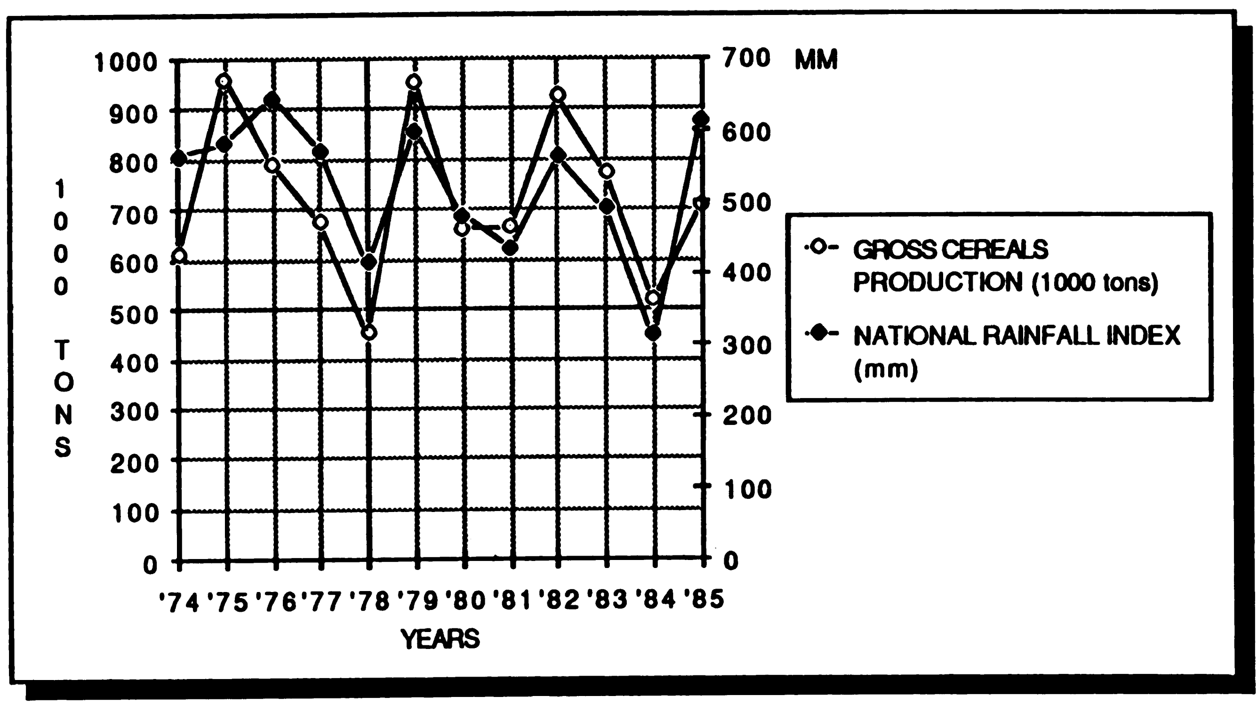
[3]See also Table 42 in Appendix A.



Source: Table 39

FIGURE 8

EVOLUTION OF THE NATIONAL SUPPLY OF CEREALS IN SENEGAL FROM 1974 TO 1985



Source: Table 42

FIGURE 9

EVOLUTION OF CEREALS NATIONAL PRODUCTION AND RAINFALL

IN SENEGAL FROM 1974 TO 1985

1974-76 to 514,580 tons in 1983-85. The share of commercial imports in the total supply of cereals increases from 35% in 1974-76 to 47% in 1983-85.[1]

Food aid[2] in the form of cereals increases 302% from 37,420 tons in 1974-76 to 150,380 tons in 1983-85. The share of food aid in the total supply of cereals increases from 5% in 1974-76 to 14% in 1983-85.[1]

The total supply of cereals per capita expressed in kilos of milled product stays around the same average level of 171 kilos during the period 1974-76 to 1983-85 (see Figure 10).[3] Expressed in kilos of unmilled product, it is always above the 200 kilos norm considered as necessary by the FAO to satisfy per capita food needs in Sahelian countries. The increase in the volume of commercial imports and food aid made it possible to maintain the consumption of cereals by the Senegalese population at a satisfactory level.[4]

Millet/sorghum has the biggest share in the total supply of cereals, but it decreases from 56% in 1974-76 to 45% in 1983-85. The share of wheat remains the same at 9%. The share of maize also stays

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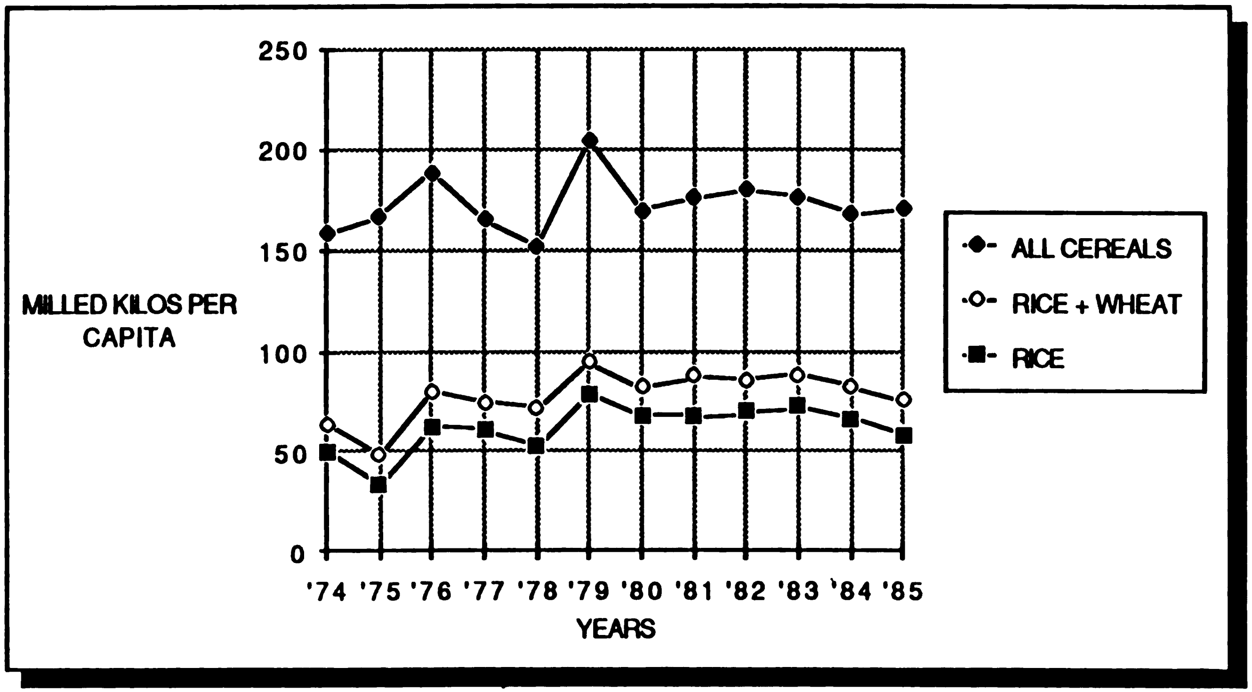
[1]See Table 40 in Appendix A.

[2]Official data on food aid varied significantly among donors and Senegalese ministries or agencies. Considerable time was spent trying to come up with better estimates of food aid distribution by donor, by product and by region by looking at the detailed monthly records of the "Commissariat à la Sécurité Alimentaire" and by visiting all the major donors.

[3]See Table 43 in Appendix A.

[4]At least compared to the FAO norm measured in kilos.



Source: Table 43

FIGURE 10

EVOLUTION OF CEREALS SUPPLY PER CAPITA

IN SENEGAL FROM 1974 TO 1985

at roughly the same level, going from 7% in 1974-76 to 8% in 1983-85. Meanwhile, the share of rice increases from 28% to 38% during the same period.[1]

The share of millet/sorghum in national cereals production is by far the largest, but it decreases from 85.5% in 1974-76 to 73.9% in 1983-85, reflecting the decrease in the average level of production from 434,550 tons to 318,200 tons during that period. The share of rice in national production increases slightly from 10.5% in 1974-76 to 14.7% in 1983-85, the production level going from 54,730 tons to 61,500 tons during the same period. The share of maize in national production increases significantly from 5% in 1974-76 to 11.3% in 1983-85, the production level going from 24,360 tons to 48,400 tons (see Figure 11).[2]

Rice is by far the most important imported cereal, followed by wheat (respectively 67% and 20% of imports from 1974 to 1985). The share of rice in the commercial imports of cereals fluctuates from year to year without any clear trend. However, the share of wheat decreases from 27% in 1974-76 to 14.5% in 1983-85. The share of millet/sorghum fluctuates a lot from year to year and represents on average 9% of commercial imports of cereals. The share of maize is marginal (4%) (see Figure 12).[2]

In food aid received by Senegal, sorghum is the most important cereal (50% of food aid from 1974 to 1985), followed by maize (20%),

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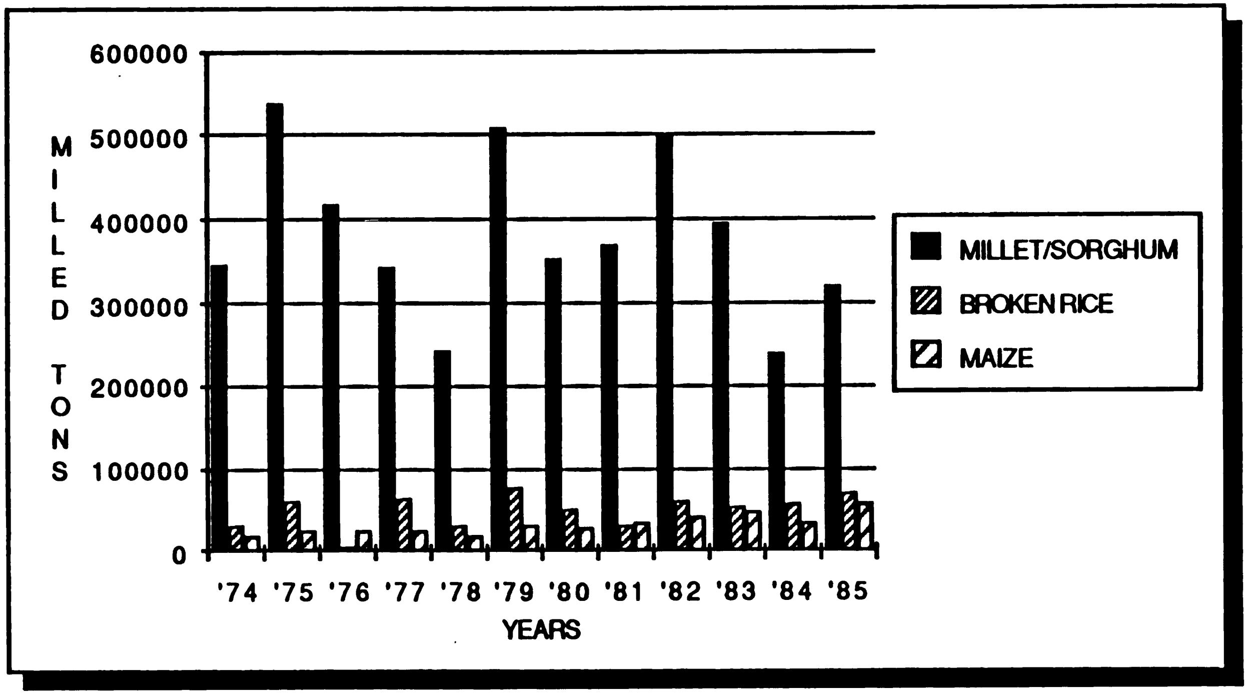
[1]See Table 41 in Appendix A.

[2]See also Tables 39 and 41 in Appendix A.

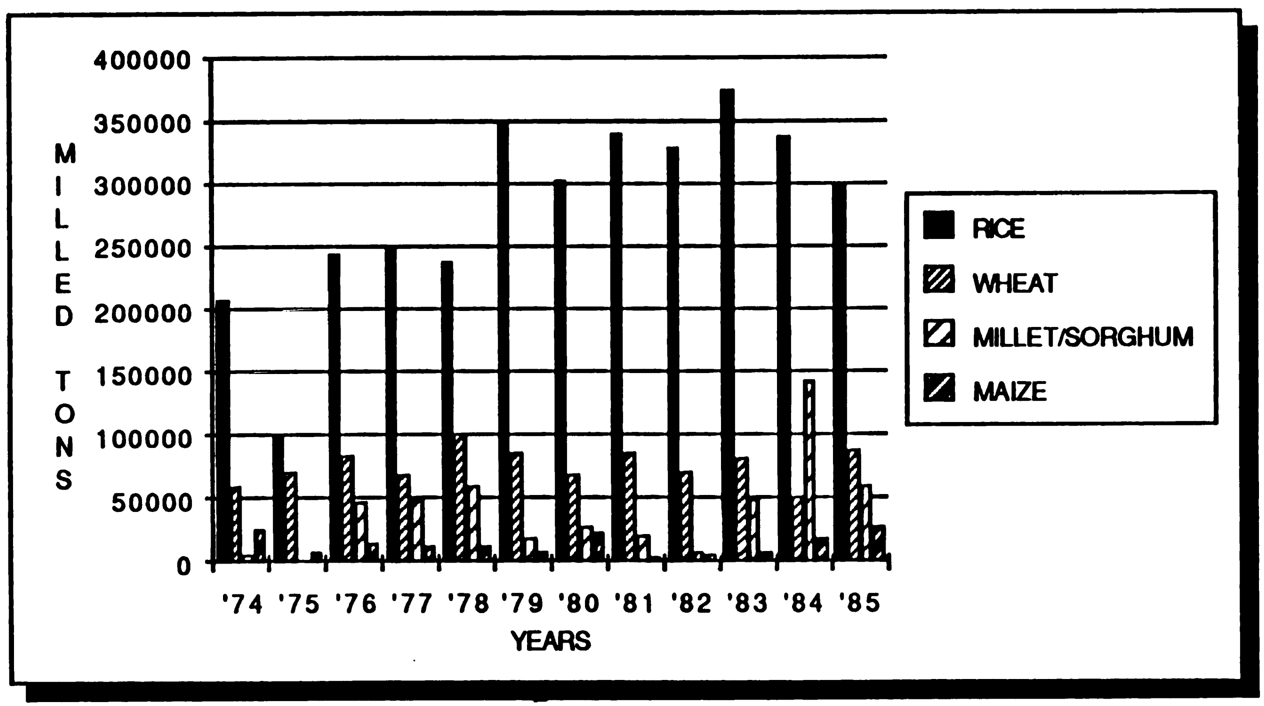


Source: Table 39

FIGURE 11

EVOLUTION OF NATIONAL PRODUCTION OF CEREALS BY PRODUCT

IN SENEGAL FROM 1974 TO 1985



Source: Table 39

FIGURE 12

EVOLUTION OF COMMERCIAL IMPORTS OF CEREALS BY PRODUCT

IN SENEGAL FROM 1974 TO 1985

wheat (16%) and rice (14%). The respective shares of the different products fluctuate a lot from year to year (see Figure 13).[1]

3.1.1.1.2 - The regional cereals balance sheets for 1983-85

As for the national cereals balance sheets, the regional cereals balance sheets[2] are presented first for all cereals combined and second for each cereal. The cereals balance sheet varies significantly from one region to the other[3], even though all regions experience an overall deficit[4] (see Figure 15).[5]

In general, the farther north in the country, the smaller the share of production and conversely the higher the shares of commercial

---

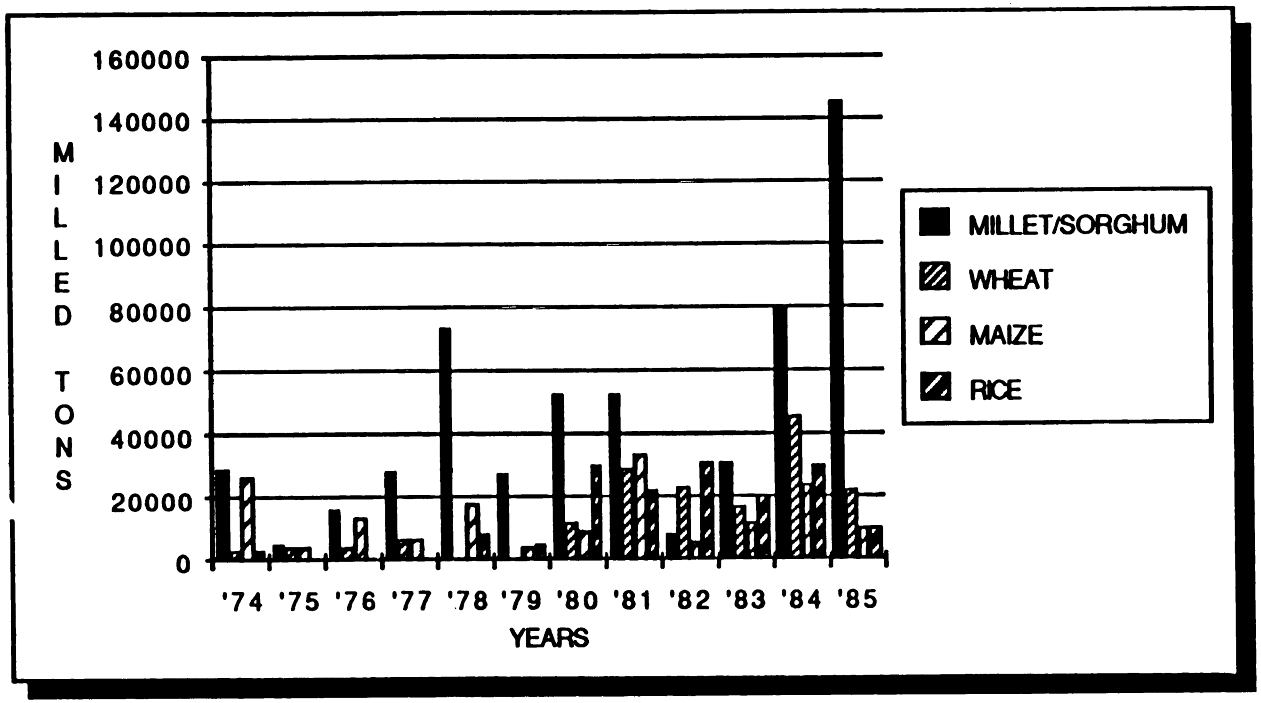
[1]See also Tables 39 and 41 in Appendix A.

[2]The regional cereals balance sheet is obtained by calculating the difference between the estimated cereals consumption and the cereals production in that region. Regional consumption is the sum of both urban and rural consumption. The latter is calculated by multiplying the estimated per capita consumption (see Table 47 in Appendix A) by the corresponding population.

[3]Senegal is disaggregated into eight regions according to administrative boundaries: Cap Vert, Casamance, Diourbel, Eastern Senegal, Fleuve, Louga, Sine-Saloum and Thiès (see Figure 14). Time series on production, trade and food aid are only available for those administrative regions. Administrative regions were redefined in 1984 as follows: Cap Vert, Ziguinchor and Kolda corresponding to the old Casamance, Diourbel, Tambacounda corresponding to Eastern Senegal, St. Louis corresponding to the Fleuve, Louga, Fatick and Kaolack corresponding to Sine-Saloum, and Thiès.

[4]When net production represents less than 50% of net consumption in a given region, this region is called a large deficit region. When net production represents more than 50% and less than 100% of net consumption, it is called a small deficit region.

[5]See also Table 48 in Appendix A.



Source: Table 39

FIGURE 13

EVOLUTION OF FOOD AID IN CEREALS BY PRODUCT

IN SENEGAL FROM 1974 TO 1985

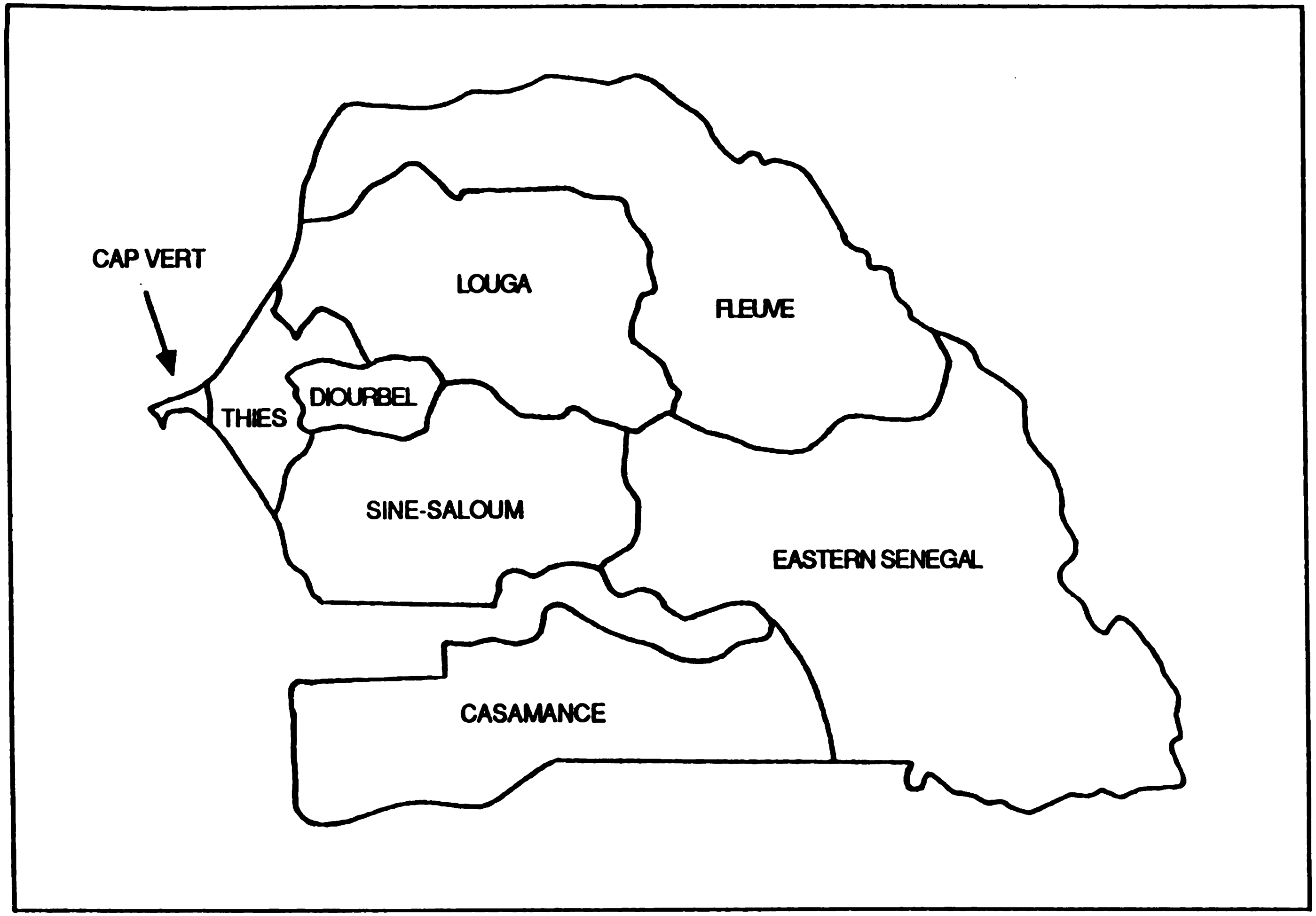
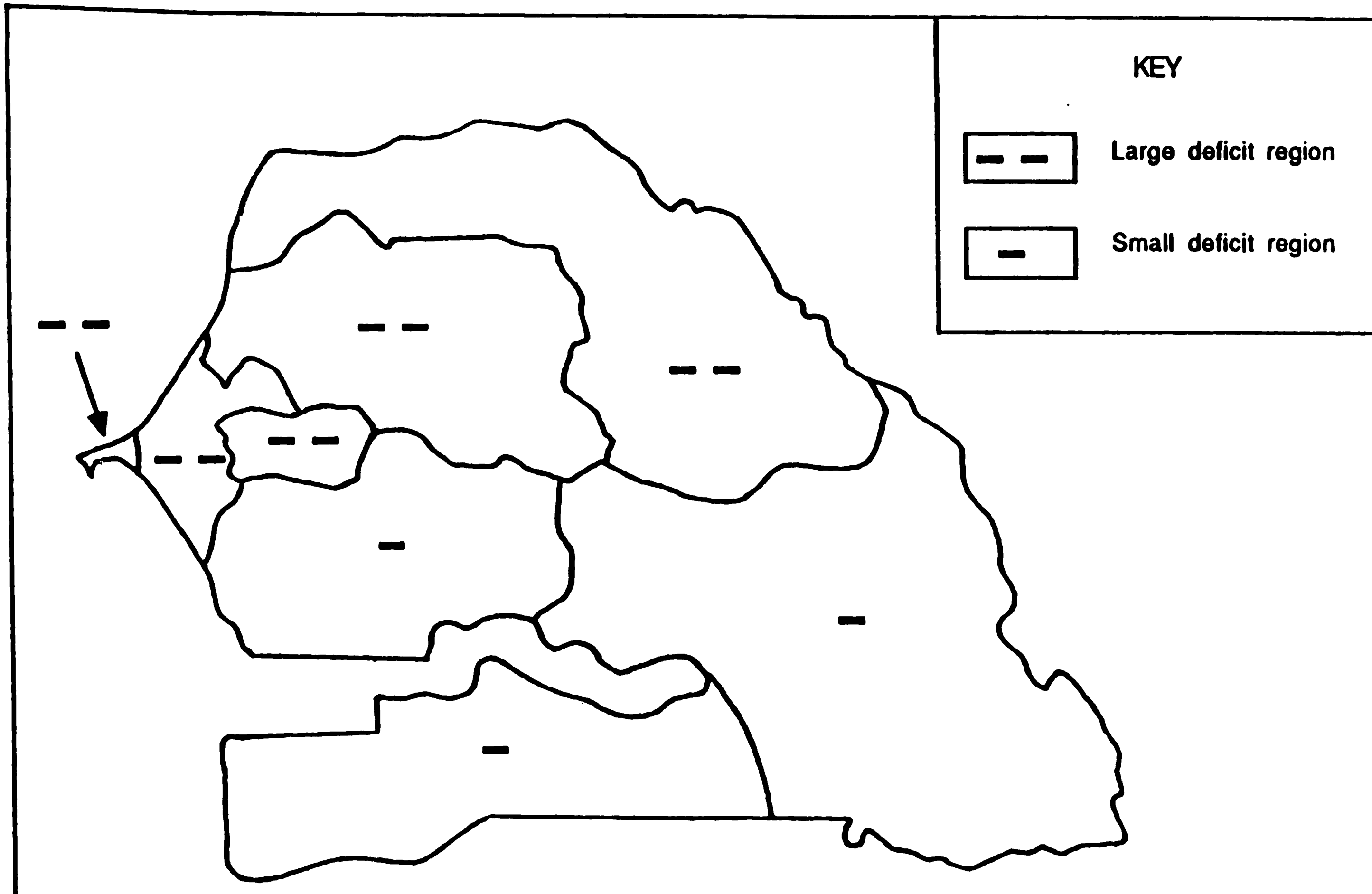


FIGURE 14

MAP OF ADMINISTRATIVE REGIONS IN SENEGAL BEFORE 1984



See footnote 2 on page 74 for definitions of the types of regions.

Source: Table 48

FIGURE 15

MAP OF CEREAL DEFICITS BY REGION IN SENEGAL IN 1983-85 imports and food aid. Ranking the regions according to the share of production in the total cereals supply gives the following results:

First comes the region of Sine-Saloum with a high share of its cereals supply from local production (66%), a 26% share from commercial imports and a small share from food aid (8%).[1] Several factors contribute to this situation: enough rainfall on average, a relatively sparse population in its eastern part so that soils are not overexploited and a relatively good access to agricultural inputs and equipment.

Second come two regions with relatively high shares of production and commercial imports: Casamance and Eastern Senegal. Production makes up on average 48.5% of the total supply of cereals, commercial imports 43%, and food aid 8.5%.[1] These two regions benefit from good rainfall, but their productive potential is constrained by the limited availability of agricultural equipment, the scarce rural population in Eastern Senegal and the shortage of good land in Lower Casamance.

Third comes another group of two regions: Diourbel and Thiès. They receive a similar share of their cereals supply from commercial imports to the one of the previous group. However the share of production is slightly lower and that of food aid slightly higher. Production makes up on average 46% of the total cereals supply, commercial imports 40% and food aid 14%.[1] These zones, which cover the center of the Groundnut Basin, are in general heavily populated which contributes to soil depletion. They were also affected by below

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[1]See Table 45 in Appendix A.

average rainfall during the period studied.

Fourth the Louga zone located further to the north experiences a high deficit. Production makes up 28% of the total supply of cereals against 28.5% for commercial imports and 43.5% for food aid.[1].

Two regions exhibit special features: the Senegal River Basin and the Cap Vert region. The development of irrigated cultivation in the Senegal River Basin makes it possible for production to represent 45% of the total supply of cereals in that zone compared to 28% for commercial imports and 26% for food aid.[1].

The Cap-Vert region is a predominantly urban area whose major supply source is commercial imports (97.5% of the total supply of cereals). Cereals production is essentially zero. Food aid is also very low in that region (2.5% of total cereals supply)[1].

The shares of each cereal in regional cereals supply[2] vary significantly from region to region:

- The supply in the Groundnut Basin regions (Diourbel, Thiès, Sine-Saloum) consists mainly of millet/sorghum (74% for Sine-Saloum and 54.5% on average for Thiès and Diourbel) which is nearly all locally produced. In those regions, rice comes second (15.5% for

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[1]See Table 45 in Appendix A.

[2]Regional cereals supply is calculated as the sum of regional production, commercial imports, and food aid sent to that region. Since we do not take into account interregional cereal transfers given the lack of data, this estimate of regional supply may be an underestimate or an overestimate of the amount available for regional consumption. However the estimate does provides insights into the relative importance of each cereal in each region.

Sine-Saloum and 33% on average for Thiès and Diourbel) and is imported;

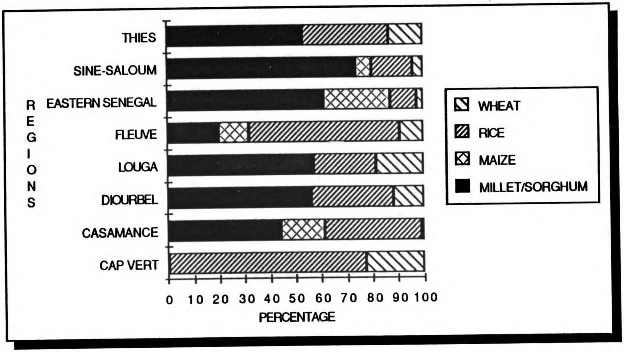
- Millet/sorghum is also important for Casamance (44%) and Eastern Senegal (61%), but other cereals (mainly locally produced) represent a significant share of the cereals supply, such as maize in Eastern Senegal and rice in Casamance (respectively 26% and 38% of the regional supply);
- The Louga region produces mainly millet/sorghum, but falls far short and must receive commercial imports of rice (24% of total cereals supply) and food aid composed of sorghum and wheat (respectively 57% and 19% of total cereals supply);
- The supply in the Fleuve region consists mainly of rice (59%) which is mainly locally produced on irrigated perimeters;
- The supply in the Cap Vert region consists mainly of rice (77% of the total supply). nearly all imported (see Figure 16[1]).

The next step after this analysis of the supply of cereals is to estimate the surplus or deficit[2] by cereal and by region. This implies matching regional production with estimated regional

---

[1]See also Table 46 in Appendix A.

[2]When net production represents less than 50% of net consumption in a given region, this region is called a large deficit region. When net production represents more than 50% and less than 100% of net consumption, it is called a small deficit region. When net production represents more than 100% and less than 150% of net consumption, it is called a small surplus region. When net production represents more than 150% of net consumption, it is called a large surplus region.



Source: Table 46

FIGURE 16

DISAGGREGATION OF THE REGIONAL SUPPLY OF CEREALS BY PRODUCT

IN SENEGAL IN 1983-85

consumption[1]:

- Regarding millet/sorghum, only one region (Casamance) exhibits a surplus and another one has a zero surplus (Sine-Saloum). The center of the Groundnut Basin (Diourbel and Thiès) and Eastern Senegal are small deficit areas. The major urban area (Cap Vert), the rainfed north of the Groundnut Basin (Louga), the irrigated areas in the north (Fleuve) are large deficit areas (see Figure 17[2]).
- Regarding maize, one region (Eastern Senegal) shows a large surplus. All other regions have large deficits, except for Casamance and Sine-Saloum that have small deficits (see Figure 18[2]).
- Regarding rice, all regions are deficit areas, even the producing regions (Fleuve and Casamance) (see Figure 19[2]).
- Regarding wheat, all regions have large deficits since this cereal is not produced in Senegal (see Figure 20[2]).

To conclude this analysis of the present cereals balance sheet and its recent evolution, it is clear that the cereals deficit has increased during the last ten years despite variations according to region and cereal. <u>Estimated on the basis of quantities of milled product, the cereals self-sufficiency level decreased from 61% in 1974-76 to 39% in 1983-85</u>. Thus, the country has been moving away from the 80% objective set by the government for the year 2000. Is it possible to correct that trend to meet the government's objective? This question is analyzed in the next part.

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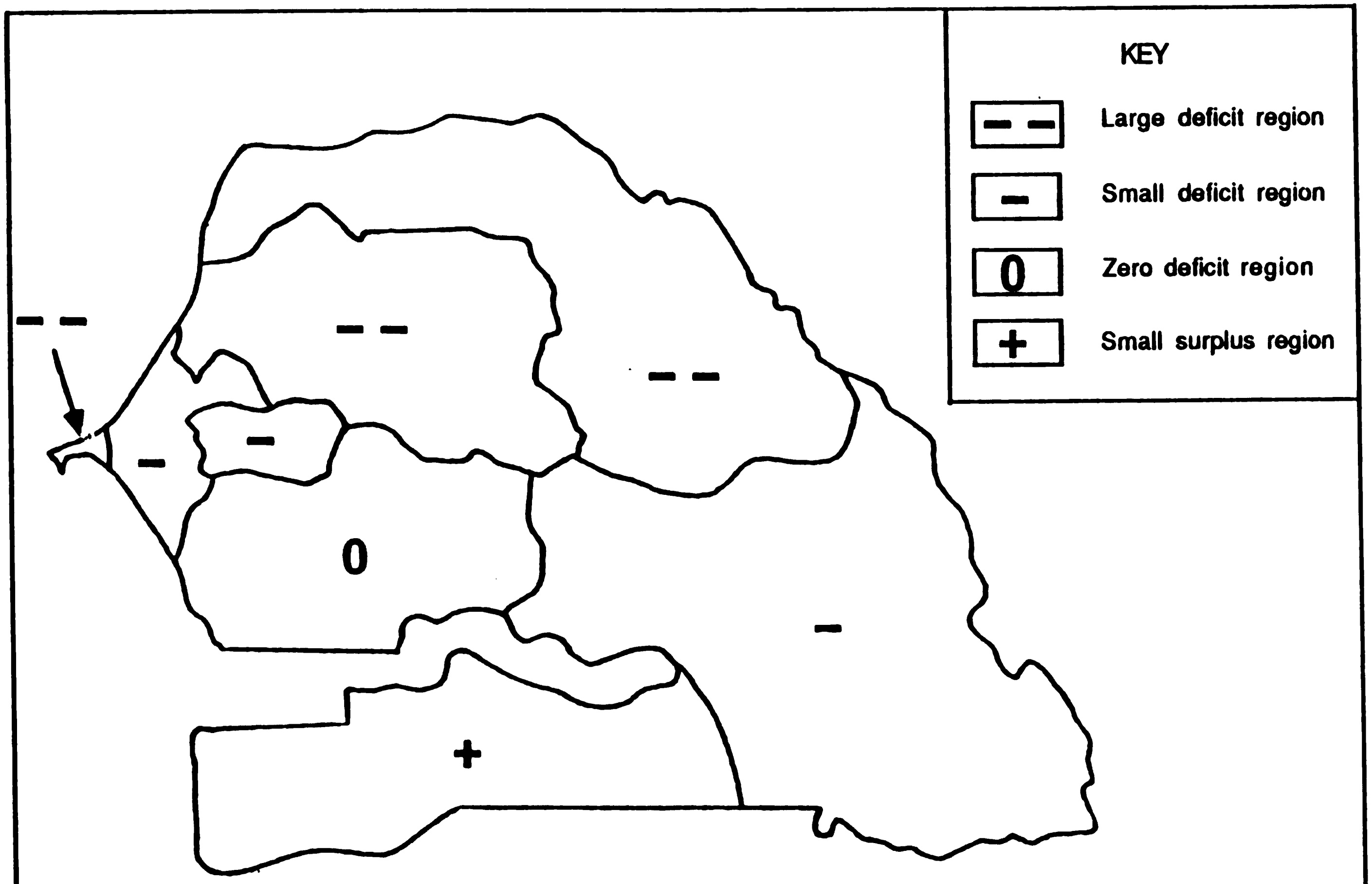
[1]See Table 47 in Appendix A.

[2]See also Table 48 in Appendix A.



See footnote 2 on page 74 for definitions of the types of regions.

Source: Table 48

FIGURE 17

MAP OF MILLET/SORGHUM DEFICITS AND SURPLUSES BY REGION IN SENEGAL IN 1983-85

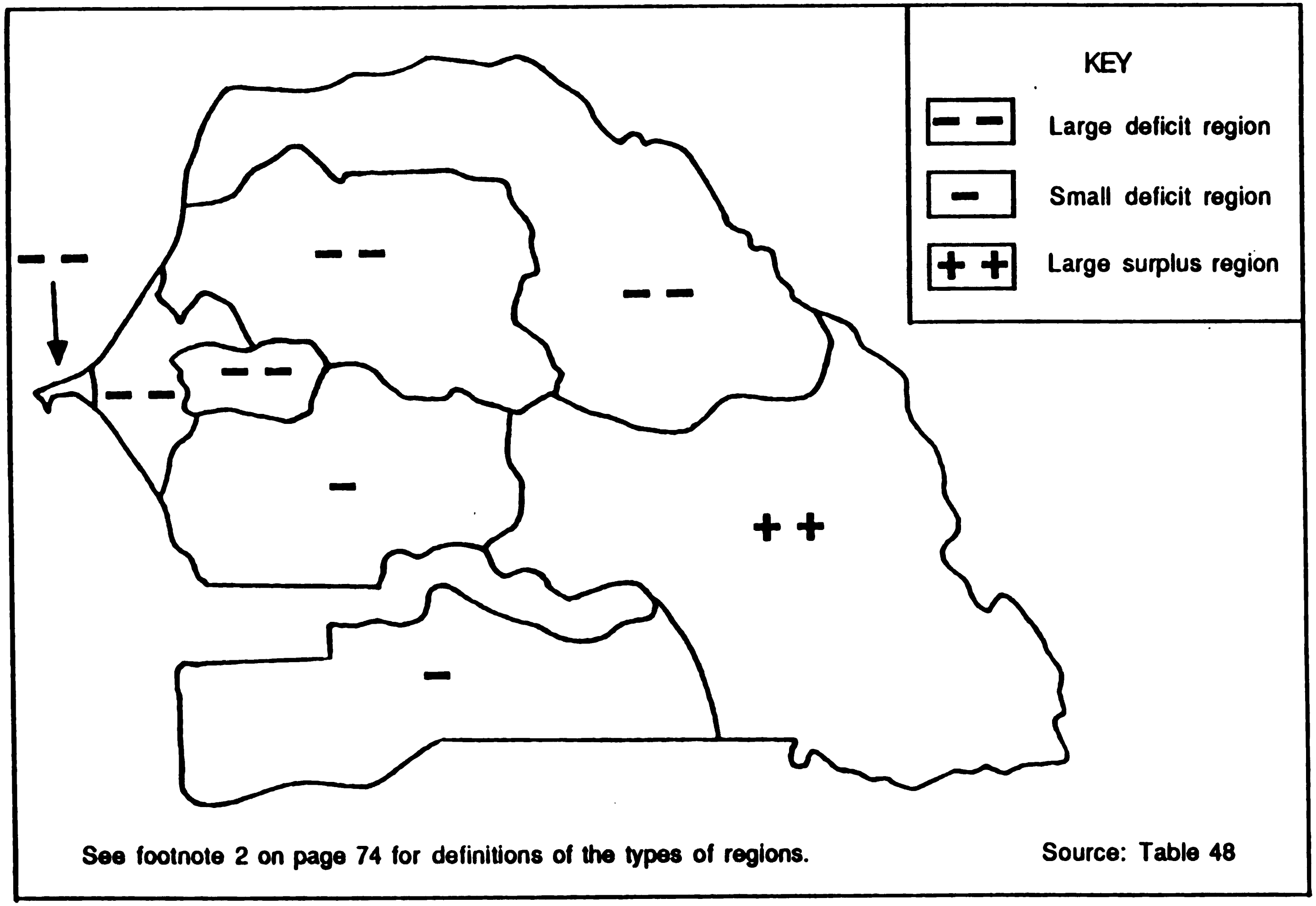
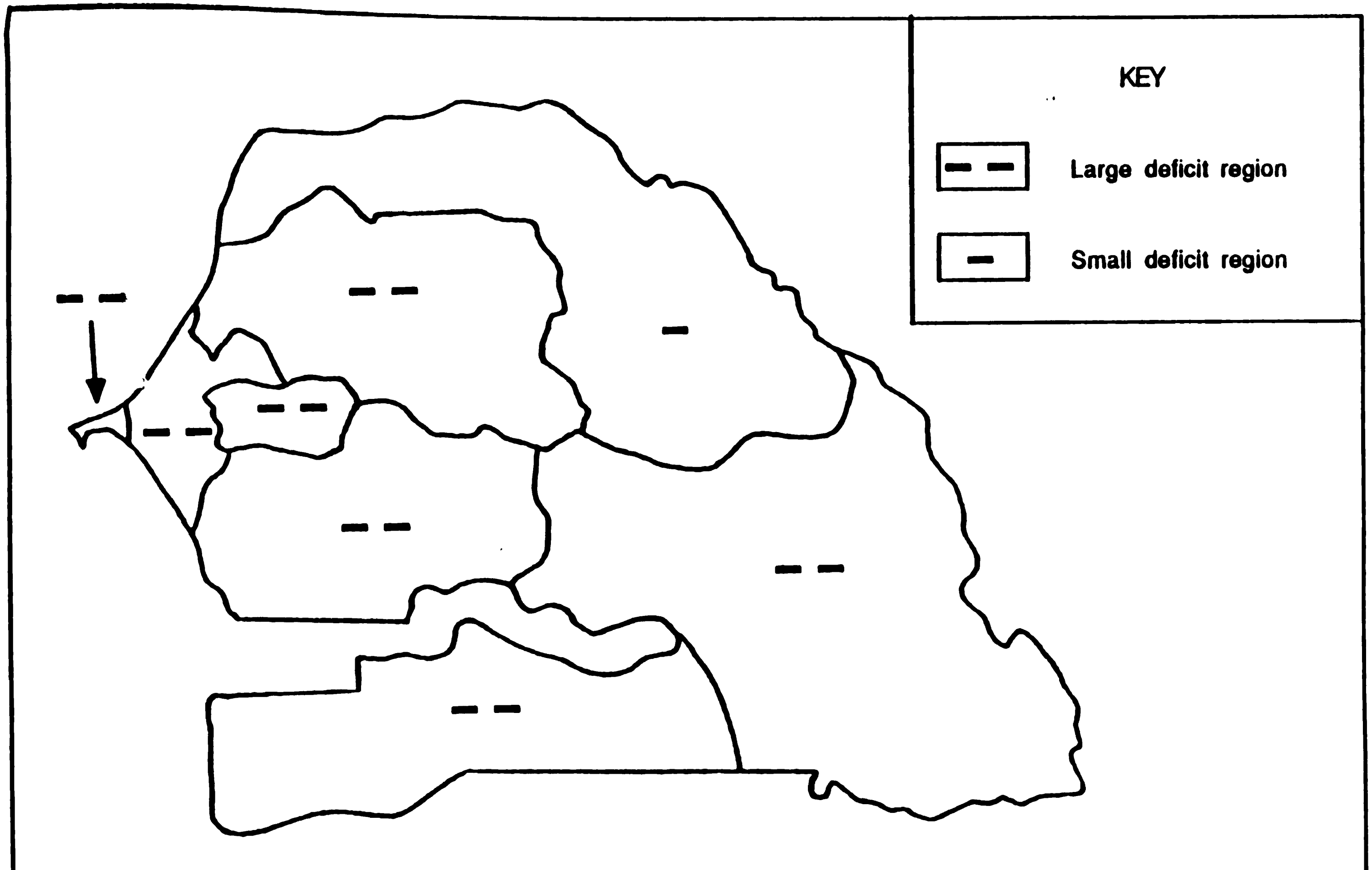


FIGURE 18

MAP OF MAIZE DEFICITS AND SURPLUSES BY REGION IN SENEGAL IN 1983-85



See footnote 2 on page 74 for definitions of the types of regions.

Source: Table 48

FIGURE 19

MAP OF RICE DEFICITS BY REGION IN SENEGAL IN 1983-85

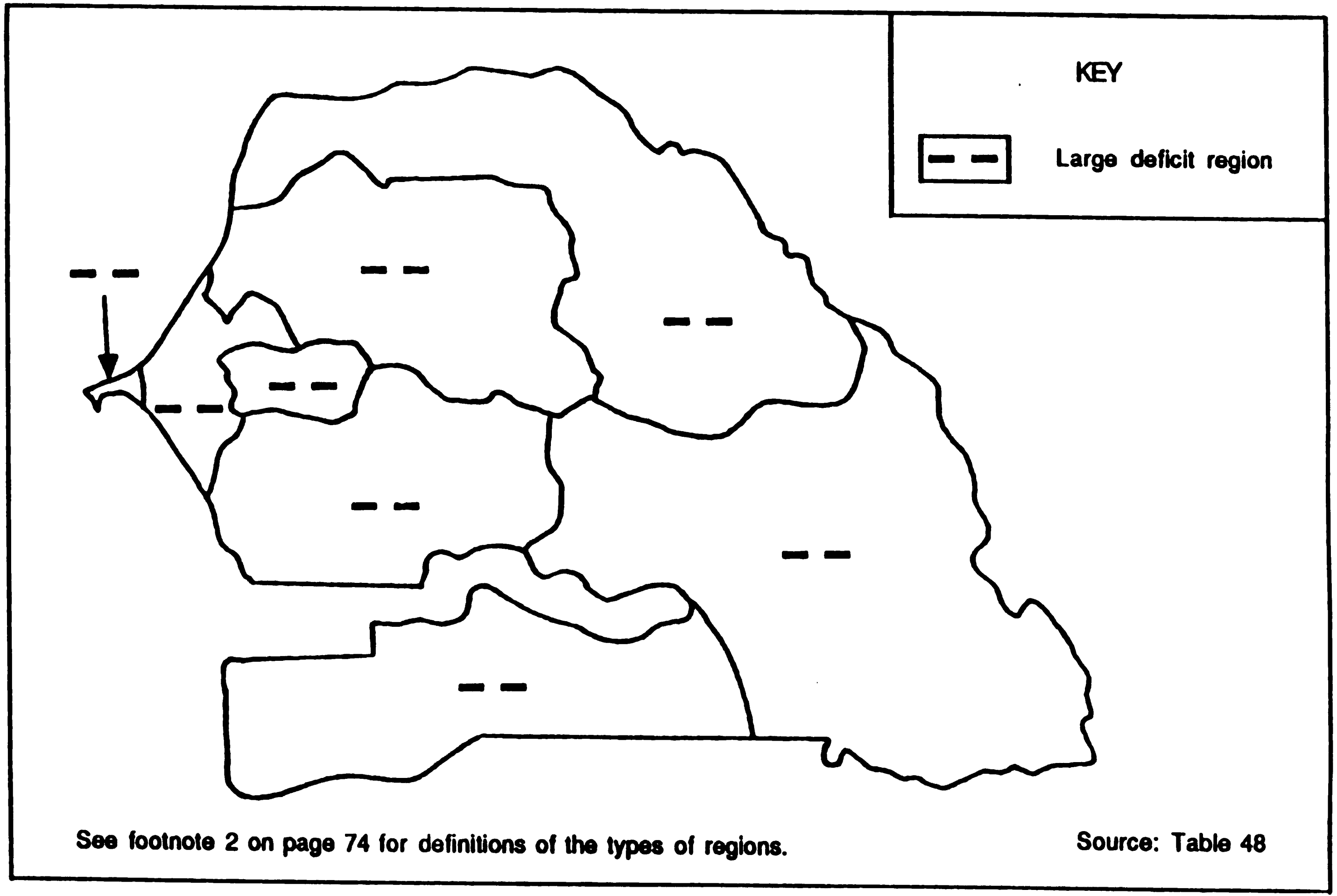


FIGURE 20

MAP OF WHEAT DEFICITS BY REGION IN SENEGAL IN 1983-85

3.1.1.1.3 - Projected cereals balance sheets

Projections of the cereals balance sheet depend of course on the assumptions made. Projections of cereals production depend on the assumed growth of cultivated areas and yields. The predicted availability of credit, agricultural inputs (seeds, fertilizers), and agricultural equipment, and the predicted relative prices of inputs and outputs, will also influence the projections. Regarding irrigated cultivation, assumptions about the increase in irrigated area and the coefficient of cropping intensity[1] play a crucial role.

On the demand side, assumptions about population growth and per capita cereals demand are critical. In general, the planned evolution of the institutional environment will have an important influence on the future cereals balance sheet, in particular the role of the state and of the private sector in the production and the marketing of agricultural inputs and outputs.

The first approach to making projections is to start from estimated future cereal needs and examine what this implies for production taking as a constraint the government's objective of 80% cereals self-sufficiency by the year 2000. This is the approach used by FAO (1985).[2] The advantage of this method is to show clearly the

---

[1]The coefficient of cropping intensity measures the extent of double cropping. For example, a coefficient of 1.4 means that 40% of the irrigated zone grows two crops per year, and 60% one crop per year.

[2]FAO makes projections only until 1995 and therefore uses a cereals self-sufficiency objective of 75% by this date. See Table 49 in Appendix A.

infeasibility of the self-sufficiency objective, in light of the heroic assumptions required to achieve it.

Apart from very optimistic assumptions[1] about the intensification of rainfed agriculture, the most unrealistic assumptions are those made for the development of irrigated agriculture. The FAO estimates that the government's objective can be reached with an annual increase of 3,800 hectares of new irrigated perimeters, a coefficient of cropping intensity of 1.8, and yields of 6 tons of paddy rice per hectare.

At present, however, only about 2800 hectares of new irrigated perimeters are created every year. Moreover, a number of irrigated perimeters are not fully cultivated and must be rehabilitated. Therefore, the real annual increase in irrigated zones is around 2,500 hectares, i.e., below the 3,800 hectare target.

The coefficient of cropping intensity on irrigated perimeters is presently a little above 1, i.e., there is very little double cropping. Perimeters that have two cropping seasons per year (for example, rice in the rainy season and tomato in the cold dry season) often do not represent true double cropping since each crop is grown on separate plots.

The completion of the Manantali dam in 1987 will make the generalization of double cropping theoretically possible. It remains

---

[1]Rainfed millet/sorghum production must go up 29.5% on average, from 562,770 tons for the period 1974-85 to 729,000 tons in 1995. The production of rainfed maize must go up 292%, from 80,400 tons for the period 1983-85 to 315,000 tons in 1995.

to be seen if farmers are ready to make the investment in money and time to double crop if single cropping can satisfy most of their food and cash needs. The realism of a coefficient of cropping intensity of 1.8 thus appears questionable.

Finally, the present average rice yield on irrigated perimeters is around 4.7 tons of paddy per hectare. The FAO assumption of an average yield of 6 tons seems a bit optimistic.

In short, the assumptions necessary to meet the government's cereals self-sufficiency objective seem unrealistic. Thus, the 80% self-sufficiency objective itself appears unattainable.

Another approach to forecasting the cereals balance sheet is to project production using realistic assumptions and then compare it with projected cereals demand. This approach is adopted by Abt Associates (1984)[1] and by the "Secrétariat d'Etat Chargé de la Décentralisation" (1984). Both studies come to the same conclusion: even with optimistic assumptions about production[2], the level of cereals and grain self-sufficiency will probably stay unchanged from 1983-85 to 1995 (see Figure 21 for the Abt Associates report projections).

The only apparent hope for improving the level of food self-sufficiency in the very long run is to reduce population growth. The birth control issue is a complex and touchy one. However the following figures suggest the importance of this issue. A study by the research

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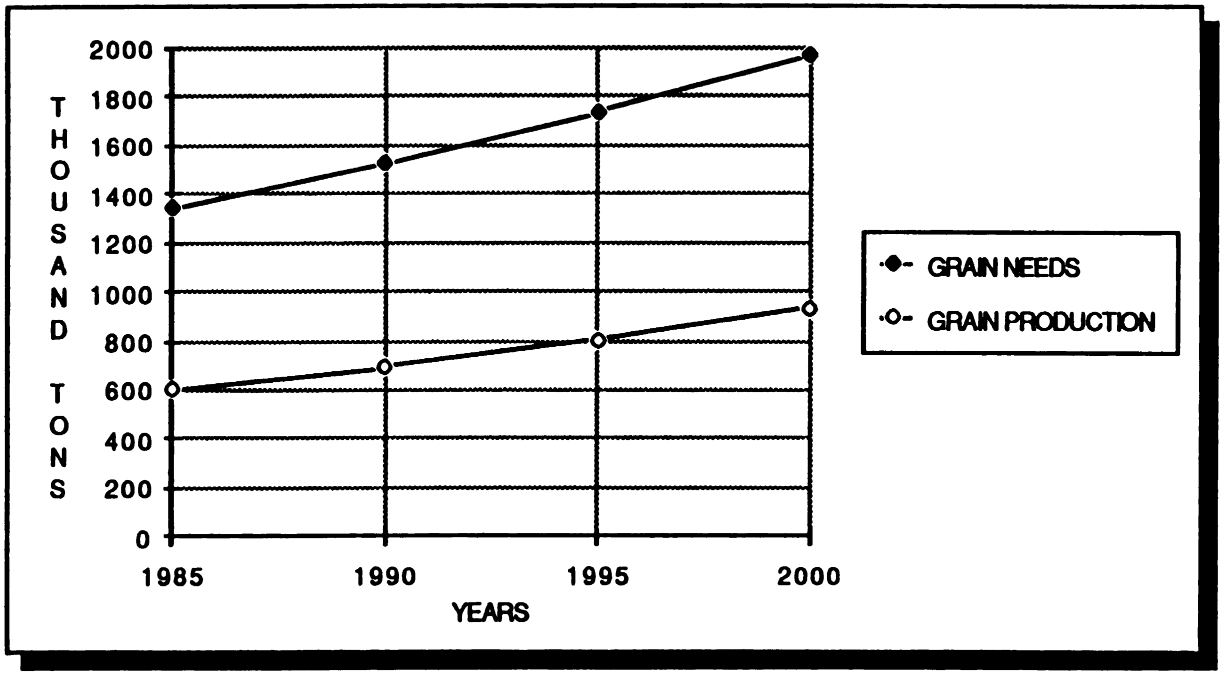
[1]The Abt Associates study makes projections for the grain balance sheet, which includes cowpeas. See Table 50 in Appendix A.

[2]See Tables 50 and 51 for the detailed assumptions.



Source: Table 50.3

FIGURE 21

PROJECTIONS OF GRAIN NEEDS AND DOMESTIC PRODUCTION

IN SENEGAL FROM 1985 TO 2000

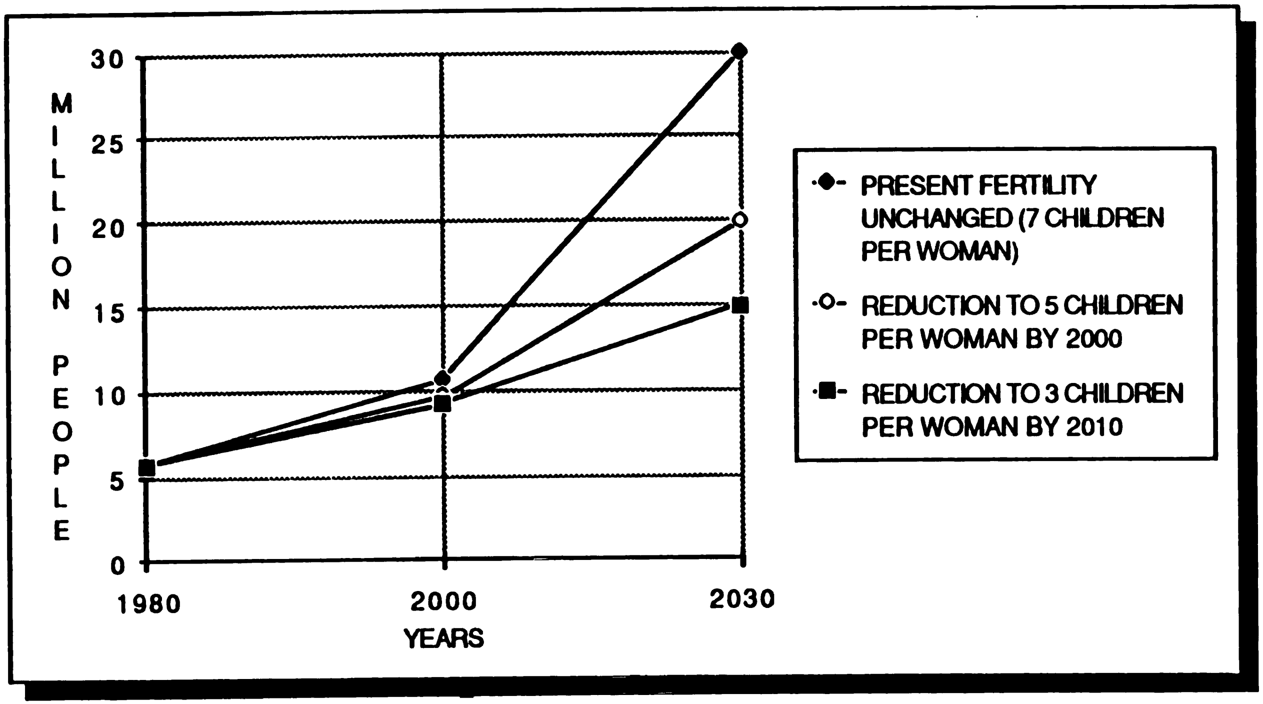
group RAPID (1984) forecasts in 2030 a population of 30 million people if current trends continue (7 children per woman), 20 million people if the birth rate is slightly reduced (5 children per woman by the year 2000) and 15 million people if the birth rate is strongly reduced (3 children per woman by the year 2010; see Figure 22).

In the past, the government's traditional approach to reducing the cereals deficit was to try to increase national cereals production. The government realized recently that more production was not enough, and that marketing system performance also had to be improved in order to handle the extra agricultural inputs and outputs.

This consideration and other factors have led the government to begin liberalizing cereals marketing. Recognizing also the importance of consumer preferences, the government has launched a program of millet and maize processing to make these locally produced cereals more competitive with imported cereals.

All these policies go in the right direction, but one must wonder whether they will be enough to reach the stated self-sufficiency objective, without complementary policies to reduce the rate of population growth and thus the demand for cereals over the long run.

To conclude this second part, the analysis of the cereals balance from 1974 to 1985, and projections of the cereals balance sheet to 2000, both suggest that the objective of 80% self-sufficiency by the year 2000 will be virtually impossible to achieve.



Source: RAPID (1984)

FIGURE 22

POPULATION GROWTH UNDER ALTERNATIVE FERTILITY HYPOTHESES

IN SENEGAL FROM 1980 TO 2030

3.1.1.2 - Other food security concerns for the Senegalese government

- The importance of the agricultural sector

The government must take into account the importance of agriculture for Senegal as a source of employment and of income. In 1980, 81% of the active population was employed in agriculture (World Bank 1987). Even if Senegalese agriculture turns out to be not very competitive on the world market, the government may choose to foster its growth in the short run as a way to assure the food security of a large part of the population. In the long run, the government may prefer to favor other sectors such as fisheries or tourism as sources of employment if Senegal has a comparative advantage in those sectors.

- The regional land management policy

The government may implement a regional land management policy. The importance of such a policy is obvious for the Senegal River Basin. The only hope for this region, which has very low and erratic rainfall, lies in the development of irrigated agriculture. Even if irrigated cultivation is not economically efficient given present conditions in the world cereals market, the government may feel that irrigation development is justified by the social and political necessity of assuring food security in that region, as well as contributing to national food security. However, alternative uses for the funds, which might produce more food per CFAF invested than irrigation projects, must be considered.

- The variations in the food bill

As mentioned in the previous chapter, the government may want to minimize fluctuations in the cost of the food bill. These fluctuations are caused by price variations and quantity variations. Which type of variation is more significant in the case of Senegal? If we use the coefficient of variation (CV)[1] to compare the variability of world prices and of domestic yields from 1970 to 1984-85, we obtain the following relationships (see Figures 23 to 26)[2]:

- The average CV of world prices denominated in constant CFA Francs (basis 1980)[3] is slightly greater than the average CV for national yields[4], respectively 0.29 and 0.23.
- The CV's for world prices vary more from product to product than the CV's for national domestic yields. The range of coefficient values for world prices in constant CFA Francs goes from 0.2 for cotton to 0.4 for rice. The range of coefficient values for national domestic yields goes from 0.19 for cotton to 0.26 for groundnut and paddy rice.
- The CV's for world prices denominated in nominal CFA Francs are in general higher than the CV's denominated in constant CFA Francs.
- The CV's of domestic yields by product are higher at the regional

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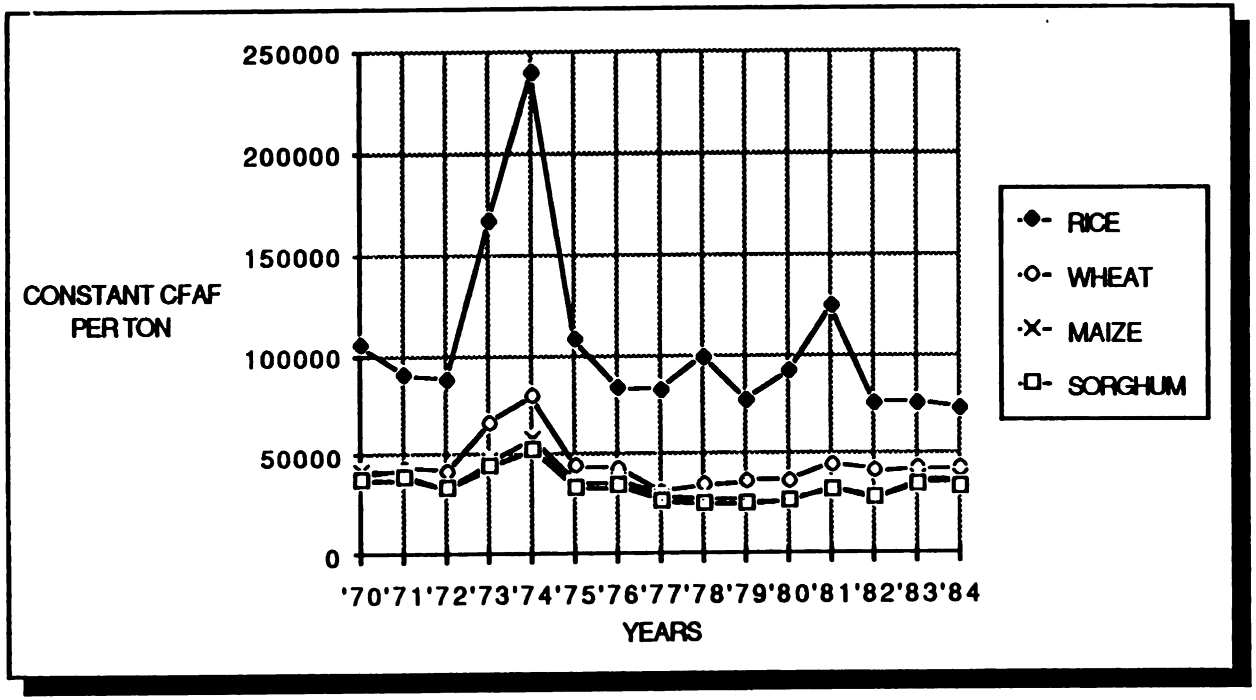
[1]The coefficient of variation is defined as the standard deviation divided by the mean of a time series.

[2]See Tables 52 and 53 in Appendix A.

[3]The deflator used is the Senegalese consumer price index.

[4]Based on official yield statistics.



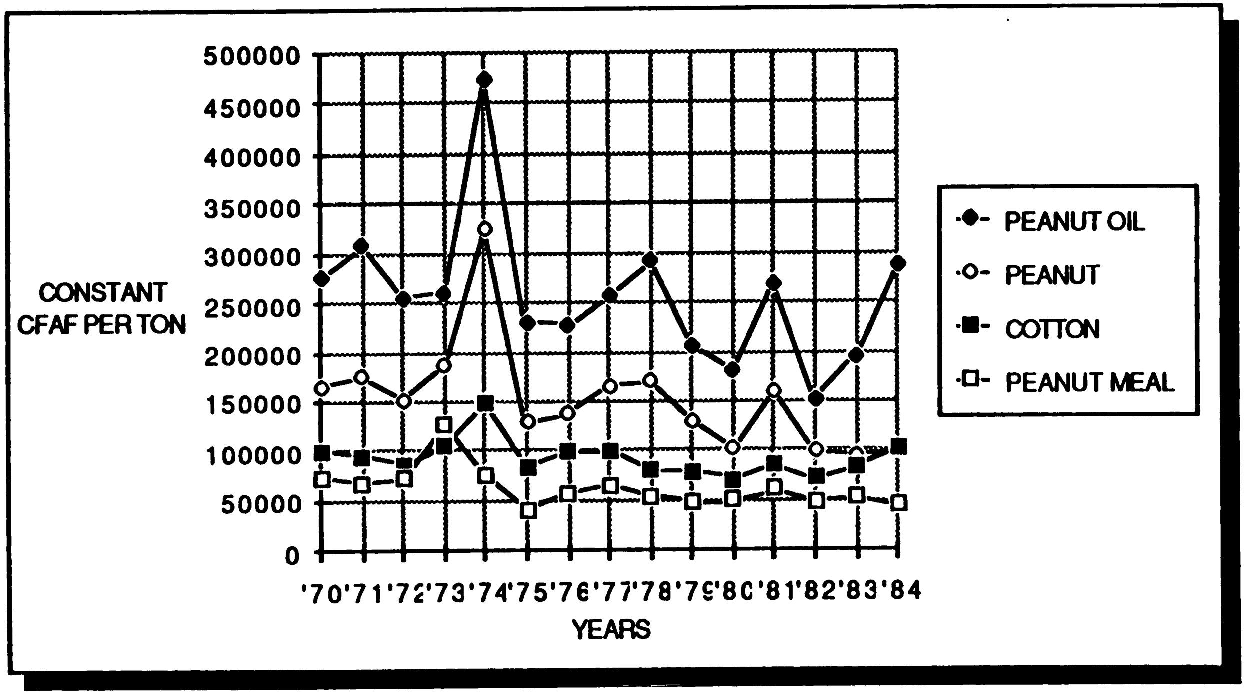
Source: Table 52

FIGURE 23

EVOLUTION OF CONSTANT WORLD PRICES FOR CEREALS

FROM 1970 TO 1984

(with 1980 as basis)



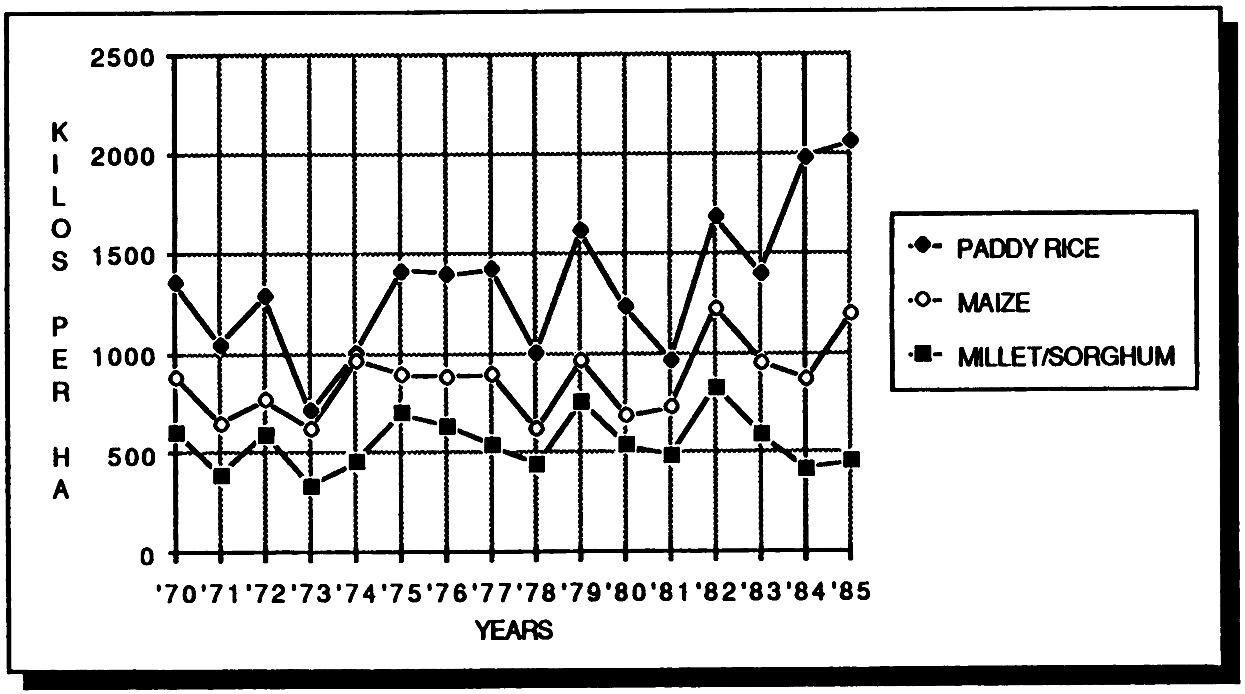
Source: Table 52

FIGURE 24

EVOLUTION OF CONSTANT WORLD PRICES FOR MAJOR EXPORT CROPS

OF SENEGAL FROM 1970 TO 1984

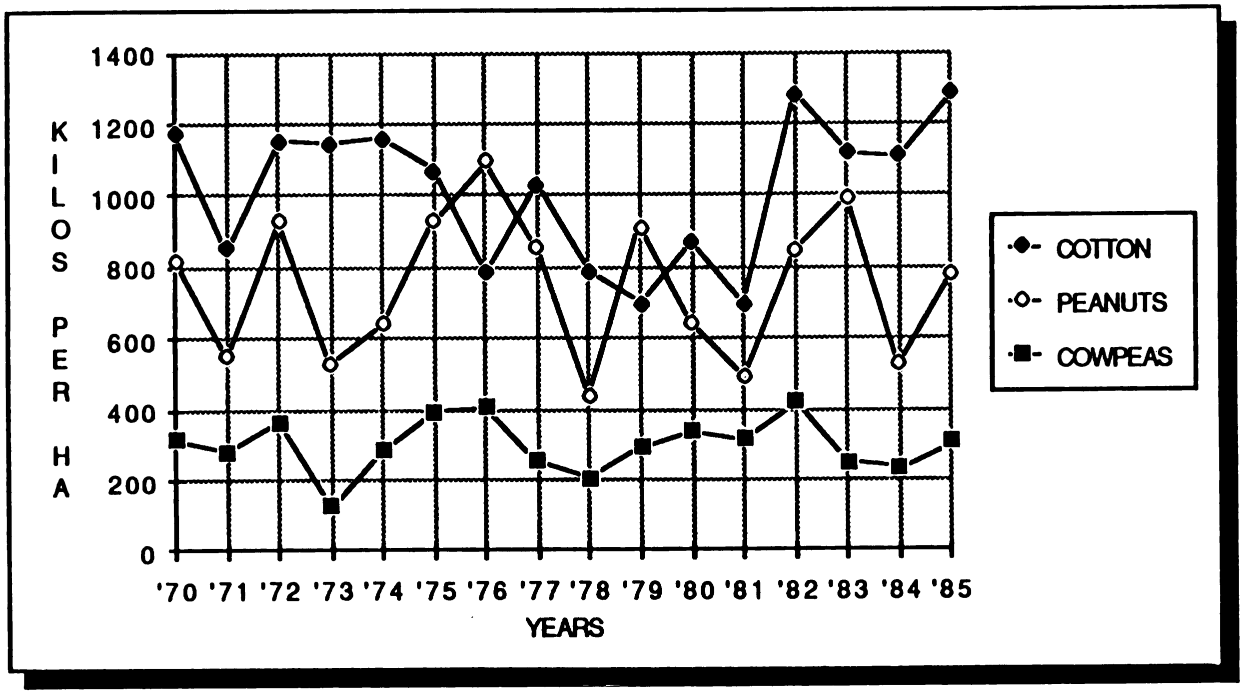
(with 1980 as basis)



Source: Table 53

FIGURE 25

EVOLUTION OF CEREALS YIELDS IN SENEGAL FROM 1970 TO 1985



Source: Table 53

FIGURE 26

EVOLUTION OF YIELDS FOR OTHER AGRICULTURAL PRODUCTS

IN SENEGAL FROM 1970 TO 1985

northern regions (Louga, Diourbel) than in southern regions (Casamance and Eastern Senegal), where rainfall is less erratic.

In summary, this analysis of year-to-year variability, which shows that world prices vary slightly more than national domestic yields, tends to argue slightly in favor of a high rather than a low level of food self-sufficiency in Senegal.

3.1.2 - Food security for the Senegalese farmer

The farm household head is responsible for assuring that the food needs of his family are met. This obligation will dictate the farming strategy. The farmer will first plant short-cycle cereals in the home gardens to make sure there is something to eat during the hungry season. He will also try to produce enough cereals to meet a large share of his family needs.[1]

The cereals balance varies also from farm to farm in any given region. Even in high producing areas such as Sine-Saloum or Casamance, a number of farms do not succeed in achieving self-sufficiency in cereals.[2] A study by Goetz (1987) found that the average net sales[3] per farm from October 1986 to July 1987 were 154 kilos for millet, sorghum and maize and -128 kilos for rice in Southeastern Sine-Saloum, and -91 kilos for millet, sorghum and maize and -86 kilos for rice in Middle Casamance. The average coarse grain production per farm in 1986 was respectively 2988 and 1323 kilos in the two regions.

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[1]For example, see Kelly (1986).

[2]See Table 54 in Appendix A.

[3]Net sales are equal to gross sales minus purchases.

Most farms experiencing a cereals deficit are small. Apart from the constraint on land available for cultivation, the decisions of small farmers to grow industrial crops on part of their land and to sell part of the cereals they produce also contribute to their cereals deficit. This a priori surprising phenomenon can be explained by the necessity for all families, including the poorest ones, to have enough income to buy basic consumer goods such as sugar, tea, and cooking oil, and to satisfy their social and religious obligations.

3.2 - Comparative advantage

As mentioned in Chapter 1, a Stanford/WARDA project[1] conducted a study of the comparative advantage of several Western African countries, including Senegal, in the mid-seventies. They concluded that Senegal did not have a comparative advantage in rice production under the prevailing technological and price conditions at that time.

This conclusion remains valid in the mid-eighties for the main rice consumer market: Dakar. Depending on the assumptions used, the cost of rice produced in the Senegal River Basin and processed and transported to Dakar is estimated to be in a range of 160-250 CFAF per kilo. The CIF price of imported Asian broken rice in Dakar varies between 50 and 100 CFAF per kilo.

For groundnuts, however, local costs of production are much more competitive with world prices as will be shown in Chapters 3 and 5.

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[1]For a detailed analysis of this question, see Pearson, Humphreys and Stryker (1981), Jabara (1979), Craven (1982) and Tuluy (1979). These studies all use data for the mid-1970's.

It therefore makes sense to produce and export groundnuts and to import rice.[1]

The comparative advantage of Senegal is not fixed, but can be modified as a result of changes in prices and costs. Let us mention a few examples:

- The extension of double cropping planned after the completion of the Manantali dam could reduce considerably the costs of production for irrigated cultivation, making locally produced rice more competitive with imported rice.
- The decrease in the oil price in 1985-86 led to a decrease in the cost of imported fertilizers. For example, SAED[2] sold urea at CFAF 118 per kilo in 1985 and at CFAF 80.5 per kilo in 1986.[3] Such changes in fertilizer prices modify significantly the costs of production in Senegal. However they affect costs in other producing countries as well, hence the net impact on comparative advantage is not clear.
- The institutional context is changing rapidly with the withdrawal of the state and the progressive transfer to the private sector of agricultural input and output marketing. These reforms will, among

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[1]Jabara (1979) showed that under certain conditions local production of rice (hence a move toward self-sufficiency) was more economic when uncertainty was considered than when it was not.

[2]The SAED is a parastatal responsible for the development of irrigated cultivation in the Senegal River Basin.

[3]The 1985 price excludes the CFAF 20 subsidy from USAID. The 1986 price is for purchase on credit, which is the most common mode of payment. The cash price was CFAF 74.5 in 1986.

other things, modify the availability and the cost of inputs, and hence the costs of production in Senegal.

It is hard to evaluate the impact of these reforms ex ante. This topic would require a separate study. The hope is that economic costs will decrease as a result of greater efficiency in the private sector. This assumes real competition among traders, rather than a situation of oligopoly or monopoly.

3.3 - Food habits

In Senegal, the food habits issue arises most importantly for rice. National production amounted to 61,500 tons of processed rice in 1983-85, i.e., 14% of the total rice supply (419,120 tons). Optimistic assumptions on the development of irrigated rice cultivation lead to projections for rice production of only 250,000 to 350,000 tons of processed rice in the year 2000. However, projecting current trends in rice consumption gives a demand of 700,000 to 900,000 tons. Quite obviously, the level of rice self-sufficiency is going to remain low (between 28% and 50%).[1]

The government is very hopeful about the policy of processing local cereals (millet/sorghum and maize) into easy-to-use products which can compete with broken rice. This policy is commendable, but it seems unlikely to have a major impact on food preferences by the year 2000.

The preference for rice seems well-established in urban areas, in particular in Dakar. Rice is presently consumed by the quasi-totality

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[1]See projections in Tables 49, 50 and 51 in Appendix A.

of Dakar households every lunch, and one dinner out of two (Ross 1980). The national dish of Senegal, the "Tiebou-Dienne", has rice as its main ingredient. Because it is hard to see how food preferences would turn rapidly against rice by the year 2000, there appears to be little hope for a significant reduction of demand for rice.

3.4 - The budget implications

The budget implications of a self-sufficiency strategy are hard to estimate in detail. At this stage of the analysis, however, we can get an idea of the cost of developing the irrigated zone in order to meet the self-sufficiency objective.

The 1985 FAO study estimates that 38,000 hectares must be irrigated by 1995 in order to meet the 75% cereals self-sufficiency objective. If we accept a cost of 1.5 million CFAF per new irrigated hectare, we obtain a required investment cost of 57 billion CFA Francs. This amount can be compared to the overall deficit in the national budget of - 55.47 billion CFAF in 1983 (IMF 1987). It is clear that the development of the irrigated zone required to meet the self-sufficiency objective will impose a major burden on the state budget, unless donors take over part of the investment costs.

3.5 - The foreign exchange implications

The strategy followed until recently by Senegal, which was based on specializing in the production and exportation of groundnut products and the importation of broken rice, has counted on exports to generate enough foreign exchange to pay for imports. Unfortunately, the latest forecast of the world market prospects for groundnut products is not encouraging. Projections indicate that the size of the world market, the world price, the market share of Senegal, and thus exports of groundnut exports will all stagnate.[1]

The two major purchasers of Senegalese groundnut products are the European livestock breeders who feed their animals with groundnut meal, and European consumers who use groundnut oil for cooking. The livestock breeders are tending to substitute soya meal for groundnut meal because the former gives leaner and thus higher value carcasses than the latter. Consumers are tending to substitute lighter oils such as sunflower or corn oils for groundnut oil.

Projections for cotton exports do not indicate any significant growth either. The world market for cotton is expected to remain stable during the foreseeable future. Moreover, a rapid increase in cotton acreage seems unlikely; because cotton exhausts soils quickly, new crop rotations (cotton, cereals and legumes) would have to be introduced, the adoption of which would probably take time. Therefore, cotton exports are likely to remain around their present level.[1]

The balance of trade in agricultural products is projected to deteriorate (see Figure 27[1]). Traditional exports will be less and less able to generate the foreign exchange required to buy the quantity of cereals necessary to meet food needs. However, the growth of fish exports and of tourism should help alleviate the foreign exchange constraint. From 1974-77 to 1982-84, the level of coverage of cereals imports by groundnut products exports went from 389% to 161%, the level of coverage of cereal imports by fish product exports from 73% to

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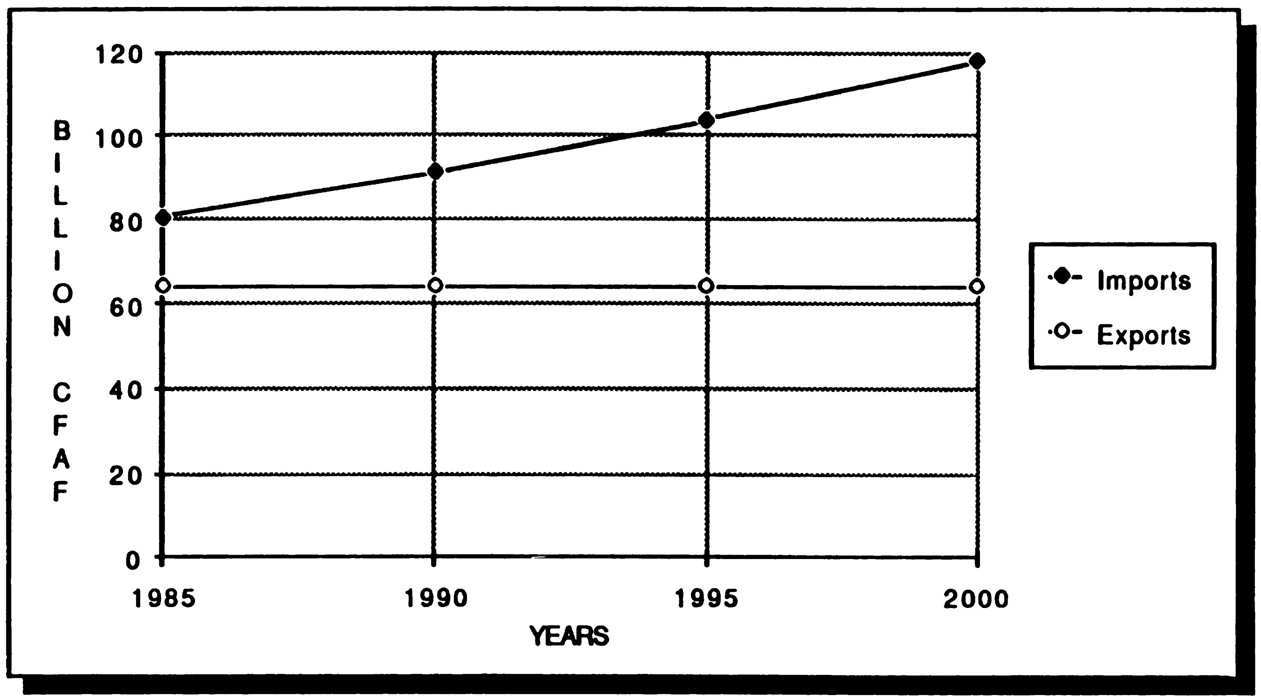
[1]See Tables 55 and 56 in Appendix A.



Source: Table 55

FIGURE 27

PROJECTION OF THE BALANCE OF TRADE FOR AGRICULTURAL PRODUCTS

IN SENEGAL FROM 1985 TO 2000

122%.[1] On a more aggregate level, the percentage of foreign exchange needed to pay for major food imports went from 38% in 1980-81 to 26% in 1986-87.[2] These figures suggest that the importance of economic sectors in Senegal is changing, with a decline in agriculture and growth in fishing and tourism. They also indicate that Senegal might be able to maintain its capacity to import food and, in that respect, a minimum level of food security.

To review this chapter, the food situation in Senegal was analyzed to provide a macro perspective of food security and comparative advantage in Senegal. The level of cereals self-sufficiency has decreased over the period 1974 to 1985 and the Senegalese government's objective of 80% cereals self-sufficiency in year 2000 does not seem realistic. The share of food aid in total cereals supply has increased significantly. However the growth of fishing and tourism might make it possible to maintain a minimum level of macro food security. The next chapter switches to a micro perspective, looking at the financial attractiveness of alternative crops for the farmer.

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[1]See Martin and Dieng (1986b).

[2]See United Nations Economic and Social Council (1987).

CHAPTER 4

ELABORATION OF CROP BUDGETS AND MARGIN ANALYSIS

In order to support the analysis of food security and comparative advantage in Senegal, data were collected and organized in the form of 181 crop budgets. These crop budgets provide insights on the most profitable crops and technologies in each region and also serve as data base for the construction of farm models described in Chapter 5.

These budgets cover all agricultural areas in Senegal, divided in 11 zones (see Figure 28). Only the presently or potentially major crops in each zone are considered. Several technical modules are distinguished to reflect the main technologies possible for each crop in Senegal. The most often used variety is considered for each crop.

Each crop budget consists of four parts:

1) A calculation of the revenues and the costs;
2) The calculation of four types of margins: gross or net of fixed costs, with or without labor cost;
3) The labor calendar describing the labor requirements by critical period for each crop and each technical module;
4) The animal traction calendar describing the labor requirements by

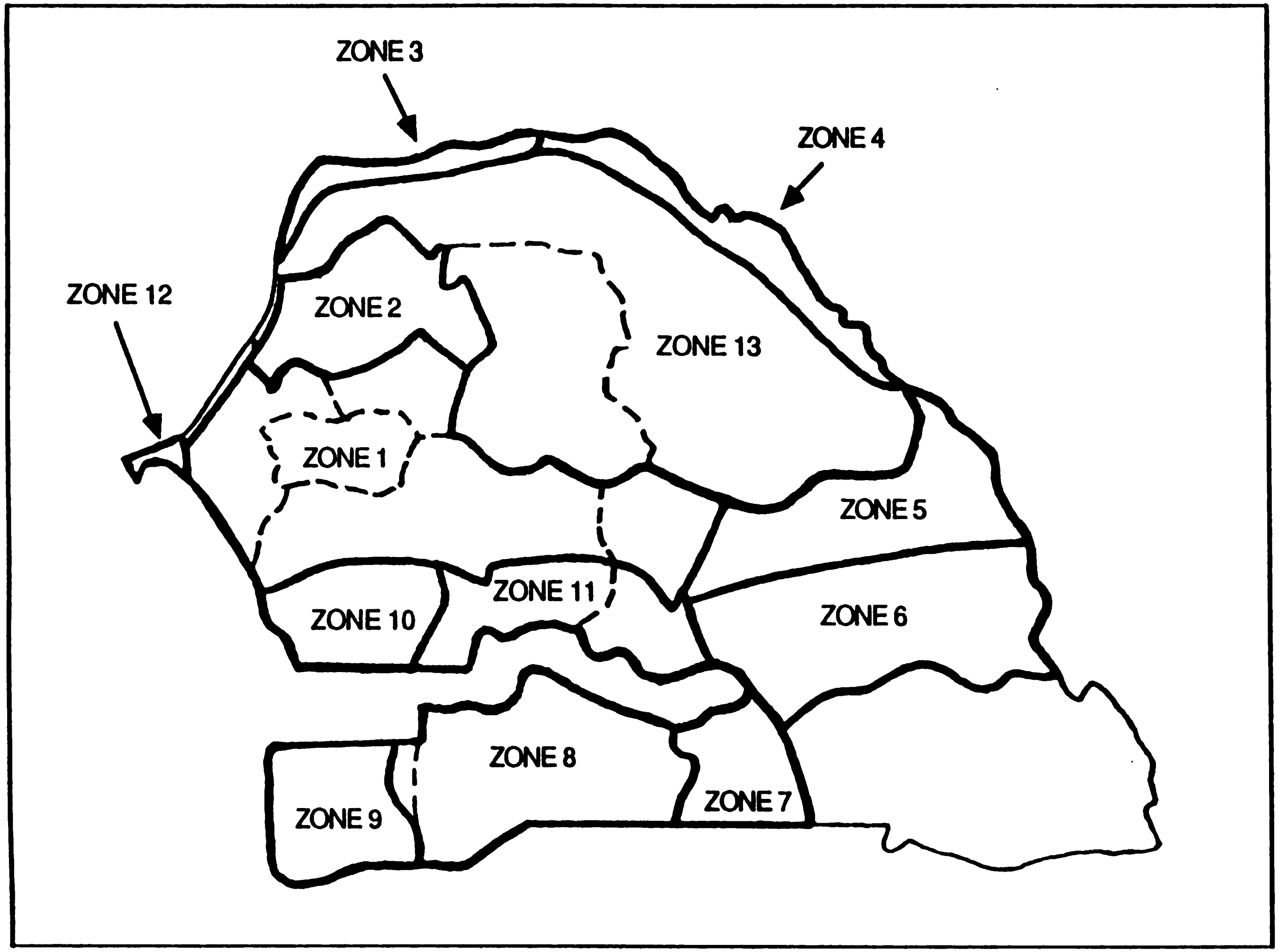

FIGURE 28

MAP OF ALL ZONES CONSIDERED IN SENEGAL FOR THIS RESEARCH critical period for each crop and each technical module.

All these figures are on a per hectare basis. The data used to elaborate those crop budgets come from several sources. First, existing and available crop budgets for Senegal were reviewed. This analysis was difficult because of the variety of assumptions made by each study, in particular regarding labor requirements.

Then, in-depth interviews were conducted with researchers from ISRA, WARDA and Regional Development Agencies. Researchers provided information on yields, timing, and labor and machinery requirements based on their experience, on agronomic experiments, and on results from recent farm surveys conducted as part of farming systems research projects. A strong effort was made to obtain a consistent set of data to make possible comparisons between technical modules, crops and zones.[1]

4.1 - Methodology used to elaborate the crop budgets

4.1.1 - Agricultural zones

Senegal was divided in thirteen zones, including eleven agricultural zones, based on the following criteria:

1) physical: soils, climate, vegetation;
2) human: ethnic group, human density;
3) agricultural: crops, level and type of agricultural equipment.

Below is a short description of each agricultural zone (see Figure 28).

- Zone 1: Center of the Groundnut Basin

This relatively large zone is historically the major agricultural

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[1]See Martin (1988) for details on crop budgets.

zone in Senegal. This zone benefitted greatly from the so-called "Agricultural Program" of credit before its disappearance in 1980, which explains a relatively high level of agricultural equipment. The major crops are millet/sorghum, groundnuts and now cowpeas in the northern part.

- Zone 2: North of the Groundnut Basin

This zone is changing rapidly as a result of the drought. Following the government's recommendations, this zone is progressively replacing groundnuts by cowpeas, so that the two major crops in the future will be millet/sorghum and cowpeas.

- Zone 3: Large irrigated perimeters of the Delta and of the Lower Middle Valley of the Senegal River

This zone is characterized by the importance of large irrigated perimeters. There are also a few small perimeters, but they can be assimilated to the large perimeters in terms of cultivation techniques (direct seeding, perimeter construction and land preparation done by SAED, the parastatal in charge of irrigation development in the Senegal River Basin).

Most of the soils in the Delta are heavy (hollalde) and salty, which limits the crop possibilities to rice and sorghum in that part of zone 3. However, in the beginning of the Middle Valley, soils become less heavy and salty, which makes it possible to grow maize and tomato.

There are three cropping seasons on irrigated perimeters: the rainy season (June to October), the cold off-season (November to March) and the hot off-season (March to July). So far, double cropping is very limited, but could expand with the completion of the Manantali dam in

1988. Rainfed cultivation of millet (dieri) has become marginal with the drought.

- Zone 4: Middle Valley of the Senegal River

This zone is characterized by irrigated cultivation on small perimeters and by the possibility of flood-recession cultivation (oualo) in the years of good rainfall in Guinea where the Senegal river starts. The mix of heavy soils (40 % of hollalde) and light soils (60 % of fonde) makes it possible to grow rice, maize, sorghum and tomato. As in zone 3, the rainfed cultivation of millet is now marginal.

- Zone 5: Upper Valley of the Senegal River and North of Eastern Senegal

This zone is characterized by irrigated cultivation on small perimeters and by the possibility of rainfed cultivation (dieri) during the years of good rainfall in that zone. The light soils (fonde) make it possible to grow rice, maize and tomato. Tomato is not grown much now, partly as a result of the absence of a marketing network in that zone. Rainfed crops are similar to those in zone 1, i.e., millet/ sorghum, groundnuts and cowpeas.

- Zone 6: Center of Eastern Senegal

This zone possesses an important agricultural potential with the possibility of growing maize and cotton apart from millet/sorghum and groundnuts. This potential has not been fully exploited so far because of the limited human density and the limited equipment owned by farmers in that zone.

- Zone 7: Upper Casamance

This zone has similar characteristics to zone 6. The major differences between the two zones are a slightly higher rainfall and the development of rainfed rice and lowland rice in Upper Casamance. The Peulhs are the main ethnic group.

- Zone 8: Middle Casamance

The originality of this zone comes mainly from its ethnic composition dominated by Mandingues and "Mandinguized" Diolas although there are also some Peulhs. In the Mandingue and "Mandinguized" Diola villages, each sex works on different types of land. Women grow lowland and aquatic rice while men grow upland crops (groundnuts, millet/sorghum, maize, rainfed rice).

It is also possible to grow cotton on the plateau, but this is still a minor crop.

- Zone 9: Lower Casamance[1]

This zone is mainly a Diola area although there are Mandingues in the Southeast. In the Diola villages, each sex does different agricultural operations. Men do the the operations requiring physical strength, in particular ploughing. Women do the operations which are less demanding physically. However, men can come and help women in their operations if there is a labor bottleneck.

Two other characteristics of Lower Casamance are its important

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[1]Zone 9 does not correspond exactly to the traditional definition of Lower Casamance since zone 9 excludes the northeast of the traditional Lower Casamance. This area is attached to Middle Casamance (zone 8) with which it shares more similarities.

aquatic area on which transplanted rice is grown and the absence of animal traction, except in the north.

- Zone 10: Southwest of the Groundnut Basin

In this zone, the importance of very sandy soils prevents the cultivation of maize. Millet/sorghum and groundnuts are the major crops. Animal traction is mainly cattle traction.

- Zone 11: Southeast of the Groundnut Basin

This zone has the biggest agricultural potential of the Groundnut Basin because of i) its soil fertility, ii) the possibility of growing maize and, up to a certain extent, cotton apart from millet/sorghum and groundnuts, and iii) the relatively high level of agricultural equipment.

The parts of Senegal excluded from the agricultural zones described above are the following:

- The Cap Vert area, considered as an urban area and called zone 12.
- The dunes zone of the Niayes, which goes from Dakar to St. Louis;
- The livestock grazing area of Ferlo, called zone 13.
- The department of Kedougou, in the lower part of Eastern Senegal, because of its low agricultural potential, limited by the low human density, the presence of dangerous human diseases and the existence of the Niokolo-Koba park.

4.1.2 - Technical modules

Technical modules are alternative input/output combinations based on different levels of input use. They vary by crop and by zone. They represent the major agricultural technologies available in Senegal. In general, five major types of modules are distinguished:

- Module 1

Module 1 represents the recommendations of agronomic research adapted to the farm environment. This means a high level of intensification which, in general, implies the use of a large quantity of fertilizer, the use of crop protection products, good land preparation and weeding with a high use of animal traction. All these result in high yields. This module is still rare or even nonexistent, depending on the zone and the crop.

- Modules 2 and 3

Modules 2 and 3 represent decreasing levels of intensification (respectively average and low) compared to module 1. These modules represent the traditional modes of production and are much more often used than module 1.

- Module 4

Module 4 concerns the home gardens ("champs de case") cultivated around villages to ensure a certain level of food security for the farmer's family. These maize and millet/sorghum fields are cultivated first, to obtain a harvest during the hungry season.

These fields receive particular care. Cultivation is mainly manual and does not include the use of chemical fertilizers. However, organic fertilization is common practice.

The home gardens represent a small part of the area cultivated by the farmer (between 5 and 10 % approximately) and, therefore, are not enough to cover the cereal needs of the farm family. But their importance in the farmer's food security strategy argues for the elaboration of a separate module.

- Module 5

Module 5 represents late cultivation relative to the optimal calendar of a given crop. This may result from a labor bottleneck or from the absence of germination after the first seeding. The yields for that module are very low because of the delay from the optimal crop calendar and of the low level of intensification.

Table 2 summarizes the crops and the corresponding number of technical modules in each zone.

4.1.3 - Agricultural inputs

For each zone, each crop, and each technical module, the agricultural equipment and animal traction used were first specified. The cost per hectare of each piece of equipment was then estimated in two steps. First, an annual cost was estimated incorporating depreciation and annual repairs. Second, the cost per hectare was estimated by dividing the annual cost by the estimated number of uses of the piece of equipment. This number of uses was estimated for a typical farm in each zone.

The cost of animal traction was estimated in a similar way to the cost of agricultural equipment. Annual costs included the cost of the typical feed ration by zone and by animal and animal health care. The possible gain resulting from the difference from the purchase price and the selling price was estimated, but not included in the annual cost because it was considered a separate activity from agriculture.

The costs of seeds, fertilizers, crop protection products were also incorporated. Labor cost was included as well, using the wage of agricultural labor to price it.

TABLE 2

CROPS AND TECHNICAL MODULES IN THE DIFFERENT ZONES OF SENEGAL

Zone number	Zone name	Crop	Number of modules by crop	Number of modules by zone
1	Center of the Groundnut Basin	millet/sorghum	5	
		cowpeas	2	
		groundnuts	4	11
2	North of the Groundnut Basin	millet/sorghum	4	
		cowpeas	2	6
3	Large irrigated perimeters:			
	- Delta of the Senegal River	rice	8	
		sorghum	4	12
	- Lower Middle Valley of the Senegal River	rice	8	
		sorghum	4	
		maize	4	
		tomato	2	18
4	Middle Valley of the Senegal River:			
	- small irrigated perimeters	rice	4	
		sorghum	4	
		maize	4	
		tomato	2	
	- flood recession	sorghum	2	16
5	Upper Valley of the Senegal River and North of Eastern Senegal:			
	- small irrigated perimeters	rice	4	
		sorghum	4	
		maize	4	
		tomato	2	
	- rainfed cultivation	millet/sorghum	5	
		cowpeas	2	
		groundnuts	4	25

TABLE 2 (CONT'D.)

Zone number	Zone name	Crop	Number of modules by crop	Number of modules by zone
6	Center of Eastern Senegal	millet/sorghum	5	
		maize	3	
		groundnuts	4	
		cotton	4	16
7	Upper Casamance	millet/sorghum	5	
		maize	3	
		rainfed rice	3	
		lowland rice	5	
		groundnuts	4	
		cotton	4	24
8	Middle Casamance	millet/sorghum	5	
		maize	3	
		rainfed rice	3	
		lowland rice	5	
		groundnuts	4	
		cotton	4	24
9	Lower Casamance	millet/sorghum	5	
		maize	4	
		lowland rice	5	
		transplanted rice	2	
		groundnuts	4	20
10	Southwest of the Groundnut Basin	millet/sorghum	5	
		groundnuts	4	9
11	Southeast of the Groundnut Basin	millet/sorghum	5	
		maize	3	
		groundnuts	4	12
Total	Senegal			181

NB: In the total for Senegal, the rice and sorghum modules for zone 3 are counted only once rather than twice (one for the Delta and one for the beginning of the Middle Valley).

4.1.4 - Crop calendar and labor requirements

The crop calendar was divided into periods during which a number of agricultural or post-harvest operations have to be done for each crop grown according to a given technical module in a given region. The number and the duration of periods vary from zone to zone to reflect climatic differences and types of cultivation. The number of periods goes from 4 to 24 and the duration from 2 weeks to 15 weeks.

It is difficult to estimate labor times required for agricultural operations because of the diversity of farmers and animals with regard to the duration and the quality of the work done. In order to take into account this diversity, different qualities of work were distinguished for a number of manual operations.

An effort was made to obtain a consistent set of data across crops and across zones. However, these labor times must be considered as approximations.

4.1.5 - Yields and states of nature

Rainfed crop yields vary a lot from year to year, mainly as a result of changing rainfall conditions. To account for this diversity, yields were estimated for three types of year: bad, average and good. Of course, the definition of these types of year varies from crop to crop according to each crop's particular requirements.

To be able to compare margins from crop to crop, 15 states of nature were distinguished in each zone. Each state of nature corresponds to one out of five categories of rainfall quantity and one out of three categories of rainfall distribution. Rainfall quantity can be very low, low, average, high or very high. Rainfall distribution over a period of five months (June to October) can be bad, average or good.

Let us make the following definitions:

q_t : Quantity of rainfall for year t (t = 1,n) in millimeters per year;

Q : Average quantity of rainfall for the n observations.

$month_{mt}$: Rainfall during month m (m = 1,5) of year t (t = 1,n);

$MONTH_m$: Average rainfall during month m for the n years;

e_t : Rainfall deviation from the mean for year t calculated with the following formula:

$$e_t = \sum_m \{ (month_{mt} - MONTH_m)^2 \}^{1/2} \quad m = 1,5$$

E : Average rainfall deviation for the n years calculated with the following formula:

$$E = 1/n \sum_t e_t$$

Table 3 shows the definition of each category for rainfall quantity and distribution. Table 4 indicates the definition of each state of nature. The probability of occurrence of each state of nature was estimated using monthly rainfall data from 1951 to 1986 for each agricultural zone (see Table 5).

Yields were estimated for each state of nature and each crop in each zone, based on an algebraic combination of the three basic yields collected for bad, average and good years (see Table 6). These estimations were made on the basis of several agronomists' opinions about the response of the particular crops to different rainfall conditions in Senegal. However, it was impossible to incorporate all the agronomic considerations that influence yields into 15 states of

TABLE 3

DEFINITION OF THE CATEGORIES OF RAINFALL QUANTITY AND DISTRIBUTION IN SENEGAL

Category	Characteristics
Rainfall quantity	
Very low	$q_t < 0.7\ Q$
Low	$0.7\ Q < q_t < 0.9\ Q$
Average	$0.9\ Q < q_t < 1.1\ Q$
High	$1.1\ Q < q_t < 1.3\ Q$
Very high	$1.3\ Q < q_t$
Rainfall distribution	
Bad	$e_t > E * 1.25$
Average	$E * 1.25 > e_t > E * 0.75$
Good	$E * 0.75 > e_t$

where:

q_t : Quantity of rainfall for year t.

Q : Average quantity of rainfall for the n observations.

e_t : Rainfall deviation from the mean for year t.

E : Average rainfall deviation for the n years.

TABLE 4

DEFINITION OF THE STATES OF NATURE IN SENEGAL

Rainfall distribution	Rainfall quantity				
	Very low	Low	Average	High	Very high
Bad	State 1	State 2	State 3	State 4	State 5
Average	State 6	State 7	State 8	State 9	State 10
Good	State 11	State 12	State 13	State 14	State 15

TABLE 5

PROBABILITY OF OCCURRENCE OF THE STATES OF NATURE

BY ZONE OF RAINFED CULTIVATION IN SENEGAL

(in percentage)

State of nature	Zone								
	1	2	5	6	7	8	9	10	11
1	0	11.1	5.6	0	0	5.6	8.3	0	6.3
2	2.8	0	2.8	0	2.9	0	0	3	0
3	2.8	0	2.8	0	5.9	2.8	2.8	3	0
4	2.8	0	0	2.8	2.9	0	2.8	3	6.3
5	11.1	8.3	11.1	11.1	14.7	8.3	11.1	12.1	12.5
6	25	13.9	8.3	13.9	0	5.6	5.6	15.2	12.5
7	5.6	2.8	8.3	16.7	26.5	13.9	11.1	6.1	6.3
8	13.9	5.6	13.9	16.7	11.8	16.7	19.4	21.2	15.6
9	5.6	8.3	5.6	13.9	5.9	19.4	11.1	3	9.4
10	5.6	13.9	5.6	0	0	0	2.8	9.1	3.1
11	0	5.6	0	0	0	0	0	0	0
12	5.6	16.7	13.9	2.8	11.8	11.1	5.6	15.2	3.1
13	8.3	8.3	13.9	13.9	17.6	16.7	16.7	9.1	21.9
14	11.1	0	8.3	8.3	0	0	2.8	0	3.1
15	0	5.6	0	0	0	0	0	0	0

Note: The rainfall data used are for the following cities:

Zone 1 : Diourbel
Zone 2 : Louga
Zone 5 : Bakel
Zone 6 : Tambacounda
Zone 7 : Vélingara
Zone 8 : Kolda
Zone 9 : Ziguinchor
Zone 10: Nioro du Rip
Zone 11: Koungheul

Source: "Direction de la Météorologie Nationale" for monthly rainfall data from 1951 to 1986.

TABLE 6

ASSUMPTIONS ABOUT CROP YIELDS FOR EACH STATE OF NATURE IN SENEGAL

Rainfall distribution	Rainfall quantity				
	Very low	Low	Average	High	Very high
			Millet/sorghum		
Bad	MA*0.9	MA*1.1	MO	MO	MA
Average	MA*1.1	MO	BO	BO	MO
Good	MO	BO*0.9	BO*1.2	BO*1.2	BO
			Maize		
Bad	MA*0.7	MA	MO	MA	MA*0.7
Average	MA*0.9	MO	BO	MO	MA
Good	(MA+MO)/2	(MO+BO)/2	BO*1.2	BO	MO
			Rice		
Bad	MA*0.6	MA*0.8	MA	MO	BO
Average	MA*0.8	MA	MO	BO	BO*1.1
Good	MA	MO	BO	BO*1.1	BO*1.2
			Cowpeas		
Bad	MA	(MA+MO)/2	MO	(MA+MO)/2	MA
Average	(MA+MO)/2	MO*1.1	BO	MO*1.1	(MA+MO)/2
Good	MO*1.1	BO	BO*1.2	BO	MO*1.1
			Groundnuts		
Bad	MA*0.9	MA*1.1	MO	(MA+MO)/2	MA*1.1
Average	MA*1.1	MO	BO	(MO+BO)/2	MO
Good	MO	BO*0.9	BO*1.2	BO	(MO+BO)/2
			Cotton		
Bad	MA*1.1	MO*0.9	MO	(MA+MO)/2	MA*1.1
Average	MO*0.9	(MO+BO)/2	BO	(MO+BO)/2	MO*0.9
Good	MO*1.2	BO*1.1	BO*1.2	BO	MO*1.2

NB: MA means estimated yield in a bad year.
MO means estimated yield in an average year.
BO means estimated yield in a good year.

nature. Only the major factors were taken into account.

In irrigated cultivation, the yield and the state of nature are not correlated, except during the hot-off season. In the rainy season and the cold off-season, the yield is relatively stable from year to year for a given technical module. However, a number of climatic events can negatively affect the yield during the hot off-season.

For irrigated crops, a unique yield is assumed for the rainy season and the cold off-season, and three possible yields are assumed for the hot off-season corresponding to bad, average and good years.

For flood recession crops, the yields are relatively stable from year to year; rainfall influences them only marginally. Flood recession crops are treated like irrigated crops during the cold off-season, i.e., a unique yield is specified.

4.1.6 - Input and output prices

Input and output prices used in the budgets are 1986-87 farm-gate prices in each zone. Input prices exclude temporary subsidies on input prices, but include subsidies that have existed for a long time.

Valuing labor is difficult, since there is no well-organized agricultural labor market. Labor is valued at a cost similar to the agricultural wage received by temporary agricultural workers who perform certain operations, such as paddy rice threshing.

Cash crops, i.e., groundnut shells and cotton, and rice in the Senegal River Basin, are sold by the farmer at the official producer price set each year by the government.

The other rice producing area, Casamance, has a large deficit for that cereal and most of the production is home consumed. Therefore, the opportunity cost of producing rice is the official consumer price of rice converted into paddy equivalent.

Tomatoes grown in the Senegal River Basin can be sold at the official price to the companies that manufacture tomato paste. The farmer can also sometimes sell his production to private traders at a higher price. The official price was used in the budgets.

The other agricultural products, i.e., millet/sorghum, maize, cowpeas, cowpea hay and groundnut hay are valued at their market price. This price depends mainly on the supply in any given year, which is in turn largely a function of the state of nature. Therefore, market prices were estimated for these products in each state of nature and each zone, based on data available from market price surveys.

4.2 - Crop margin analysis

In order to identify the most profitable crops and technical modules from the farmer's perspective, crop margins are calculated on the basis of current input and output prices, i.e., in financial terms. This analysis does not evaluate economic profitability based on the use of shadow prices intended to represent the opportunity cost of inputs and of outputs, nor does it not consider the food security objective of the farmer. Both considerations are analyzed in the modelling exercise presented in the next two chapters.

Four margins were calculated for each combination of crop, technical module, and zone:

- The gross margin with labor cost, i.e., gross revenue minus variable costs including labor cost;
- The gross margin without labor cost, i.e., gross revenue minus

variable costs excluding labor cost;

- The net margin with labor cost, i.e., gross revenue minus fixed costs minus variable costs including labor cost;
- The net margin without labor cost, i.e., gross revenue minus fixed costs minus variable costs excluding labor cost.

These margins were calculated on a per hectare basis as well as on a per man-day basis. The margins per hectare were ranked for the worst possible state of nature (state 1) and for the most frequent states of nature in each zone.

For rainfed cultivation zones, margins were first ranked by technical module to identify the most profitable crops for a given level of intensification. Only modules 1, 2 and 3 were considered in that ranking since they correspond respectively to high, medium and low levels of intensification.

A second ranking was made including all crops and all technical modules for a given zone to find the most profitable crops and modules overall in that zone. All five technical modules were included in that ranking.

For irrigated zones, the ranking by module is not relevant since most irrigated crop budgets were built for only one level of intensification. This ranking was replaced by a ranking by the number of crops per year, i.e., single or double cropping.

Apart from the ranking by zone, two rankings were made at the national level. First, margins in the different regions where a given crop is grown were ranked to determine where it made most sense to promote the crop.

Second, a ranking was made across all crops and all zones to identify the most profitable agricultural activities in Senegal. Both kinds of national rankings were made for state of nature 8, which corresponds to average rainfall quantity and distribution.

Overall, 724 rankings were made. A summary of the rankings and their policy implications is presented below.[1] The rankings by zone are discussed first. The zones have been combined into three regions: the Groundnut Basin, Eastern Senegal and Casamance, and finally the Senegal River Basin.

4.2.1 - Margin analysis for the Groundnut Basin

The Groundnut Basin combines four zones: the Center (zone 1), the North (zone 2), the Southwest (zone 10) and the Southeast (zone 11). The margin rankings for these zones are presented in Tables 7, 8, 9, and 10 respectively.

Three important issues arise in that region:

1) Are cowpeas more profitable than groundnuts?
2) What is the potential for cereals production expansion in that region to contribute to the government's objective of 80% food self-sufficiency in year 2000?
3) Is production intensification financially attractive?

The first issue is important for the center and the north of the Groundnut Basin. Faced with declining yields in the North (zone 2), especially for groundnuts, the Senegalese government is promoting the substitution of cowpeas for groundnuts since cowpeas are more resistant

[1]For a complete presentation of the rankings, see Martin (1988).

TABLE 7

MARGIN RANKINGS IN THE CENTER OF THE GROUNDNUT BASIN (ZONE 1)

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification for states of nature 1, 5, 6, 8 and 14. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.

Rank	GMWL	GMNL	NMWL	NMNL
1	Groundnuts	Cowpeas	Groundnuts	Groundnuts
1				Cowpeas
2	Mil./sorg.	Groundnuts	Mil./sorg.	
3	Cowpeas	Mil./sorg.	Cowpeas	Mil./sorg.

2 - Rankings for all technical modules

One ranking was made for each state of nature 1, 5, 6, 8 and 14. To summarize those rankings, the average rank for a given crop was calculated and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Groundnuts	Cowpeas	Groundnuts	Cowpeas
2	Mil./sorg.	Groundnuts	Mil./sorg.	Groundnuts
3	Cowpeas	Mil./sorg.	Cowpeas	Mil./sorg.

TABLE 8

MARGIN RANKINGS IN THE NORTH OF THE GROUNDNUT BASIN (ZONE 2)

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification for states of nature 1, 6, 10 and 12. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.

Rank	GMWL	GMNL	NMWL	NMNL
1	Mil./sorg.	Cowpeas	Mil./sorg.	Cowpeas
2	Cowpeas	Mil./sorg.	Cowpeas	Mil./sorg.

2 - Rankings for all technical modules

One ranking was made for each state of nature 1, 6, 10 and 12. To summarize those rankings, the average rank for a given crop was calculated over all technical modules and then a ranking of the average ranks was made. Since this table is the same as the above table, it is not repeated.

TABLE 9

MARGIN RANKINGS IN THE SOUTHWEST OF THE GROUNDNUT BASIN (ZONE 10)

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification for states of nature 1, 5, 6, 8 and 12. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.

Rank	GMWL	GMNL	NMWL	NMNL
1	Groundnuts	Groundnuts	Groundnuts	Groundnuts
2	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.

2 - Rankings for all technical modules

One ranking was made for each state of nature 1, 5, 6, 8 and 12. To summarize those rankings, the average rank for a given crop was calculated over all technical modules and then a ranking of the average ranks was made. Since this table is the same as the above table, it is not repeated.

TABLE 10

MARGIN RANKINGS IN THE SOUTHEAST OF THE GROUNDNUT BASIN (ZONE 11)

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification for states of nature 1, 5, 6, 8 and 13. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.

Rank	GMWL	GMNL	NMWL	NMNL
1	Groundnuts	Groundnuts	Groundnuts	Groundnuts
2	Maize	Maize	Maize	Maize
3	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.

2 - Rankings for all technical modules

One ranking was made for each state of nature 1, 5, 6, 8 and 13. To summarize those rankings, the average rank for a given crop was calculated over all technical modules and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Maize	Maize	Maize	Maize
2	Groundnuts	Groundnuts	Groundnuts	Groundnuts
3	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.

to drought than groundnuts. While the decline of groundnut cultivation seems inevitable in zone 2, it is worth looking at the comparative profitability of cowpeas and groundnuts further south in the Center of the Groundnut Basin.

One problem with cowpea cultivation is the significant labor requirements, in particular for manual harvest. For example, module 2 in an average year requires 95 man-days for cowpeas compared with 42 for millet/sorghum and 38 for groundnuts.

As a result, cowpeas are last after groundnuts and millet/sorghum in the rankings by module according to the margins with labor cost, whatever the intensification level. However, in the rankings according to the margins without labor cost, cowpeas rank higher in general than millet/sorghum and sometimes higher than groundnuts.

Cowpea cultivation implies slightly higher fixed costs than those for groundnuts because of the insecticide sprayings, which require a sprayer. Therefore, cowpeas rank better according to the gross margin than according to the net margin.

Cowpeas can be considered as a potential alternative to groundnut if the producer can mobilize enough labor at harvest time and if the insecticides required for cowpeas cultivation are available at the right time. This conclusion depends on the assumption made for cowpea price. The government policy pushing producers to raise the area planted in cowpeas will probably result in an increased supply.

The capacity of domestic or foreign demand to absorb this extra supply and the evolution of the cowpea price is hard to estimate precisely. Presumably, cowpea prices will fall from their past level.

In the past, prices of 250 or 300 CFA Francs per kilo could be found on local markets. The cowpea budget assumes an average price of 100 CFAF, a low of 60 CFAF and a high of 140 CFAF per kilo. These prices were based on the most recent price data, and on experts' opinions.

The second important issue in that zone concerns the development of cereals cultivation, which is a government priority. One important requirement for the expansion of cereal area cultivated is that cereals should be more profitable than other crops, in particular groundnuts. The rankings give ideas about the present relative profitability of the different cereals. The conclusions are different depending on the cereal.

In all the zones covering the Groundnut Basin, millet/sorghum is almost always less profitable than groundnuts whatever the type of margin, gross or net, with or without labor cost and whatever the level of intensification. Thus, it is hard to see the financial interest to the farmer of increasing his millet/sorghum production for sale under present price conditions. This does not mean that millet/sorghum is not an interesting crop, in particular from a food security perspective at the farm level.

In the rankings with all crops and all modules, module 4 (home garden) for millet/sorghum is often highly placed. This position can be explained by the limited use of inputs by this module and by the good manual care given, which results in high yields. One must remember that this module is not grown for sale, but to contribute to the farm household's food security. In any case, areas reserved for these home gardens are limited to the village surroundings and could not be expanded significantly.

Maize is ranked much higher than millet/sorghum. In the Southeast of the Groundnut Basin, which is the only zone of the Groundnut Basin where it can be grown, maize is more profitable than groundnuts in a low rainfall year and comes just after groundnuts in an average or high rainfall year.

This difference in ranking can be explained partly by the difference in the price setting mechanisms for the two crops. Groundnuts are sold at the official producer price which does not vary according to the yield. This means that yield variations are automatically translated into income variations.

On the other hand, maize is sold at the market price which fluctuates inversely to supply. If we assume a positive correlation between the typical farm yield and the market supply, the market price of maize will fluctuate inversely to the yield variations, which results in a certain income stabilization.

As a result of this difference in price setting mechanisms, the groundnut income falls more than the maize income in a low rainfall year. Conversely, in a high rainfall year, the groundnut income increases more than the maize income.

The third issue concerns the financial attractiveness of intensified production. The highest intensification level (module 1) is financially attractive in a good rainfall year. However, in a low rainfall year, the best modules are module 3 for groundnuts and millet/sorghum and module 2 for cowpeas (module 3 does not exist for that crop). These results seem logical since the high input costs of module 1 are worthwhile only in the case of good rainfall, which converts the high level of intensification into high yields.

This is another illustration of the classical correlation between the level of profit and the level of risk. The level of intensification chosen by the farmer depends on his risk aversion. Given the important climatic vagaries, the persistence of the drought, and the subsistence orientation of many farmers in that region, especially in the northern part, the level of intensification chosen is likely to be average or even low.

The late planting module is in general not very attractive financially, but one must realize that the alternative to that module is not another module, but not to plant at all. If there is a labor bottleneck during the normal planting period, the farmer may well decide to do some late planting with the idea that the resulting yield, however small, will at least cover the seeds used and bring some surplus.

4.2.2 - Margin analysis for Eastern Senegal and Casamance

Eastern Senegal (zone 6) and Casamance (zones 7, 8 and 9) benefit from better climatic conditions than the Groundnut Basin. This means yields are higher and the range of crops that can be grown is wider in general. The margin rankings are presented in Tables 11 to 17.

Three policy issues arise in those regions:

1) Are maize and cotton financially attractive?

2) Are the different types of rice cultivation profitable?

3) Is production intensification attractive financially?

Maize and cotton are two crops that could potentially be developed

TABLE 11

MARGIN RANKINGS IN THE CENTER OF EASTERN SENEGAL (ZONE 6)

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification in states of nature 1, 6, 7, 8, 9 and 13. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.

Rank	GMWL	GMNL	NMWL	NMNL
1	Groundnuts	Groundnuts	Groundnuts	Groundnuts
1	Maize		Maize	
2		Maize		Maize
3	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.
4	Cotton	Cotton	Cotton	Cotton

2 - Rankings for all technical modules

A ranking was made for each state of nature 1, 6, 7, 8, 9, and 13. To summarize those rankings, an average rank was calculated for each crop over all technical modules and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Maize	Maize	Maize	Maize
2	Groundnuts	Groundnuts	Groundnuts	Groundnuts
3	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.
4	Cotton	Cotton	Cotton	Cotton

TABLE 12

MARGIN RANKINGS IN UPPER CASAMANCE (ZONE 7) WITH LOW RAINFALL

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification in states of nature 1 and 7. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.
Low. rice means lowland rice.
Rain. rice means rainfed rice.

Rank	GMWL	GMNL	NMWL	NMNL
1	Groundnuts	Groundnuts	Groundnuts	Groundnuts
2	Maize	Maize	Maize	Maize
2	Mil./sorg.		Mil./sorg.	
3	Cotton	Cotton		Mil./sorg.
3				Cotton
4		Mil./sorg.	Cotton	
5	Low. rice	Low. rice	Low. rice	Low. rice
6	Rain. rice	Rain. rice	Rain. rice	Rain. rice

2 - Rankings for all technical modules

A ranking was made for each state of nature 1 and 7. To summarize those rankings, an average rank was calculated for each crop over all technical modules and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Groundnuts	Groundnuts	Groundnuts	Groundnuts
2	Maize	Maize	Maize	Maize
3	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.
4	Cotton	Cotton	Cotton	Cotton
5	Low. rice	Low. rice	Low. rice	Low. rice
6	Rain. rice	Rain. rice	Rain. rice	Rain. rice

TABLE 13

MARGIN RANKINGS IN UPPER CASAMANCE (ZONE 7) WITH HIGH RAINFALL

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification in states of nature 5 and 13. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.
Low. rice means lowland rice.
Rain. rice means rainfed rice.

Rank	GMWL	GMNL	NMWL	NMNL
1	Rain. rice	Low. rice	Low. rice	Low. rice
1	Low. rice		Groundnuts	
2	Groundnuts	Groundnuts	Rain. rice	Rain, rice
2	Maize			Groundnuts
3	Mil./sorg.	Rain. rice	Mil./sorg.	
3			Maize	
4	Cotton	Cotton	Cotton	Maize
4				Mil./sorg.
5		Maize		Cotton
6		Mil./sorg.		

2 - Rankings for all technical modules

A ranking was made for each state of nature 5 and 13. To summarize those rankings, an average rank was calculated for each crop over all technical modules and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Rain. rice	Low. rice	Rain. rice	Low. rice
2	Low. rice	Rain. rice	Low. rice	Rain. rice
3	Groundnuts	Groundnuts	Groundnuts	Groundnuts
4	Maize	Maize	Maize	Maize
5	Mil./sorg.	Cotton	Mil./sorg.	Mil./sorg.
6	Cotton	Mil./sorg.	Cotton	Cotton

TABLE 14

MARGIN RANKINGS IN MIDDLE CASAMANCE (ZONE 8) WITH LOW RAINFALL

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification in states of nature 1 and 7. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.
Low. rice means lowland rice.
Rain. rice means rainfed rice.

Rank	GMWL	GMNL	NMWL	NMNL
1	Groundnuts	Groundnuts	Groundnuts	Groundnuts
1	Maize			
2		Maize	Maize	Maize
3	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.
4	Cotton	Cotton	Cotton	Cotton
5	Low. rice	Low. rice	Low. rice	Low. rice
5			Rain. rice	
6	Rain. rice	Rain. rice		Rain. rice

2 - Rankings for all technical modules

A ranking was made for each state of nature 1 and 7. To summarize those rankings, an average rank was calculated for each crop over all technical modules and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Maize	Groundnuts	Groundnuts	Groundnuts
2	Groundnuts	Maize	Maize	Maize
3	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.
4	Cotton	Cotton	Cotton	Cotton
6	Low. rice	Low. rice	Low. rice	Low. rice
5	Rain. rice	Rain. rice	Rain. rice	Rain. rice

TABLE 15

MARGIN RANKINGS IN MIDDLE CASAMANCE (ZONE 8)

WITH AVERAGE AND HIGH RAINFALL

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification in states of nature 5, 8, 9 and 13. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.
Low. rice means lowland rice.
Rain. rice means rainfed rice.

Rank	GMWL	GMNL	NMWL	NMNL
1	Low. rice	Low. rice	Low. rice	Low. rice
1	Rain. rice	Rain. rice	Rain. rice	Rain. rice
2	Groundnuts	Groundnuts	Groundnuts	Groundnuts
4	Maize	Maize	Maize	Maize
4		Cotton		
5	Mil./sorg.		Mil./sorg.	Mil./sorg.
6	Cotton	Mil./sorg.	Cotton	Cotton

2 - Rankings for all technical modules

A ranking was made for each state of nature 5, 8, 9 and 13. To summarize those rankings, an average rank was calculated for each crop over all technical modules and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Trans. rice	Trans. rice	Trans. rice	Trans. rice
2	Low. rice	Low. rice	Low. rice	Low. rice
3	Maize	Groundnuts-Maize	Maize	Groundnuts
4	Groundnuts		Groundnuts	Maize
5	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.

TABLE 16

MARGIN RANKINGS IN LOWER CASAMANCE (ZONE 9) WITH LOW RAINFALL

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification in states of nature 1 and 7. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.
Low. rice means lowland rice.
Trans. rice means transplanted rice.

Rank	GMWL	GMNL	NMWL	NMNL
1	Trans. rice	Trans. rice	Trans. rice	Trans. rice
1	Maize		Maize	
2		Groundnuts	Groundnuts	Groundnuts
2				Maize
3	Groundnuts	Maize		
4	Mil./sorg.	Mil./sorg.	Mil./sorg.	
5	Low. rice	Low. rice	Low. rice	Low. rice

2 - Rankings for all technical modules

A ranking was made for each state of nature 1 and 7. To summarize those rankings, an average rank was calculated for each crop over all technical modules and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Trans. rice	Trans. rice	Trans. rice	Trans.rice
2	Maize	Groundnuts	Groundnuts-Maize	Groundnuts
3	Groundnuts	Maize		Maize
4	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.
5	Low. rice	Low. rice	Low. rice	Low. rice

TABLE 17

MARGIN RANKINGS IN LOWER CASAMANCE (ZONE 9)

WITH AVERAGE AND HIGH RAINFALL

1 - Rankings for all levels of intensification

One ranking was made for each of the three levels of intensification in states of nature 5, 8, 9 and 13. To summarize those rankings, the most often encountered rank for a crop is given to that crop in the table below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg. means millet/sorghum.
Low. rice means lowland rice.
Trans. rice means transplanted rice.

Rank	GMWL	GMNL	NMWL	NMNL
1	Trans. rice	Trans. rice		Trans. rice
1	Low. rice	Low. rice	Low. rice	
2			Trans. rice	Low. rice
3	Groundnuts	Groundnuts	Groundnuts	Groundnuts
3	Maize		Maize	
4		Maize		Maize
4	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.

2 - Rankings for all technical modules

A ranking was made for each state of nature 5, 8, 9 and 13. To summarize those rankings, an average rank was calculated for each crop over all technical modules and then a ranking of the average ranks was made, which appears in the table below.

Rank	GMWL	GMNL	NMWL	NMNL
1	Trans. rice	Trans. rice	Trans. rice	Trans.rice
2	Maize	Groundnuts	Groundnuts-Maize	Groundnuts
3	Groundnuts	Maize		Maize
4	Mil./sorg.	Mil./sorg.	Mil./sorg.	Mil./sorg.
5	Low. rice	Low. rice	Low. rice	Low. rice

in those regions much more than they are presently. Maize area expansion could contribute to reaching the government's self -sufficiency objective. Cotton area expansion could lead to an increase in exports.

In Eastern Senegal and in a low rainfall year, the rankings in order of decreasing profitability are: maize, groundnuts, millet/sorghum and cotton. In an average or high rainfall year, groundnuts supersede maize at the top. This difference in the ranking order can be explained by the price setting mechanisms for each crop already mentioned for the Groundnut Basin.

Cotton is nearly always last. Net margins for cotton are negative in a bad rainfall year, unlike for other crops. These poor results for cotton can be explained partly by the large quantity of inputs required for that crop. Variable costs without labor for module 2 amount to 63,975 CFA Francs for cotton, 9,340 F for millet/sorghum, 18,740 F for maize and 25,600 F for groundnuts. Cotton also requires more labor than other crops, in particular during the harvest period. Module 2 requires 66 man-days per hectare for millet/sorghum, 49 for maize, 69 for groundnuts and 81 for cotton.

Similar results can be found in Casamance, leaving aside the rice modules. In short, maize seems a promising crop while cotton is not attractive at present prices.

The second issue concerns rice, which is grown mainly in Casamance. Rice is important because it is the major staple for the urban population. One component of the government's food strategy involves substituting local rice for imported rice. Rice can be grown in only two regions of Senegal: the Senegal River Basin and the Casamance. It is therefore important to assess the potential for rice expansion in Casamance.

In that region, rice can be grown in several traditional ways following the toposequence: rainfed on the plateau, on lowland or transplanted. Rainfed rice occurs mainly in Upper and Middle Casamance (zones 7 and 8). Lowland rice can be found in Upper, Middle and Lower Casamance (zones 7, 8 and 9). Transplanted rice is found mainly in Lower Casamance (zone 9).

In a low rainfall year, rice ranks last. Conversely, in a high rainfall year, rice is very well positioned. This difference in the rankings comes from the especially high positive correlation between rainfall quantity and rice yield.

Lowland rice ranks better than rainfed rice according to the margins without labor cost, but sometimes worse according to the margins with labor cost. This results from the large quantity of labor required by lowland rice. For example, lowland rice module 2A (mechanized) requires 182 man-days per hectare, lowland rice module 2BO (manual), 162 man-days and rainfed rice module 2, 114 man-days.

In Lower Casamance, transplanted rice is clearly the most profitable crop. This can be explained by the limited amount of inputs used, except for labor, and by high and stable yields. Overall, rice seems a financially interesting crop in Casamance, although a risky one for lowland rice and especially for rainfed rice.

One major constraint for rice expansion in Casamance is land availability. The areas where transplanted rice and lowland rice cultivation is possible are stagnating at best, and regressing in many areas, because of the lower level of the water table and the associated increased salt content of water.

Rainfed rice so far is mainly cultivated as "pam pam" rice on recently cleared forest. The government's policy of protecting the fragile environment by classifying forest areas limits the possible expansion of this type of rice cultivation.

The third issue is the financial attractiveness of production intensification. This is especially relevant for Lower Casamance where use of animal traction and agricultural equipment is minimal, except in the northern part.

Two modules 2 were distinguished for maize and lowland rice in Lower Casamance, and for lowland rice in Middle and Upper Casamance: one mechanized (2A) and one manual (2BO). Both modules obtain similar ranks, although the manual modules tend to be slightly more profitable.

Mechanizing the cultivation of these crops does not seem very attractive financially at first glance. However, mechanization helps avoid labor bottlenecks at critical periods, for example during rice transplanting. For an average year, lowland rice mechanized module 2A requires 162 man-days compared to 182 man-days for module 2B.

In general, the more intensive modules for each crop are ranked higher in terms of net margins, which should result in a positive attitude of farmers towards production intensification. Finally, as in the Groundnut Basin, modules 4 for cereals generally rank high for the reasons already mentioned.

4.2.3 - Margin analysis for the Senegal River Basin

The Senegal River Basin includes three zones: the large perimeters of the Delta and the beginning of the Middle Valley of the Senegal River (zone 3), the Middle Valley of the Senegal River (zone 4) and the Upper Valley of the Senegal River and the North of Eastern Senegal (zone 5). The main characteristic of this whole region is the development of irrigated agriculture. The margin rankings are presented in Tables 18 to 20.

Four policy issues arise in this region:

1) Is rice the most profitable irrigated crop?

2) Is double cropping more profitable than single cropping?

3) Is irrigated agriculture more profitable than rainfed agriculture and flood recession agriculture?

4) Is irrigated cultivation on large perimeters more profitable than on small perimeters?

The first issue, i.e., the profitability of rice, is important because a major component of the Senegalese government's food strategy is the development of irrigated agriculture in the Senegal River Basin, with rice as the major crop. It is therefore important to assess the profitability of rice in the eyes of the farmer.

Rice is clearly the most profitable irrigated crop. In single cropping, the rankings give, in order of decreasing profitability, rice, tomato, sorghum and maize. In double cropping, the order is a double crop of rice, one crop of rice followed by another crop, and one crop other than rice followed by one crop other than rice.

In the Middle and the Upper Valley, tomato margins are close to

TABLE 18

MARGIN RANKINGS IN THE DELTA AND THE BEGINNING OF

THE MIDDLE VALLEY OF THE SENEGAL RIVER (ZONE 3)

Two rankings were made: one ranking by number of crops (single or double) and one overall ranking. To summarize those rankings, the average rank of each crop or combination of crops was calculated and then a ranking of the average ranks was made, as is presented below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Rice+Rice means a double crop of rice.
Rice+Other means one crop of rice followed by one crop of either sorghum or maize.
Sorghum+Any means one crop of sorghum followed by one crop of either sorghum or maize.
Maize+Any means one crop of maize followed by one crop of either maize or sorghum.

Rank	GMWL	GMNL	NMWL	NMNL
1	Rice+Rice	Rice+Rice	Rice+Rice	Rice+Rice
2	Rice+Other	Rice+Other	Rice+Other	Rice+Other
3	Rice	Sorghum+Any	Rice	Rice
4	Sorghum+Any	Rice	Tomato	Sorghum+Any
5	Tomato	Tomato-Maize+Any	Sorghum+Any	Tomato
6	Maize+Any		Sorghum	Sorghum
7	Sorghum	Sorghum	Maize+Any	Maize+Any
8	Maize	Maize	Maize	Maize

TABLE 19

MARGIN RANKINGS IN THE MIDDLE VALLEY OF THE SENEGAL RIVER

(ZONE 4)

Two rankings were made: one ranking by number of crops (single or double) and one overall ranking. To summarize those rankings, the average rank of each crop or combination of crops was calculated and then a ranking of the average ranks was made, as is presented below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
SorghumI means irrigated rice.
SorghumO means flood recession rice.
Rice+Rice means a double crop of rice.
Rice+Other means one crop of rice followed by one crop of either sorghum or maize.
Sorghum+Any means one crop of sorghum followed by one crop of either sorghum or maize.
Maize+Any means one crop of maize followed by one crop of either maize or sorghum.

Rank	GMWL	GMNL	NMWL	NMNL
1	Rice+Rice	Rice+Rice	Rice-Rice+Rice	Rice+Rice
2	Rice-Rice+Other	Rice+Other		Rice+Other
3		Rice	Tomato-Rice+Other	Rice
4	Tomato	Tomato		Tomato
5	SorghumI -Sorghum+Any	Sorghum+Any	SorghumI	Sorghum+Any
6		Maize+Any	Sorghum+Any	Maize+Any
7	Maize-Maize+Any	SorghumI	SorghumO	SorghumI
8		Maize	Maize+Any	Maize
9	SorghumO	SorghumO	Maize	SorghumO

TABLE 20

MARGIN RANKINGS IN THE UPPER VALLEY OF THE SENEGAL RIVER

AND IN THE NORTH OF EASTERN SENEGAL (ZONE 5)

Two types of rankings were made: one ranking for rainfed crops for states of nature 1, 5, 8, 12 and 13 and one overall ranking with irrigated crops and rainfed crops for states of nature 1 and 13. To summarize those rankings, the average rank of each crop or combination of crops was calculated and then a ranking of the average ranks was made, as is presented below.

GMWL means gross margin with labor cost.
GMNL means gross margin with no labor cost.
NMWL means net margin with labor cost.
NMNL means net margin with no labor cost.
Mil./sorg.//sorg. means rainfed millet/sorghum.
SorghumI means irrigated rice.
Rice+Rice means a double crop of rice.
Rice+Other means one crop of rice followed by one crop of either sorghum or maize.
Sorghum+Any means one crop of sorghum followed by one crop of either sorghum or maize.
Maize+Any means one crop of maize followed by one crop of either maize or sorghum.

Rank	GMWL	GMNL	NMWL	NMNL
1	Rice+Rice	Rice+Rice	Rice	Rice+Rice
2	Rice	Rice+Other	Rice-Rice	Rice+Other
3	Rice+Other	Rice	Rice+Other	Rice
4	Tomato	Tomato	Tomato	Tomato
5	Groundnuts	Sorghum+Any	Groundnuts	Sorghum+Any
6	SorghumI	Maize+Any	SorghumI	Maize+Any
7	Sorghum+Any	SorghumI	Mil./sorg.	Groundnuts
8	Mil./sorg. -Maize+Any	Groundnuts	Maize+Any	SorghumI
9		Maize	Sorghum+Any	Maize
10	Maize-Cowpeas	Cowpeas	Cowpeas	Cowpeas
11		Mil./sorg.	Maize	Mil./sorg.

that of rice margins, especially when including labor cost. In fact, the labor requirements for rice are much higher than those for tomato (respectively 233 and 149 man-days per hectare).

Two reasons for this clear advantage of rice compared to competing cereals are 1) the higher yield of rice (4.5 tons per hectare for paddy rice, 3 for sorghum, and 1.7 for maize) 2) and the higher price of rice (CFAF 85 per kilo of paddy rice, 70 for sorghum, and 80 for maize). The tomato yield is much higher than the rice yield (15 tons per hectare of tomato), but the tomato price is much lower than the paddy rice price (CFAF 25 per kilo of tomato).

If the farmer wants to diversify, his best alternatives in decreasing order of profitability are tomato, sorghum and maize. However, tomato and maize expansion are limited by a soil constraint; the soils of the Delta are too heavy and too salty for tomato and maize cultivation. The only crops there possible are rice and sorghum.

Tomato expansion is also constrained by the absence of an organized marketing system in the Upper Middle and Upper Valley of the Senegal River. The only organized marketing system for tomato exists in the lower Middle Valley.

The second issue in the Senegal River Basin concerns the profitability of double cropping versus single cropping. At present, technical reasons limit the area available for double cropping, but the completion of the Manantali dam in 1988 should make it possible to control the flow of water of the Senegal river all year round and, therefore, to generalize double cropping.

This is an important issue because the extension of double cropping could reduce production costs, dividing fixed costs roughly by a factor of two. Domestic irrigated rice would then become more competitive with imported rice.

The rankings indicate that double cropping seems generally worth the extra effort in the case of rice. If the farmer goes from a single crop of rice to two crops of rice, his margin increases from 278,392 CFA Francs per hectare to 701,317 F, i.e., an increase of 422,925 F. Since double cropping requires 118 man-days of extra work per hectare, each extra day brings 3,584 F to the farmer. This figure can be compared to the agricultural labor wage of 500 to 700 CFA Francs per day. Therefore, it seems that rice double cropping is financially attractive.

However, a single crop of rice can bring more money than most double crops other than rice. Considering the extra work required for double cropping, the margin per day of labor is much higher for a single crop of rice than for non-rice double crops.

For example, the net margin without labor cost for module 2 of irrigated rice planted early during the rainy season is 266,525 F per hectare for 103 days of work, i.e., 2,588 F per day. The same margin for the combination sorghum-tomato, which is the best combination without rice, is 200,516 F per hectare for 199 days of work, i.e., 1,008 F per day. The margin for the combination maize-maize, which is the worst combination without rice, is 50,082 F per hectare for 204 days of work, i.e., 264 F per day.

An important issue is the opportunity cost of time. The opportunity cost used above is the agricultural wage labor. The opportunity cost could instead be based on the returns to off-farm employment in trade or transport activities, but no data were available on this. It could also be based on the value of leisure, which is virtually impossible to measure empirically. Because of the difficulties of estimating the opportunity cost of labor, which is an important cost element, our conclusion that rice double cropping is more financially attractive than rice single cropping must be treated with caution.

Other factors are important in evaluating the value of double cropping compared to single cropping. In particular, one problem with double cropping is that it requires the farmer to stick to a precise crop calendar, to prevent the two crop calendars from overlapping. Therefore, double cropping is much more rigid than single cropping.

Also, problems of overlapping calendars mean that all combinations of crops are not possible. Often, one crop has to be planted late to allow enough time to finish the growing cycle of the previous crop and to harvest. From the rankings, it is clear that late planting means reduced yields, and so, reduced margins. The margin for double cropping is less than the sum of the two single crops.

The third issue concerns the relative profitability of irrigated agriculture compared to rainfed cultivation and flood-recession cultivation. These last two types of cultivation were the only ones before the introduction of irrigated agriculture on a large scale in the mid-sixties.

Both have seen their importance decrease as a result of the drought. Rainfed cultivation on _dieri_ land is now mainly limited to the Upper Senegal Valley and the North of Eastern Senegal (zone 5). Flood recession cultivation on oualo land is mainly limited to the Middle Valley of the Senegal River (zone 4).

Although flood recession cultivation is supposed to disappear as a result of the control of the floods with the dams of Diama and Manantali, this will probably not happen before 1995. Until then, flood recession cultivation remains an alternative in the years when the water level is adequate.

Two rankings have been made for zone 5 to compare irrigated crops with rainfed crops in two states of nature: the worst possible state (state 1) and the best possible state in that zone (state 13).

If the worst state of nature occurs for rainfed crops, irrigated crops rank better than rainfed crops according to the margins without labor cost. They also rank better according to the margins with labor cost, except for irrigated crop combinations including sorghum and maize. The latter are dominated by a number of rainfed crop modules, in particular groundnut modules.

In the second ranking, with the best probable state of nature for rainfed crops, irrigated crops remain in general more profitable than rainfed crops, but the difference between the two is smaller, in particular for the ranking according to the margins with labor cost.

Rainfed crops require less work than irrigated crops. Module 2 requires 47 man-days per hectare for groundnuts, 42 for millet/sorghum, and 95 for cowpeas, compared to 233 for rice in the rainy season, 165 for maize in the rainy season, 179 for sorghum in the rainy season and 129 for tomato. Overall, irrigated crops seem more profitable than rainfed crops in zone 5.

Let us now compare irrigated cultivation and flood recession cultivation in the Middle Valley of the Senegal River (zone 4). Sorghum, which is the only flood recession crop, is the least profitable of all irrigated crops in the rankings according to the margins without labor cost. In the rankings according to the margins with labor cost, it ranks ahead of only single or double cropping combinations with maize. In fact, flood recession sorghum is not grown for sale, but as a home consumption crop requiring minimal inputs, which therefore leads to low yields.

To sum up, irrigated cultivation appears more profitable than rainfed or flood recession cultivation. Another advantage of irrigation is its independence from weather vagaries, except during the hot off-season. This contrasts sharply with rainfed and flood recession cultivation. The area available for flood recession cultivation varies considerably from year to year depending on the importance of rainfall in Guinea, and hence the magnitude of the flood downstream in Senegal. The area suitable for rainfed cultivation varies as well depending on the importance of rainfall in the Upper Senegal River Valley.

However, irrigated cultivation also presents some drawbacks from the farmer's perspective. First, it is limited by the amount of irrigated land available. Second, its profitability depends on the availability of the right inputs at the right time. It is much more dependent on the input marketing system than the other traditional types of cultivation. Third, at a more general level, it depends on the policies of the parastatal in charge of irrigation development in the Senegal River Basin: the SAED.

The fourth issue concerns the relative profitability of large versus small perimeters. Large perimeters are found in the Delta and the lower Middle Valley (zone 3). Small perimeters are found in the Middle and the Upper Valley (zones 4 and 5). There are some small perimeters in zone 3, but they follow the same cultivation practices as large perimeters in zone 3 and can therefore be grouped with them.

Elsewhere, large perimeters and small perimeters use different techniques for rice cultivation. On large perimeters, land preparation is done mechanically by SAED and rice is seeded directly. On small perimeters, land preparation is done manually and rice is transplanted.

In terms of gross margins, the profitability of irrigated crops on large perimeters is greater than on small perimeters. In terms of net margins, irrigated crops on large perimeters are less profitable than on small perimeters, except for rice. The profitability of irrigated crops on small perimeters is also relatively higher than on large perimeters when labor cost is excluded.

These results can be explained by the difference in factor intensities on both types of perimeters. Large perimeters are more capital intensive, which increases the share of fixed costs in total cost and consequently reduces net margins. Small perimeters are labor intensive, which reduces margins with labor cost.

Overall, it is hard to reach a definitive conclusion on the relative profitability of small versus large perimeters. If the net margin without labor cost was the sole criterion, then small perimeters would be more profitable than large perimeters.

Other factors must be considered in choosing between large and small perimeters. From past experience, it seems clear that farmers are far more enthusiastic about small perimeters than about large perimeters. Small perimeters are by definition easier to control and are usually settled by a more ethnically homogeneous population than large perimeters.

However, small perimeters have generally been set up where manual land preparation was possible. Future perimeters will probably require some mechanical land preparation. Given the disadvantages of large perimeters and the limits of small perimeters, SAED is now favoring the concept of intermediate perimeters; large perimeters are being disaggregated into smaller units for the management of certain operations.

4.2.4 - Margin analysis at the national level

Two issues arise at the national level:

1) In which region does it make sense to promote a given crop?

2) What are the most profitable agricultural activities in Senegal?

To give insights on the first issue, a ranking of the net margins under average rainfall conditions (state of nature 8) with and without labor was made across all regions where a given crop is grown. In the ranking for millet/sorghum, irrigated sorghum in the whole Senegal River Basin comes first according to the net margin without labor cost. In the ranking by net margin with labor cost, irrigated sorghum in the Delta and the beginning of the Middle Valley (zone 3) is first, but irrigated sorghum in the Middle Valley and the Upper Valley (zones

4 and 5) rank at the 20th and 22nd positions. This results from the high labor cost on the small perimeters in zones 4 and 5.

The second and third ranks for millet/sorghum go respectively to rainfed millet/sorghum in the South (zones 10 and 11) and in the Center (zone 1) of the Groundnut Basin. The last place is taken by rainfed millet/sorghum in the North of the Groundnut Basin (zone 2) if labor cost is excluded and to flood recession sorghum in the Middle Valley of the Senegal River (zone 4) if labor cost is included.

In the ranking for maize, Lower and Middle Casamance occupy the first place. Irrigated maize ranks last.

In the ranking for rice, irrigated rice in the Senegal River Basin is more profitable (financially) than traditionally grown rice in Casamance. In the ranking by net margin with labor cost, irrigated rice in the Delta and the beginning of the Middle Valley (zone 3) is more profitable than rice in the Middle and Upper Valley (zones 4 and 5). In the ranking by net margin without labor cost, irrigated rice in zones 4 and 5 is more profitable than in zone 3. This difference comes from the high labor use on small perimeters in zones 3 and 5. Transplanted rice in Lower Casamance (zone 9) is the most profitable of the traditional types of rice in Casamance, followed by lowland rice and rainfed rice.

In the ranking for groundnuts, the south of the Groundnut Basin (zones 10 and 11) is the most profitable. The high intensity module (module 1) in the Casamance (zones 7, 8 and 9) is also highly ranked according to net margin without labor cost. At the bottom of the ranking are the low intensity modules in Casamance and in the Center of the Groundnut Basin (zone 1). It seems clear that the center of gravity of groundnut production is moving from the Center to the South of the Groundnut Basin.

In the ranking for cotton, Upper Casamance (zone 7) is the most profitable region, ahead of Eastern Senegal (zone 6) and Middle Casamance (zone 8). All net margins with labor cost are negative, except for zone 7. This means that cotton is not a profitable crop in zones 6 and 8 at present prices. Even in zone 7, cotton is outranked by most other crops. Cotton is a marginal crop which occupies 7% to 8% of the cultivated areas in zones 6, 7 and 8. This percentage is currently decreasing as cotton area declines. Cotton is not grown for its profitability, but as a way to get access to agricultural inputs and credit supplied by SODEFITEX, the parastatal initially created to foster cotton cultivation.

In the ranking for cowpeas, the Center of the Groundnut Basin (zone 1) is more profitable than the North of the Groundnut Basin (zone 2), where the climatic conditions are less favorable. Whether cowpeas should be developed in zone 1 and not in zone 2 depends on the alternatives open to farmers. In zone 1, groundnuts are in general better ranked than cowpeas while in zone 2, there is no real alternative to cowpeas.

In the rankings for tomato, small perimeters in the Middle and Upper Valley of the Senegal River (zones 4 and 5) are more profitable than large perimeters in the Delta and the beginning of the Middle Valley (zone 3). This result must be interpreted cautiously since the same price was assumed to be paid for all tomato producers in zones 3, 4 and 5. Right now, most of the tomato is produced close to the tomato paste plants located at the border of zone 3 and zone 4. However, tomatoes that could be produced in the future in the Upper Middle and Upper Valley would probably be paid a lower price given the distance from the plants and other markets.

To identify the most profitable crops in Senegal, a ranking by net margin with and without labor was made for all crops in all zones. The overall ranking by crop gives:

1) irrigated rice
2) irrigated tomato
3) groundnuts
4) maize
5) millet/sorghum
6) cowpeas
7) cotton.

To identify the most profitable regions in Senegal, a composite ranking of crops by zone was made. The results were not significant, indicating that there is no best agricultural region in this country across all crops.

4.2.5 - Summary of findings and policy implications

The present price policy does not especially favor rainfed cereals. Millet/sorghum is clearly not an interesting cash crop, and is grown mainly for home-consumption. Maize is much more profitable and can be competitive with groundnuts in some cases, although overall, groundnuts remain the most profitable rainfed crop. This does not seem consistent with the Senegalese government's objective of significantly increasing the level of cereals self-sufficiency.

The present price policy strongly favors irrigated rice in the Senegal River Valley. Irrigated rice is the most profitable irrigated crop and the most profitable crop overall in Senegal. This reflects the very high priority given by the Senegalese government to increasing domestic rice production and to developing the Senegal River Basin.

Cotton poses no challenge to groundnuts as the dominant export crop. Cotton is less profitable than most crops and, quite often, not profitable at all. The current price structure does not seem consistent with the efforts of the parastatal SODEFITEX to promote cotton cultivation.

The present price structure generally makes intensification of production financially attractive in the southern part of the Groundnut Basin (zones 10 and 11), Eastern Senegal (zone 6) and the Upper and Middle Casamance (zones 7 and 8). However, intensification does not seem very profitable in the rainfed regions located more to the north. This pattern makes sense since intensification should be favored primarily in the zones with the best agricultural potential.

To review this chapter, a number of detailed crop budgets were constructed to describe agricultural production in Senegal. These crop budgets vary by crop, by zone and by technical module. Uncertainty on yields and prices was incorporated. Margins were calculated and analyzed to evaluate the profitability of alternative crops and technical modules in all agricultural zones of Senegal. The crop budgets were also used as data base for a modelling exercise described in the next chapter.

CHAPTER 5

METHODOLOGY FOR THE EMPIRICAL MODELLING EXERCISE

The crop budgets provide a good idea of the financial attractiveness of the major crops for the Senegalese farmer. However, the profit motive is only one side of the coin. The other important component of the farmer's utility function is the food security objective.

This objective pushes him to grow food crops for home consumption and to select crops for sale in order to guarantee a minimum income whatever the state of nature. Both actions may run counter to the profit maximization objective. Therefore, the farmer often has to make trade-offs among conflicting objectives.

The farmer also operates under resource constraints. Land, labor and capital must be allocated to competing production activities. Some resource constraints are binding and force a change of production strategy.

A farm model that tries to include these key variables and their interactions can provide a number of insights about the farmer's opportunity set and his probable behavior when faced with different price policies.

Therefore, our concern for understanding the farmers' micro strategies and their implications for macro food policy led us to build a number of farm models and link them into a larger agricultural sector model. The stages of the modelling exercise are presented first, followed by a detailed description of the typical farm model and of the agricultural sector model.

5.1 - The stages of the modelling exercise

5.1.1 - The construction of a set of farm models

A typical farm was modelled in each agricultural zone previously identified, except in two zones where two submodels were constructed to account for the diversity in those zones.[1] In total, 13 farm models were constructed.

Linear programming techniques were used for these models. The objective function specified for the producer was to maximize profits under a number of food security and resource constraints. Only major crops were considered as production activities. Livestock activities were not included for several reasons:

- Policy choices regarding the livestock sector are less important than policy choices regarding the crop sector in Senegal. The most

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[1] In zone 3, one model was built for the Delta of the Senegal River where the only crops possible are rice and sorghum. Another model was built for the Lower Middle Valley where tomato and maize cultivation are also possible. In the Upper Valley of the Senegal River and the North of Eastern Senegal (zone 5), one model was built for the areas close to the Senegal and Faleme rivers where both irrigated cultivation and rainfed cultivation are possible. Another model was built for the areas away from those rivers where only rainfed crops are possible.

important agricultural policy issue in this country concerns the optimal mix of food crops and cash crops;

- The government's policies have a much more important impact on crop production than on the livestock sector in Senegal. The government has a limited influence on two major components of the livestock sector: the subsistence activity at the farm level where goats and sheep are raised for the milk and meat needs of the farm household; and a commercial activity which is integrated to a large extent in international trade flows of cattle and camels within West Africa;
- The livestock sector is less well-known than the crop sector. Livestock data is limited and often not very reliable.

Nonetheless, the existence of a livestock sector was considered indirectly by this research in several ways:

- In the farm models, a value is given to groundnut hay and cowpea hay. Hay, especially groundnut hay, is an important livestock feed in Senegal;
- In the farm models, land available for crop activities is equal to total cultivable land minus estimated cultivable land used for livestock activities;
- In the agricultural sector model, food needs to be satisfied are equal to total food needs minus food needs satisfied through consumption of animal products and food crops other than cereals.

The farm models were calibrated by running them with the financial prices for inputs and outputs for the mid-1980's and then comparing the models' results with the data available on 1) the regional pattern of cultivated acreage by crop and by technical module and 2) farm income for those years. Data on the percentage of cultivated area allocated to each crop came from the Ministry of Rural Development and from farm surveys conducted by ISRA and WARDA researchers. The figures from the Ministry of Rural Development came from yearly area and yield surveys conducted by the regional services of the Ministry and by regional development agencies. The percentage of the cultivated area allocated to each technical module for a given crop, and farm income were estimated for each zone on the basis of farm surveys conducted by ISRA and the expertise of several ISRA researchers.

No major differences between the observed pattern of production and the farm models results occurred. When some minor discrepancies existed, changes in the food security constraints, which are described later in this chapter, and in the structure of cereals demand by the farm household made a fine-tuning of the farm models possible.

The only exception was for cotton acreage. As mentioned in the margin analysis section, cotton is the least financially attractive crop. As a consequence, the initial solution of the farm models, in which cotton was a possible production activity, did not include any cotton. In practice, cotton represents on average 7 to 8% of the cultivated area in Eastern Senegal and in Casamance. It is mainly grown to get access to credit and inputs, in particular fertilizers, from SODEFITEX, a regional development agency which was initially created to favor cotton cultivation. To reflect this situation, a minimum constraint on the cultivated area allocated to cotton was added in the models run with financial prices. This constraint was of course eliminated in the models with economic prices.

5.1.2 - The aggregation of agricultural supply at the zone level and at the national level

The number of farms in each zone was estimated in several ways:

1) By looking at the sparse data available on farm numbers;
2) By dividing the actual total cultivated area of the zone (calculated using data from the Ministry of Rural Development) by the size of the typical farm modelled for that zone (calculated from farm surveys conducted by ISRA and WARDA));
3) By dividing the actual zone production (calculated using data from the Ministry of Rural Development) by the optimal output from the typical farm modelled for each crop. This gave one farm number estimate by crop considered.

The number of farms that seemed the most consistent was chosen for each zone. A final consistency check was done at a later stage by comparing the national production obtained by summing up optimal production from all the farm models over all zones for each crop and national production figures for this crop calculated by the Ministry of Rural Development.

The production of each crop at the zone level was calculated by multiplying the optimal farm output levels by the number of farms in the zone. National production was calculated by adding production from all zones. Net production at the zone and at the national levels was then calculated by multiplying gross production by a coefficient which incorporated the effects of storage and processing losses and reconstitution of seed stocks.

5.1.3 - The derivation of agricultural products supply curves

The farm models were run with several different price vectors. Each price vector is a particular set of input and output prices which is consistent across all zones. The price of a given input or output is not assumed to be the same in each region, but rather varies to reflect differences in transportation and marketing costs.

The basic price vector used was the financial price vector composed of 1986-87 prices for inputs and outputs at the farm gate. Five higher price vectors were derived from this basic price vector by increasing all cereals prices by a given percentage: 20%, 40%, 60%, 80%, and 100%.

The supply responses of the typical farm were then multiplied by the estimated number of farms in each zone to provide the zone supply curves, which added together gave the national supply curve. The zone supply in tons corresponding to any price vector was converted into calories to be able to compare it to the food needs expressed also in calories.

Thus, six points on the supply curve of each cereal were obtained. It is worth pointing out that these are not standard supply curves since all cereals prices were varied together and not separately. Also these supply curves are normative, i.e., derived by simulating the impact of different output price policies on the production of the typical farms modelled. They do not come from the statistical analysis of time series data.

Nonetheless, the derivation of these supply curves provided insights into the likely response of cereals supply to price policies which are plausible for Senegal. They also served as the interface between the micro farm models and the macro agricultural sector model.

An economic price vector was also calculated, using import or export parity prices for traded goods and the domestic market prices for non-traded goods. The farm models were run with this economic price vector to evaluate the "true" opportunity cost of production and the present comparative advantage of Senegal.

5.1.4 - The construction of an agricultural sector model

The agricultural sector model includes national production activities corresponding to the six different price vectors, processing activities, domestic and international trade activities for inputs and outputs, and consumption activities.

Separable programming techniques were used. The objective function was to minimize the net cost of meeting the food needs of the Senegalese population (minus the value of exports) under a set of constraints on food habits, input and output transfers, and macro food security. Solving this model gives the "optimal" pattern of production and trade for Senegal, given the assumptions of the modelling exercise about farmers' and the government's behaviors.

The agricultural sector model was applied as follows. Let us start from the present level of agricultural prices and the present structure of production and trade. As mentioned in Chapter 3, the current level of cereals self-sufficiency in Senegal using milled product weights expressed in calories varies usually between 40% and 50% depending on the year. However, the Senegalese government has set an 80% cereals self-sufficiency objective for the year 2000.

A macro food security constraint forces the model to meet a self-sufficiency objective. This objective can be set at different levels such as 55% or 60%. Since these levels are higher than that obtainable with current prices, the government must then offer higher cereals prices to producers to induce a higher supply of cereals. The model chooses the level of prices that is required to meet the cereals self-sufficiency constraint at least cost. If no price vector is able to meet the self-sufficiency level desired, there is no feasible solution.

The agricultural model was run for levels of cereals self-sufficiency corresponding to current prices, a 40% increase in cereals prices, and an 80% increase in cereals prices (running the model with the other price vectors resulted in marginal changes in production and trade compared to the results with these three price vectors). This provided a better idea of the trade-offs between the objectives of self-sufficiency and economic efficiency as well as a better appreciation of the feasibility of the government's objectives. This is an important output of this research since it provides the Senegalese government with a menu of feasible policy choices. A maximum realistic level of cereals self-sufficiency was estimated for Senegal as well as the opportunity cost of higher and higher self-sufficiency levels within this limit.

The agricultural sector model was calibrated by comparing the model's results regarding the international and interregional flows of inputs and outputs with data for the mid-eighties from the Ministry of Economy and Finance and the Ministry of Trade, and with experts' opinions. When minor discrepancies were observed, adjustments were made in the structure of cereals demand by urban consumers.

5.1.5 - Policy analysis and experimental design

The overall modelling exercise, i.e., solving the farm models, deriving the supply curves and solving the agricultural sector model, was conducted several times to examine key policy alternatives.

First, the impact of several price policies was evaluated. Apart from the basic run mentioned above, where rice, maize and millet /sorghum prices were raised simultaneously, the effect of increasing only the price of rice was also examined in order to look at the probable impact on rice production of a tariff on rice imports. Such a tariff would probably be imposed as part of establishing a protected regional cereals market, a proposal made by the Mindelo CILSS-Club du Sahel (1987) conference in 1986 and under study right now.

Second, the agricultural sector model was run using economic prices to estimate the present comparative advantage of Senegal in agriculture.

Third, the agricultural sector model was run using the world prices in 1983-84 which were much higher than the world prices in 1986-87 for the major agricultural products traded by Senegal. The prices of those commodities tend to fluctuate in a similar way in the long run (see World Bank 1987c). The world prices projected for the end of the century by the World Bank lie between the 1983-84 level and the 1986-87 level, although much closer to the 1986-87 level (World Bank 1987a). Thus, running the agricultural sector model with a low level of world prices (1986-87) and a high level of world prices

(1983-84) was considered sufficient to estimate the impact of the world price level on the solution.

The impact of several changes in the land constraint was analyzed. The analysis described above assumes that the cultivable area is fixed. The land constraint is often one of the binding constraints in the farm models.

However, marginal rainfed land would probably be put into cultivation if prices for rainfed cereals increased. The irrigated area is also going to increase with the creation of new perimeters. The completion of the Manantali dam will make the extension of double cropping possible. Therefore, the model was run allowing for these increases in cultivated land to estimate their impact on the cereals self-sufficiency rate.

Finally, an experimental design procedure was employed to identify the most important variables affecting certain performance criteria. This approach is sometimes used in simulation studies; see Crawford (1982) for a discussion and illustration.

The experiment set up here involved running the agricultural sector model for three levels of production (or desired self-sufficiency levels), two sets of food habit constraints and two sets of world prices. A variance decomposition analysis was then conducted to identify how much each variable contributed to the variation in two performance variables: the objective function of the agricultural sector model (a rough proxy for the economic cost of cereals self-sufficiency), and the foreign exchange balance for agricultural inputs and outputs calculated in the model.

5.2 - The structure of the farm models

The farm model calculates the "optimal" pattern of production and consumption from the producer's perspective.

5.2.1 - Activities

The farm model includes production, input procurement, risk transfer columns, food buying and output selling activities.

- Production activities

The production activities correspond directly to the technical modules analyzed in the crop budgets. The cereals activities are repeated twice since cereals help satisfy two different needs: production for home consumption and production for sale to generate cash income.

This distinction is also helpful for the incorporation of uncertainty in the model. The uncertain variable in the cultivation of food crops grown for home consumption is the yield. For cereals grown for sale, the uncertain variable is the income per hectare since generally both the price and the yield fluctuate. The exception is rice in the Senegal River Basin, for which the official price is usually the price paid to the producer, which eliminates market price uncertainty. Separating the cereal hectarage into hectarage for home-consumption and hectarage for sale makes it easier to separate the different sources of uncertainty and to consider their relative importance.

- Input procurement

The farmer can buy seeds, fertilizers and crop protection products. He can also hire labor for key periods of the cropping season and borrow capital to finance purchases of agricultural inputs and to buy food during the hungry season. It is assumed that all the cereals purchases by the farmer happen during the hungry season (June to September).

- Risk transfer columns

These activities are part of the methodology used to incorporate the effects of uncertainty on the farmer's decisions. Basically, these columns represent the link between values observed in the past for uncertain variables and the present pattern of activities. A more detailed explanation is given in part 5.2.3 on the description of the food security constraints.

- Cereals buying activities

The farmer has the option of buying cereals instead of producing them.

- Output selling activities

The farmer can sell cash crops and cereals grown for sale.

5.2.2 - Objective function coefficients

The objective function to be maximized is the income of the farmer net of cereals purchases. This specification does not mean that farmers are treated exclusively as profit maximizers. Farmers have other objectives in terms of food security and meeting social obligations. These objectives are treated as constraints in the model which, in fact, amounts to giving them priority over profit maximization.

The coefficients in the objective function are specified as follows:

- For any production activity, the cost of inputs not specified in the input procurement activities, but used in this production activity. This will basically cover the variable costs of using agricultural equipment (fuel, spare parts) and the fixed costs for agricultural equipment and animal traction.

  Since a cereal grown for home-consumption is not intended to be sold, its only value to the farmer is in helping satisfy the food security constraints. This value is determined by the model. Thus, the coefficient in the objective function is not a gross margin measuring the value of this food crop on the market, minus variable costs of production not individually accounted for. It is simply equal to the latter costs;
- For any input procurement activity, the cost of that input. In the case of capital, it is assumed that the farmer can borrow money from the local trader for four months from early June to early October to buy food and agricultural inputs at a given monthly interest rate (in cash or in kind). The types of inputs which can be financed only with the starting capital vary from zone to zone. In general, in rainfed cultivation zones, fertilizers purchases and hired labor wages have to be financed this way. In irrigated cultivation zones, only hired labor wages are usually financed this way;
- For any risk transfer column, zero since there is no cost or price attached to the risk transfer column;
- For any cereal buying activity, the farm-gate purchase price of that cereal;
- For any output selling activity, the farm-gate sale price of that

output.

The objective function is thus defined as follows for each producing zone r:

$$\text{Max } \Phi_r = - \sum_j \sum_m TNC_{jmr} A_{jmr} - \sum_i \sum_j \sum_m P_{ir} IN_{ijmr}$$

cost of non-itemized inputs — cost of itemized inputs

$$- \sum_f P_{fr} ACER_{fr} + \sum_j P_{jr} SAL_{jr} \quad (1)$$

cost of cereals purchases — sale of agricultural products — Units: CFA Francs

where:

r : Index for zones producing agricultural products; r = 1,13;

j : Product index; j = 1,6 maximum (variable from zone to zone);

m : Technical module index; m = 1,5 maximum (variable from product to product and from zone to zone);

i : Input index; i = 1,31 maximum (variable from zone to zone);

f : Cereal index; f = 1,4 maximum (variable from zone to zone);

TNC_{jmr}: Total net cost of producing product j cultivated with module m for the typical farm in zone r;

A_{jmr} : Area cultivated in crop j cultivated with module m by the typical farm in zone r;

P_{ir} : Price of input i in zone r;

IN_{ijmr}: Quantity of input i used to produce product j cultivated with module m by the typical farm in zone r

P_{fr} : Price of cereal f in zone r;

$ACER_{fr}$: Quantity of cereal f bought by the typical farm of zone r;

P_{jr} : Price of product j in zone r;

SAL_{jr} : Quantity sold of product j by the typical farm of zone r.

5.2.3 - Constraints

The farm model includes constraints on input availability, accounting identities, food security objectives at the farm level and food consumption habits.

- Constraints on inputs

There are constraints on the availability of land, seeds, fertilizers, crop protection products, labor and animal traction at key peak periods as well as starting capital. Starting capital is the amount of capital available for investment once social obligations have been satisfied.

For each input i in zone r,

$$\sum_j \sum_m a_{ijmr} A_{jmr} \leq b_{ir} \quad (2)$$

Units: units of input i

where:

a_{ijmr} : Quantity of input i required to cultivate one hectare of product j cultivated with module m by the typical farm in zone r;

A_{jmr} : Area cultivated in crop j cultivated with module m by the typical farm in zone r;

b_{ir} : Quantity of input i available to the typical farm in zone r.

- Accounting identities

The quantity of any product sold cannot be greater than the quantity produced on the farm.

For each product j in zone r,

$$SAL_{jr} \leq \sum_m A_{jmr} MY_{jmr} \quad (3)$$

Units: kilos

where:

SAL_{jr} : Quantity sold of product j by the typical farm of zone r;

A_{jmr} : Area cultivated in crop j cultivated with module m by the typical farm in zone r;

MY_{jmr} : Mean yield of crop j cultivated with module m by the typical farm in zone r.

- Food security constraints at the farm level

Several constraints are imposed to reflect the priority given to food security by the producer. This priority is particularly strong for the "chief of concession" or head of the compound, who has the social responsibility of ensuring that the food needs of all the members of the "concession" are satisfied.

i) A constraint on the minimum level of cereals needs: The farm household must satisfy its nutritional needs defined in terms of calories either through home consumption of food crops or through purchases of food.

$$\sum_{g}\sum_{m} MY_{gmr}\, A_{gmr}\, CAL_g + \sum_{f} ACER_{fr}\, CAL_f \geq CNEED_r \quad (4)$$

Units: thousands of calories

where:

g : Index for cereals grown for home consumption;

MY_{gmr} : Mean yield of crop g cultivated with module m by the typical farm in zone r;

A_{gmr} : Area cultivated in crop g cultivated with module m by the typical farm in zone r;

CAL_g : Thousands of calories per kilo of cereal g;

$ACER_{fr}$: Quantity of cereal f bought by the typical farm of zone r;

CAL_f : Thousands of calories per kilo of cereal f;

$CNEED_r$: Caloric needs of the typical farm household in zone r.

ii) <u>A constraint on the minimum level of cereals self-sufficiency</u>: The farm household wants to produce on average a large share of the cereals required to cover its needs, for example 70% in zone 1. Even in the worst year, it wants to cover a minimum share of its needs, for example 30% again in zone 1. These needs are defined in calories.

To include these considerations, additional rows are introduced in the LP tableau. They contain the deviations from the mean during the worst possible states of nature for the uncertain variables, i.e., the yields of food crops produced for home consumption. A bad year for one crop might mean an average year for another, resulting in offsetting inter-crop yield variations.

The mean yield is calculated by weighting the yield associated with each state of nature by the probability of occurrence of that state of nature. The yields are expressed in thousand calories to allow for the same unit across all crops.

Excerpts of the LP tableau for the farm model in the Center of the Groundnut Basin (zone 1) are presented in Table 1 as an illustration of the way these constraints operate. There is only one cereal grown for home consumption, millet. There is only one row of negative yield deviations for state of nature 1 since this state is worse than all others for all crops and all modules. The negative yield deviations are the largest in absolute value for that state.

In state of nature 1, the farmer will get only 581 thousand calories of millet for food per hectare under module 1, i.e., 1,103 thousand calories below average for every unit of module 1 in the

TABLE 21

EXCERPTS OF THE LP TABLEAU FOR THE FARM MODEL IN ZONE 1

CONCERNING MINIMUM CEREALS SELF-SUFFICIENCY CONSTRAINTS

	Millet for Home Consumption (ha)			Millet for Sale (ha)			Risk Transfer Column	Sign	RHS
	Mod. 1	Mod. 2	Mod. 3	Mod. 1	Mod. 2	Mod. 3			
Deviation from the mean yield in state of nature 1 (thousand calories)	-1103	-977	-727	581	465	349	1	≥	0
Minimum level of cereals self sufficiency (thousand calories)	1684	1442	1076				-.429	≥	4270

NB: 1) Mod. means technical module.
2) RHS means right hand side.
3) 1684, 1442 and 1076 are the weighted mean yields.
4) 581, 465 and 349 are the yields in the worst state of nature.
5) -1103, -977 and -727 are the negative deviations from the weighted mean yields in the worst state of nature.

solution. Similarly he will get only 465 and 349 thousands of calories of millet for food per hectare under modules 2 and 3, i.e., 977 and 727 thousand calories below the average yield for modules 2 and 3.

To make up for those downside deviations from the mean, the farmer can substitute some millet he grew for sale initially, namely 581 thousand calories for module 1 or 465 thousand calories for module 2 or 349 thousand calories for module 3. However, if the level of "millet for sale" activities is not enough to cover the downside deviation, there is a risk penalty. This penalty is transferred through the risk transfer column to the constraint on the minimum level of cereals self-sufficiency where its effect is to increase the level of production of food crops for home consumption.

The -.429 figure means that the farmer is assumed to want to be insured that, even in the worst year, he will produce at least 42.9% of his average level of production of cereals, which is constrained to be equal to 70% of his cereals needs (4,270). The farmer is thus sure to cover at least 30% (42.9% * 70%) of his cereals needs even in the worst year. It is assumed that the other 70% would be covered through purchases of cereals using off-farm income, transfers of food or money from better off members of the extended Senegalese family, and food aid.

It is of course very difficult to get empirical data on the percentages of cereals self-sufficiency desired by the farmer in an average year and in the worst possible year. The method used was to run the model with different values for these percentages to analyze the impact of different levels of producer risk aversion. The percentages chosen initially were very high: 80 % in an average year and 50 % in the worst year.

The result was an infeasible solution in most cases, i.e., the objectives set in terms of cereals self-sufficiency were too optimistic, given the uncertainty of the environment and the structure of the farm (land size, technology available, and population size). These percentages were then progressively diminished until the model had a solution which was consistent in terms of acreage allocation to the observed allocation to different crops and modules.

The constraint on the level of cereals self-sufficiency is a variation of the Minimization of Total Absolute Deviation (MOTAD) model developed by Hazell (1971). Assuming the farmer is risk-averse, the MOTAD model looks for the production mix that minimizes the downside risk of the uncertain variable (yield or income per acre) for a given level of this variable. This minimization procedure is repeated for different levels of the uncertain variable to estimate the trade-off between the level and the risk of the uncertain variable (see Hazell et al. 1986).

In our model, the constraint on the level of food self-sufficiency offsets the risk of a downside deviation in food crop production by increasing the level of food crop production above its optimal level when risk is not considered. The risk penalty is represented by the opportunity cost of the extra food production above the solution in which risk is not considered.

For each state of nature t in zone r,

$$\sum_g \sum_m (Y_{gmrt} - MY_{gmr})\, A_{gmr}\, CAL_g + \sum_h \sum_m Y_{hmrt}\, A_{hmr}\, CAL_h$$

$$+ DEVC_{tr} \geq 0 \quad (5)$$

Units: thousand calories

where:

t : Index for states of nature (t = 1,15);

h : Index for cereals for sale;

Y_{gmrt} : Yield of cereal for home-consumption g cultivated with module m by the typical farm in zone r when state t occurs;

MY_{gmr} : Mean yield of cereal for home consumption g cultivated with module m by the typical farm in zone r;

A_{gmr} : Area cultivated in cereal for home consumption g cultivated with module m by the typical farm in zone r;

CAL_g : Thousand calories per kilo of cereal g;

Y_{hmrt} : Yield of cereal for sale h cultivated with module m by the typical farm in zone r when state of nature t occurs;

A_{hmr} : Area cultivated in cereal for sale h cultivated with module m by the typical farm in zone r;

CAL_h : Thousand calories per kilo of cereal h;

$DEVC_{tr}$: Negative deviation from the mean yield expressed in calories for the typical farm in zone r when state of nature t occurs which is not compensated by a transfer of cereals grown for sale to home consumption.

Also:

$$\sum_g \sum_m MY_{gmr}\, A_{gmr}\, CAL_g - WORST_r\, DEVCMAX_r \geq SNEED_r \quad (6)$$

Units: thousand calories

where:

MY_{gmr} : Mean yield of cereal for home consumption g cultivated with module m by the typical farm in zone r;

A_{gmr} : Area cultivated in cereal for home consumption g cultivated with module m by the typical farm in zone r;

CAL_g : Thousand calories per kilo of cereal g;

$WORST_r$: Risk transfer coefficient from the worst state of nature row to the minimum self-sufficiency row in zone r;

$DEVCMAX_r$: Largest negative deviation from the mean yield expressed in calories across all states of nature for the typical farm in zone r which is not compensated by a transfer of cereals grown for sale to home consumption;

$SNEED_r$: Quantity of calories corresponding to a desired level of cereals self-sufficiency by the typical farm members in zone r.

iii) <u>A constraint on the minimum income from the sale of food crops and cash crops</u>: The farm household wants to obtain a minimum income from agricultural activities to cover part of its expenses. To include this objective, additional rows are introduced in the LP tableau in a way similar to that for the constraint on the level of cereals self-sufficiency. These rows contain the deviations from the mean income of each producing activity for the worst possible states of nature. A bad year for one crop might mean an average year for another, resulting in offsetting inter-crop income variations. The mean income is calculated by weighting the income associated with each state of nature by the probability of occurrence of that state of nature.

The yield is the uncertain variable for cash crops and rice, for which there are fixed official prices. Income per hectare is the uncertain variable for all food crops grown for sale except rice, since both the yield and the price of these crops fluctuate.

Excerpts of the LP tableau for the farm model in zone 1 are presented in Table 2 as an illustration of the way these constraints

TABLE 22

EXCERPTS OF THE LP TABLEAU FOR THE MODEL IN ZONE 1

CONCERNING MINIMUM INCOME CONSTRAINTS

	Millet for sale (ha)			Groundnut (ha)			Risk Transfer column	Sign	RHS
	Module 1	Module 2	Module 3	Module 1	Module 2	Module 3			
Deviation from the mean income (CFA F)									
State 1	-18300	-16652	-12342	-65887	-60480	-56975	1	≥	0
State 2	-18800	-17052	-12642	-54751	-50552	-48299	1	≥	0
Minimum level of income (CFA F)	40800	34652	25842	136492	123570	112055	-1	≥	100000

NB: 1) RHS means right hand side.
2) The figures on the line for the minimum level of income are the average weighted income for each hectare of module of the two crops considered.
3) The figures on the line corresponding to state 1 are the negative deviations from the mean income if that state of nature occurs. The same is true for state 2.

operate. There is only one cash crop, groundnuts, and one cereal grown for sale, millet. Two rows are presented for each crop, containing the deviations from the mean of groundnuts and millet for sale income in states of nature 1 and 2. These states are the worst possible states of nature from an income perspective. State 1 dominates state 2 for cowpeas and groundnuts, but state 2 dominates state 1 for millet. So both states have to be considered.

The downside deviations have an impact on the choice of income earning activities through a risk transfer column. In the constraint on the minimum level of producer's income, the coefficient of the risk transfer row is -1, transferring the worst negative income deviation into the minimum income row. The right hand side is set at the estimated minimum income desired by the farmer in the worst year.

The issue of estimating this minimum income arises empirically as in the case already mentioned for the percentages on the desired level of self-sufficiency in an average year and in the worst year. Again, the methodology used was to try different values to see the impact of different levels of risk aversion on the model's results. Initially, a high figure was used; then, it was reduced to obtain a solution that was feasible and consistent with the observed acreage, production and income.

The food security constraint on the maximum level of income variation represents another variant of the MOTAD model. Instead of minimizing the downside variation of the uncertain variable as does the MOTAD model, this model guarantees the farmer a minimum income in the worst year. The fact that the objective function is to maximize net income explains why a minimum income constraint was set only in the worst year and not on average. Therefore, the treatment was slightly different between the minimum cereals self-sufficiency constraint and the minimum income constraint.

For each state of nature t in zone r,

$$\sum_k \sum_m (Y_{kmrt} A_{kmr} P_{krt} - MINC_{kmr}) + DEVI_{tr} \geq 0 \quad (7)$$

Units: CFA Francs

where:

k : Index for products for sale;

Y_{kmrt} : Yield of crop for sale k cultivated with module m by the typical farm in zone r when state of nature t occurs;

A_{kmr} : Area cultivated in crop for sale k cultivated with module m by the typical farm in zone r;

P_{krt} : Price of product k in zone r when state of nature t occurs;

$MINC_{kmr}$: Mean income of growing one hectare of crop k cultivated with module m for the typical farm in zone r;

$DEVI_{tr}$: Negative income deviation from the mean in state of nature t for the typical farm in zone r.

Also:

$$\sum_k \sum_m MINC_{kmr} A_{kmr} - DEVIMAX_r \geq INEED_r \quad (8)$$

Units: CFA Francs

where:

$MINC_{kmr}$: Mean income of growing one hectare of crop k cultivated with module m for the typical farm in zone r;

A_{kmr} : Area cultivated in crop for sale k cultivated with module m by the typical farm in zone r;

$DEVIMAX_r$: Largest negative income deviation from the mean across all states of nature for the typical farm in zone r;

$INEED_r$: Minimum desired level of agricultural income for the typical farm in zone r in the worst state of nature.

iv) A constraint on the minimum level of "home garden" modules:

The Senegalese household always plants a certain number of fields around its village, called "home gardens" ("champs de case" in French), with cereals for home consumption. Constraints are put on the minimum and the maximum levels of land that can be cultivated with these modules.

$$MINA_{4r} \leq \sum_{g} A_{g4r} \leq MAXA_{4r} \quad (9) \qquad \text{Units: hectares}$$

where:

$MINA_{4r}$: Minimum area cultivated in cereals for home consumption g cultivated with module 4 (home gardens) by the typical farm in zone r;

A_{g4r} : Area cultivated in cereal for home consumption g cultivated with module 4 by the typical farm in zone r;

$MAXA_{4r}$: Maximum area cultivated in cereals for home consumption g cultivated with module 4 (home gardens) by the typical farm in zone r.

- Constraints on food consumption habits

The quantity consumed by the farm household of different cereals must stay within certain bounds.

For each cereal f consumed in zone r,

$$CONSMIN_{fr} \leq CONS_{fr} \leq CONSMAX_{fr} \quad (10) \qquad \text{Units: kilos}$$

where:

$CONSMIN_{fr}$: Minimum quantity of cereal f consumed annually by the typical farm household in zone r;

$CONS_{fr}$: Quantity of cereal f consumed annually by the typical farm household in zone r;

$CONSMAX_{fr}$: Maximum quantity of cereal f consumed annually by the typical farm household in zone r.

5.3 - The structure of the agricultural sector model

The agricultural sector model calculates the optimal pattern of production, domestic and international trade, and consumption. This model covers all the thirteen zones identified in Senegal, consisting of eleven agricultural zones, one livestock grazing zone and one urban zone. Agricultural zones are both producing and consuming zones. The urban zone, the Cap Vert zone which includes the capital city Dakar, is a consuming zone as well as the zone through which all imports and exports pass, except for groundnut oil and meal which are also exported from Lower Casamance.

5.3.1 - Activities

The agricultural sector model includes aggregate production activities, processing, domestic and international trade, consumption and price vector activities:

- Aggregate production activities: Given a vector of input and output prices, each agricultural zone produces a combination of products which is optimal from the producers' standpoint. For each price vector, there is a different optimal regional production pattern. The optimal regional production (and input) levels are then aggregated at the national level.
- Processing activities: The model includes the most important processing activities of export products and food products in the zones where such activities currently exist.
- International trade activities: The model includes import activities

for major inputs and food products. It includes export activities for major cash crops and food crops. All foreign trade goes through the urban zone, but exports of groundnut products also pass through Lower Casamance.

- Domestic trade activities: Agricultural products, whether locally produced or imported, can be transferred from one zone to another.
- Consumption activities: The population in each zone consumes some quantity of several cereals.
- Price vector activities: Several price vectors are considered in the model as mentioned earlier. Each price vector is considered a separate activity.

5.3.2 - Objective function coefficients

The objective function to be minimized is the cost of meeting the population's cereal needs minus the value of exports. The coefficients of the objective function are:

- For aggregate production activities, the cost of producing them, equal to the sum over all products and all zones of the quantity produced in each zone of each product multiplied by its price in the relevant price vector;
- For processing activities, the unit cost of processing, which can vary as a function of the quantity processed due to economies of scale. Therefore, a cost consistent with the quantity processed determined ex post was chosen;
- For international trade activities, the CIF price for food imports and the FOB price for exports of cash products and food crops. The cost of imported inputs being already taken into account in the cost

of regional product combinations, the coefficient for input import activities in the objective function is zero;

- For domestic trade activities, the transfer costs of products from one zone to another;
- For consumption activities, zero coefficients;
- For price vector activities, zero coefficients.

The objective function in the national model is therefore:

$$\text{Min } \Omega = \sum_{p} TCNATPROD_p \; NATPROD_p + \sum_{v}\sum_{q} CP_{qv} \; X_{qv}$$

cost of producing primary products — cost of processed products

$$+ \sum_{f} PW_f \; IMP_f \quad - \quad \sum_{l} PW_l \; EXP_l$$

cost of cereals imports — value of exports of agricultural products

$$+ \sum_{l}\sum_{v}\sum_{v'} CTRANS_{lvv'} \; TRANS_{lvv'} \quad (1)$$

cost of transportation of products

Units: CFA Francs

where:

p : Price vector index;

j : Primary product index;

q : Processed product index;

l : Product index;

f : Cereal index;

r : Agricultural zone index (r = 1,11);

v : Zone index including agricultural zones and the capital city area (zone 12);

$TCNATPROD_p$: Total cost of producing the aggregate production activity associated with price vector p;

$NATPROD_p$: Aggregate production activity associated with price vector p;

CP_{qv} : Unit cost of processing product q in zone v;

X_{qv} : Quantity of processed product q produced by zone v;

PW_f : World price of cereal f;

IMP_f : Quantity imported of cereal f;

PW_l : World price of agricultural product l;

EXP_l : Quantity exported of agricultural product l;

$CTRANS_{lvv'}$: Cost of transportation of agricultural product l from zone v to zone v';

$TRANS_{lvv'}$: Quantity of agricultural product l transported from zone v to zone v'.

5.3.3 - Constraints

The agricultural sector model includes separable programming, accounting, food security, and consumption habits constraints.

- Separable programming constraints

Each zone must face the same price vector. This does not mean that the prices are the same in all zones, but rather that they are consistent with one another in the sense that the difference between prices of a given good in two given zones only reflect transportation costs and marketing margins between these zones.

To achieve this consistency, separable programming constraints are added in the agricultural sector model. Excerpts of the LP tableau for the agricultural sector model are presented in Table 3 as an illustration of the way these constraints operate. Only three price vectors are taken into consideration.

TABLE 23

EXCERPTS OF THE LP TABLEAU FOR THE AGRICULTURAL SECTOR MODEL CONCERNING SEPARABLE PROGRAMMING CONSTRAINTS

	Aggregate production activities			Price vectors			Sign	RHS
	P1	P2	P3	P1	P2	P3		
Separable row				1	1	1	≤	1
P1	1			- 1			=	0
P2		1			- 1		=	0
P3			1			- 1	=	0

NB: RHS means right hand side.

$$\sum_p PV_p \leq 1 \quad (2)$$

where:

PV_p : Price vector p

For each price vector p,

$$NATPROD_p - PV_p = 0 \quad (3)$$

where:

$NATPROD_p$: Aggregate production activity associated with price vector p;

PV_p : Price vector p.

- Accounting constraints

Demand must be equal to supply for inputs, primary products and processed products:

i) Inputs

The total quantity of input i required to produce the aggregate production combination in the solution must be less than or equal to the sum of the quantity supplied by the initial national endowment and the quantity imported of that input.

For each input i for which this constraint applies (such as fertilizers):

$$\sum_p INPUT_{ip} \, NATPROD_p \leq E_i + IMP_i \quad (4)$$

Units: tons

where:

$INPUT_{ip}$: Quantity of input i required to produce the aggregate production activity associated with price vector p;

$NATPROD_p$: Aggregate production activity associated with price vector p;

E_i : Initial national endowment in input i;

IMP_i : Quantity imported of input i.

ii) <u>Primary products</u>

For each agricultural zone r, the quantity of primary product j consumed in zone r must be less than or equal to the quantity produced in zone r plus the quantity transferred from other zones minus the quantity transferred to other zones minus the quantity used for processing in zone r.

For each agricultural zone r and primary product j:

$$CONS_{jr} \leq \sum_p X_{jrp}\ NATPROD_p + \sum_v TRANS_{jvr} - \sum_v TRANS_{jrv} - \sum_q s_{jqr}\ X_{qr} \quad (5)$$

Units: tons

where:

$CONS_{jr}$: Quantity of primary product j consumed in zone r;

X_{jrp} : Quantity of product j produced in zone r in the aggregate production activity associated with price vector p;

$NATPROD_p$: Aggregate production activity associated with price vector p;

$TRANS_{jvr}$: Quantity of agricultural product j transferred from zone v to zone r;

$TRANS_{jrv}$: Quantity of agricultural product j transferred from zone r to zone v;

s_{jqr} : Quantity of primary product j required to produce one unit of processed product q in zone r;

X_{qr} : Quantity of processed product q produced in zone r.

For the Cap Vert area (zone 12), the quantity of primary product j consumed must be less than or equal to the quantity imported plus the quantity transferred from other zones minus the quantity exported minus the quantity transferred to other zones minus the quantity used for processing in zone 12.

For each primary product j:

$$CONS_{j12} \le IMP_j + \sum_r TRANS_{jr12} - EXP_j - \sum_r TRANS_{j12r} - \sum_q s_{jq12}\, X_{q12} \quad (6) \qquad \text{Units: tons}$$

where:

$CONS_{j12}$: Quantity of primary product j consumed in zone 12;

IMP_j : Quantity imported of primary product j;

$TRANS_{jr12}$: Quantity of agricultural product j transported from zone r to zone 12;

EXP_j : Quantity exported of primary product j;

$TRANS_{j12r}$: Quantity of agricultural product j transported from zone 12 to zone r;

s_{jq12} : Quantity of primary product j required to produce one unit of processed product q in zone 12;

X_{q12} : Quantity of processed product q produced in zone 12.

iii) Processed products

For each agricultural zone r, the quantity of processed product q consumed in zone r must be less than or equal to the quantity processed in zone r plus the quantity transferred from other zones minus the quantity transferred to other zones.

For each agricultural zone r and processed product q:

$$CONS_{qr} \le X_{qr} + \sum_v TRANS_{qvr} - \sum_v TRANS_{qrv} \quad (7) \qquad \text{Units: tons}$$

where:

$CONS_{qr}$: Quantity of processed product q consumed in zone r;

X_{qr} : Quantity of processed product q produced in zone r;

$TRANS_{qvr}$: Quantity of processed product q transported from zone v to zone r;

$TRANS_{qrv}$: Quantity of processed product q transported from zone r to zone v.

For the Cap Vert area (zone 12), the quantity of processed product q consumed must be less than or equal to the quantity imported plus the quantity transferred from other zones minus the quantity transferred to other zones.

For each processed product q:

$$CONS_{q12} \leq IMP_q + \sum_r TRANS_{qr12} - EXP_q - \sum_r TRANS_{q12r} \quad (8)$$

Units: tons

where:

$CONS_{q12}$: Quantity of processed product q consumed in zone 12;

IMP_q : Quantity imported of processed product q;

$TRANS_{qr12}$: Quantity of processed product q transported from zone r to zone 12;

EXP_q : Quantity exported of processed product q;

$TRANS_{q12r}$: Quantity of processed product q transported from zone 12 to zone r.

- Food security constraints

The agricultural sector model includes:

i) A nutritional constraint. The quantity of calories obtained by each zone through consumption of cereals must be above a nutritionally satisfactory level. This level is net of calories coming from food products other than cereals such as as animal products or sugar products.

For each zone v:

$$\sum_f CONS_{fv}\ CAL_f \geq NEEDSC_v \quad (9)$$

Units: millions of calories

where:

$CONS_{fv}$: Quantity of cereal f consumed in zone v;

CAl_f : Millions of calories per ton of cereal f;

$NEEDSC_v$: Caloric needs of the population in zone v.

ii) <u>The cereals self-sufficiency objective of the policy-maker</u>. This objective can be modified to look at the cost of meeting cereals needs under several levels of cereals self-sufficiency.

$$\sum_p \sum_r \sum_f X_{frp}\ NATPROD_p\ CAL_f \geq OBJ\ NEEDSC \quad (10)$$

Units: millions of calories

where:

X_{frp} : Quantity of cereal f produced in zone r in the aggregate production activity associated with price vector p;

$NATPROD_p$: Aggregate production activity associated with price vector p;

CAL_f : Millions of calories per ton of cereal f;

OBJ : Cereals self-sufficiency objective of the policy-makers as a percentage of national cereals needs;

NEEDSC : National cereals needs.

- Food consumption habits constraints

The quantity consumed by each zone of different cereals must stay within certain bounds to reflect consumption habits. Separate food habits were considered for urban and rural areas within each zone since there are wide differences between the food habits in each area.

For each zone v:

$CONSMIN_{fv} \leq CONS_{fv} \leq CONSMAX_{fv}$ (11) Units: thousands of tons

where:

$CONSMIN_{fv}$: Minimum quantity consumed of cereal f by the population of zone v;

$CONS_{fv}$: Quantity of cereal f consumed in zone v;

$CONSMAX_{fv}$: Maximum quantity consumed of cereal f by the population of zone v.

Now that we have presented the general structure of the agricultural sector model, let us comment on certain specific features. There are no processing capacity constraints in the model because all processing activities considered were operating well below capacity.

Although this agricultural sector model is not a macroeconomic model by definition, it can provide insights on two important macroeconomic performance indicators that the government would consider in its evaluation of different food strategies: the foreign exchange balance and the public budget. The model does not include a foreign exchange constraint since it is reasonable to assume that the Senegalese government will always import whatever food is needed to meet food demand. This is a basic condition for political survival.

However, the model includes a row which accounts for all uses and sources of foreign exchange, so that the net foreign exchange balance for agricultural inputs and outputs can be calculated. The impact of alternative production and trade policies on another important macroeconomic performance indicator, namely the public budget, can be roughly estimated by looking at the extra cost paid for higher and higher levels of cereals self-sufficiency. It is worth mentioning that this extra cost could be shared between the state (in the form of subsidies) and consumers (in the form of higher cereals consumer prices). It is up to the government to decide on the consumers' share and its share.

To review this chapter, the stages of the modelling exercise were outlined, including the construction of a set of empirical models, the aggregation of agricultural supply at the zone level and at the national level, the derivation of agricultural products supply curves, the construction of an agricultural sector model, and finally the use of experimental design techniques. Then the structures of the farm models and of the agricultural sector model were described, looking at the activities, the objective function coefficients and the constraints for each type of model. The results of this modelling exercise are presented in the next chapter.

CHAPTER 6

ANALYSIS OF THE RESULTS OF THE EMPIRICAL MODELLING EXERCISE

The empirical modelling exercise presented in Chapter 5 provided a number of insights on the issues of food security and comparative advantage in Senegal, both at a micro level and at a macro level. This chapter presents first some interesting microeconomic results coming from the farm models. Then, the implications of three price policies on several performance indicators are analyzed. Finally, some key policy variables affecting food system performance are identified.

6.1 - Farm level analysis

The typical farm models provide insights on the possible rates of cereals self-sufficiency (abbreviated thereafter as CSS) at the farm level, the profitability of agriculture and the key binding constraints in different zones of Senegal.

6.1.1 - Cereals self-sufficiency at the farm level

The farm models include a set of constraints on the levels of CSS that must be met in an average year and in the worst possible year from a climatic point of view. Initially set at very high levels, these constraints could not be met and resulted in an infeasible solution.

The target self-sufficiency levels were reduced until the models had a solution that was feasible and that best fitted the observed farm data, in particular data on crop acreage.

These levels are presented in Table 24 and provide insights on the feasible rates of CSS for the typical farm in each region. The rates are rather high in an average year (although only one zone achieves a rate of 80%), but are much lower in a very bad rainfall year. For rainfed cultivation zones, the rates are lower in the north (zones 2 and 5) than in the south (zones 6 to 11).

In the zones of irrigated perimeters in the Senegal River Basin, there is a difference between the large perimeters of zone 3 and the small perimeters of zone 4. In the large perimeters, individual plots are big enough to meet a high level of self-sufficiency. On small perimeters, the small size of the individual plots and the high population density prevent the farm model from reaching high self-sufficiency levels.

A situation similar to the case of the small perimeters can be found in Lower Casamance (zone 9), which has a high ratio of persons per hectare and a small farm size. In Middle and Upper Casamance (zones 8 and 7), the farm size is larger than in Lower Casamance, but the number of persons per farm remains high, which limits the possible rate of CSS.

The CSS rate in the Center of Eastern Senegal (zone 6) is higher than in High and Middle Casamance because the share of the cultivated area going to maize is higher in zone 6. In Middle and Upper Casamance, the upland cultivated area, where maize can be grown, is

TABLE 24

FARM SIZE AND CEREALS SELF-SUFFICIENCY RATES FOR THE TYPICAL FARMS OF SENEGAL IN AVERAGE AND WORST RAINFALL YEARS

Zone number	Zone name	Farm size		Ratio of persons per hectare	Cereals self-sufficiency rate (%)	
		Ha	Person		Average year	Worst year
	<u>Groundnut Basin</u>					
1	Center of the Groundnut Basin	6.5	9.5	1.5	70	30
2	North of the Groundnut Basin	8	9.5	1.2	60	20
10	Southwest of the Groundnut Basin	7	9	1.3	75	40
11	Southeast of the Groundnut Basin	8.5	9.7	1.1	80	50
	<u>Eastern Senegal and Casamance</u>					
6	Center of Eastern Senegal	4.5	9	2	75	40
7	Upper Casamance	4.5 (a)	9	2	65	25
8	Middle Casamance	4.5 (a)	9	2	65	25
9	Lower Casamance	2.2 (b)	7.8	3.5	60	20

NB: ha means hectare.

(a) 3.9 ha of upland cultivation and 0.6 ha of lowland cultivation.
(b) 1.48 ha of upland cultivation, 0.26 ha of lowland cultivation and 0.46 ha of transplanted rice.

TABLE 24 (CONT'D.)

Zone number	Zone name	Farm size		Ratio of persons per hectare	Cereals self-sufficiency rate (%)	
		Ha	Person		Average year	Worst year
	<u>Senegal River Basin</u>					
3	Large irrigated perimeters of the Lower Senegal River Basin	2	8.5	4.3	80	50
4	Middle Valley of the Senegal River	1.3 (c)	8.5	6.5	50	30
5	Upper Valley of the Senegal River and North Eastern Senegal	4.65 (d)	8.5	1.8	60	20

NB: ha means hectare

(c) 0.3 ha of irrigated perimeter and 1 ha of flood recession cultivation (<u>oualo</u>).
(d) 0.15 ha of irrigated perimeter and 4.5 ha of rainfed cultivation (<u>dieri</u>).

Source: Farm models built by the author.

less important because farmers also cultivate rice in the lowlands. Since rice has a slightly lower caloric content than maize (respectively 2420 and 3170 calories per kilo (Keita 1987)), it is more difficult to reach a high level of self-sufficiency expressed in calories in zones 8 and 7 than in zone 6.

The highest rates of CSS for rainfed cultivation are those of the South of the Groundnut Basin (zones 10 and 11) where farms tend to be larger and less populated, especially in the eastern part.

6.1.2 - Profitability at the farm level

The ranking of the zones according to the farm models' net margin[1] per hectare is presented in Table 25. Since the farm models were built using the crop budgets mentioned in Chapter 4 as a data base, it is logical that this ranking should be consistent with the national ranking of crops according to the net margin presented at the end of Chapter 4. However, the two rankings are slightly different because the model's ranking takes into account factors other than just profitability.

Irrigated rice and irrigated tomato arrived at the top of the crop profitability ranking. In the model's ranking, the large irrigated perimeters (zone 3) come first by far. However, the margins for the small perimeters of the Middle and the Upper Valley (zones 4 and 5) are

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[1]The net margin is equal to gross revenue minus expenses for purchased inputs. Since the objective function of the farm model is the net margin minus the value of cereal purchases, the net margin is calculated by adding the value of cereal purchases to the objective function value in the solution.

TABLE 25

RANKING OF THE ZONES IN SENEGAL ACCORDING TO THE NET MARGIN PER HECTARE FOR THEIR TYPICAL FARM

Rank	Zone number	Zone name	Model's net margin per hectare (FCFA)
1	3	Large irrigated perimeters of the Lower Senegal River Basin	144,400
2	10	Southwest of the Groundnut Basin	53,205
3	11	Southeast of the Groundnut Basin	51,928
4	9	Lower Casamance	50,076
5	5	Upper Valley of the Senegal River and North Eastern Senegal	47,790
6	6	Center of Eastern Senegal	43,216
7	1	Center of the Groundnut Basin	26,326
8	7	Upper Casamance	19,921
9	8	Middle Casamance	18,034
10	2	North of the Groundnut Basin	4,684
11	4	Middle Valley of the Senegal River	- 13,372

Source: Farm models built by the author.

much smaller.

The reason for this different performance is the irrigated land constraint in zones 4 and 5. The individual plots on the small perimeters are too small to generate enough cereals to cover all the family's needs, or enough income to be able to purchase the missing food. This is particularly the case for zone 4 which ranks last with a negative net margin. Zone 5 ranks better than zone 4 because it can grow some rainfed crops along with the plot on the small irrigated perimeter.

Groundnuts were the most profitable rainfed crop in the national crop ranking. The regions that grow a lot of groundnuts are highly ranked in the models' margin ranking. The Southwest, the Southeast and the Center of the Groundnut Basin are ranked respectively second, third and seventh out of eleven zones.

The only part of the Groundnut Basin that ranks poorly (tenth) is the North of the Groundnut Basin (zone 2). This results mainly from harsh climatic conditions that reduce the yields.

Cotton was the least profitable crop in the national crop ranking. In the initial run, the solutions of the models for Eastern Senegal, Upper and Middle Casamance (zones 6, 7 and 8) did not include any cotton. As mentioned in Chapter 4, cotton is grown not because it is profitable, but because it is one way for farmers to get access to credit and fertilizers supplied by the parastatal SODEFITEX. To take this factor into account, a minimum cotton acreage was added to force some cotton in the solution. This results into lower net margins and rankings. Zones 6, 7 and 8 are ranked sixth, eight and ninth.

6.1.3 - Most binding constraints

The most binding constraints in each zone were identified by comparing the shadow price of each resource in the dual solution to the unit cost of the resource considered. These constraints are presented in Table 26. Overall, the land constraint is binding in all models, which is typical for LP farm models. However, it is interesting to note that this constraint is most binding for irrigated land in the Senegal River Basin and for lowland in Casamance. An increase in the size of the irrigated plots would greatly increase profitability.

The best example is in the small perimeters of the Middle Valley of the Senegal River (zone 4). A run was made for the typical farm in this zone with an increase from 0.3 to 1 hectare of irrigated land. The improvement in the farmer's situation was impressive:

- All cereal needs were covered by a mix of production and purchases while only 70% of those needs could be covered before;
- The cereals self-sufficiency level increased from 50% in an average year and 30% in the worst year to 60% and 40% respectively;
- The net margin went from a negative CFAF -17,800 to a positive CFAF 149,000.

The other region where land is a major constraint is Casamance. In that region, upland is not really binding, but lowland is a scarce resource, limiting the area that the farmer can plant in lowland and transplanted rice. Unfortunately, the lowland area cannot be expanded like the irrigated land area in the Senegal River Basin since it is mainly the result of climatic factors.

Capital is a scarce resource in most zones. The major exception

TABLE 26

MOST BINDING CONSTRAINTS IN THE TYPICAL FARM MODELS

IN ALL THE ZONES OF SENEGAL

Zone number	Zone name	Most binding constraints in the farm models
	<u>Groundnut Basin</u>	
1	Center of the Groundnut Basin	- Land - Capital
2	North of the Groundnut Basin	- Labor period for cowpeas harvest
10 11	Southwest and Southeast of the Groundnut Basin	- Land - Labor period for weeding and thinning
	<u>Eastern Senegal and Casamance</u>	
6	Center of Eastern Senegal	- Land - Labor period for seeding, ploughing, first weeding and fertilizer spreading - Capital
7	Upper Casamance	- Lowland - Labor period for seeding, ploughing, first weeding and fertilizer spreading - Capital
8	Middle Casamance	- Lowland - Male and female labor periods for the first two months of the rainy season - Capital
9	Lower Casamance	- Land for transplanted rice and lowland - Labor period for seeding, ploughing, first weeding and fertilizer spreading - Capital

TABLE 26 (CONT'D.)

Zone number	Zone name	Most binding constraints in the farm models
	<u>Senegal River Basin</u>	
3	Large irrigated perimeters of the Lower Senegal River Basin	- Irrigated land - Double cropping possibility - Labor periods for rice harvest during the rainy season
4	Middle Valley of the Senegal River	- Irrigated land - Double cropping possibility
5	Upper Valley of the Senegal River and North Eastern Senegal	- Irrigated land - Double cropping possibility

NB: The most binding constraints in each zone were identified by comparing the shadow price of each resource in the dual solution to the unit cost of the resource considered.

Source: Farm models built by the author.

is the Senegal River Basin where relatively cheap public credit is available from SAED. The national public credit and input supply system broke down in 1980 and was suppressed at that time. Since that time, the capital constraint has become very binding, which limits the adoption of intensive technical modules.

Labor is a constraint in a number of models at critical periods which vary depending on the zone and the crop. The cowpea harvest time in the North of the Groundnut Basin, the rice harvest in the Lower Senegal Valley, the start of the cropping season in Eastern Senegal and in Casamance, the weeding and thinning period in the South of the Groundnut Basin are periods when labor bottlenecks occur and force the farmer to hire labor if profitable.

6.2 - Analysis of a general cereals prices increase policy

One major use of the empirical model was to simulate the probable impact of several levels of increases in the cereals producer prices in Senegal. This price policy could be a major component of a strategy aiming at increasing the level of CSS. The modelling exercise provides insights on the implications of this price policy on several performance indicators, in particular:

- The level of CSS;
- The production of major crops;
- The level of technology used and the quantity of inputs used;
- The cost of meeting population food needs minus the value of exports;
- The state budget;
- The trade balance.

6.2.1 - Implications for the cereals self-sufficiency rate

Output in the model does not seem to respond significantly to an increase in the prices of all cereals. When the farm models are run to simulate the cereal price increases, even if the cereals prices increase 100%, the CSS rate increases only 8.3 percentage points, going from 47.3% to 55.6% (see Table 27).

When optimistic assumptions are made about the creation of new irrigated perimeters and the development of double cropping until the year 2000[1], the CSS rate with present prices increases 10.2 percentage points, reaching 57.5%.[2] When marginal rainfed land is included in the farm models and a 40% increase in cereal prices is considered, the CSS rate increases 6.4 percentage points compared to 5.9 percentage points for just a 40% price increase (with no marginal land). When both optimistic assumptions about expansion of irrigated agriculture and marginal land are included, the CSS rate increases 17.1 percentage points with a 40% cereals price increase, reaching 64.4%.

Whatever the assumptions made, the resulting CSS rate comes far short of the 80% target level of the Senegalese government. However, it is possible that the methodology used results in an underestimate of

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[1]It is assumed that irrigated areas increase 10% per year in zone 3, 20% in zone 4 and 30% in zone 5. This represents an overall annual increase of 4120 hectares. The double cropping coefficient goes from 1.1 to 1.5. Flood recession cultivation disappears as a result of the completion of the Manantali dam.

[2]The CSS rate is calculated on the basis of the cereals needs of the present population. In the case when irrigated land available in 2000 is included, this results in a higher CSS than would occur in reality since the Senegalese population, and thus cereal needs, would increase from 1986 to 2000.

TABLE 27

LEVELS OF CEREALS SELF-SUFFICIENCY IN SENEGAL ACCORDING TO SEVERAL LEVELS OF INCREASES IN THE PRICES OF ALL CEREALS AND ASSUMPTIONS ABOUT LAND USE

Assumptions about cereal prices and land use	Production of cereals (billion calories)[1]	Cereals self sufficiency rate[2] (%)
- Present cultivated area		
. Present prices	1,503	47.3
. 20% increase in cereal prices	1,519	47.8
. 40% increase in cereal prices	1,693	53.2
. 60% increase in cereal prices	1,752	55.1
. 80% increase in cereal prices	1,767	55.6
. 100% increase in cereal prices	1,767	55.6
- Present cultivated area plus irrigated land available in 2000		
. Present prices	1,828	57.5
- Present cultivated area plus marginal rainfed land		
. 40% increase in cereal prices	1,708	53.7
- Present cultivated area plus marginal rainfed land plus irrigated land available in 2000		
. 40% increase in cereal prices	2,048	64.4

[1]This is net production which is equal to the gross production multiplied by a coefficient that takes into ac.ount storage losses, seed stock reconstitution, and milling into consumable products.

[2]The cereals self-sufficiency rate is calculated on the basis of the cereals needs of the present population.

Source: Supply curves derived by the author.

the price elasticity of cereals supply. This underestimation could come from the use of survey data that cover only the existing technological relationships. However, the data base used to build the farm models included not only existing technical modules, but also more intensive ones. Intensive techniques are currently little used if at all, but could become attractive with higher cereal prices.

A more relevant source of underestimation of the price elasticity of the cereals supply response is the possibility of factor market adjustments following the changes in relative product prices. In particular, an increase in the profitability of growing cereals could potentially trigger a labor migration from urban to rural areas. This would increase labor supply, remove some labor bottlenecks and make the adoption of more labor-intensive technical modules possible.

It is very difficult to come up with reasonable assumptions on the importance of the adjustment on the labor market and its effect on agricultural farm labor supply and choice of technical modules in the different zones. However, let us point out that the migration to the countryside would occur only if there were a significant financial incentive to leave the urban area. In that respect, the current structure of the farm model considers indirectly that possibility since it is possible to hire labor in different periods at the estimated agricultural day wages. These wages are considered to be the minimum that the urban labor would ask to go back to work in agriculture. The farm model can hire extra labor, once family labor is completely used, if it is profitable to do so.

Another possible source of underestimation of the price elasticity is an underestimation of the amount of marginal land that would be cultivated with a cereals price increase. First, there is the technical issue of estimating the amount of cultivable marginal land. Authorities[1] generally agree that the amount available in the Groundnut Basin is very limited, except in the Southeast. In the past, there have been various opinions regarding the potential in Eastern Senegal and Casamance. Right now, most agronomists and soil scientists think there is a potential for expansion of cultivated areas, but not as big as envisioned initially by some studies.[2] The figures used in this research were calculated on the basis of the National Land Management Plan[1] of 1984 which presented a disaggregated analysis of this issue (see Table 28).

Even if marginal rainfed land is available, several factors may impede its cultivation. To start with, farmers usually cultivate the most fertile land, which implies that the non-cultivated areas are less fertile. The assumption made in the farm models is that the yield on marginal land is 50% of the yield on "regular" land for a given technical module. This makes cultivation of marginal land much less financially attractive.

Also farmers tend to cultivate the area around their village. Thus, uncultivated land is farther away and cultivating it would imply more transport time. It would also be harder to watch for birds or animals and the farmer would be less prone to adopting high levels

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[1]Secrétariat d'Etat Chargé de la Décentralisation (1984).

[2]See ABT Associates (1984).

TABLE 28

ESTIMATION OF THE POTENTIAL FOR AN INCREASE IN THE CULTIVATED AREA BY ZONE OF RAINFED CULTIVATION IN SENEGAL

(percentage of presently cultivated areas)

Zone number	Zone name	Land increase potential
	Groundnut Basin	
1	Center of the Groundnut Basin	5
2	North of the Groundnut Basin	5
10	Southwest of the Groundnut Basin	5
11	Southeast of the Groundnut Basin	15
	Eastern Senegal and Casamance	
5	Upper Senegal River Valley and North of Eastern Senegal	15
6	Center of Eastern Senegal	30
7	Upper Casamance	30
8	Middle Casamance	30
9	Lower Casamance	5

Source: The land increase potential was calculated on the basis of the estimations of the National Land Management Plan (see Secrétariat d'Etat Chargé de la Décentralisation 1984, p. 149 and p. 230).

of intensification on this land.[1]

Finally, labor or capital constraints might prevent the cultivation of marginal land. This is the case for the farm model of the Middle Casamance where only part of the marginal land available was put into cultivation because of labor constraints. It is therefore reasonable to think that the increase in cultivated land resulting from a cereals price increase would be limited.

Overall, the research results constitute strong evidence that <u>the price elasticity of cereals supply is rather low in Senegal</u> and that <u>the government's objective of 80% CSS by the year 2000 is too optimistic</u>. Two main reasons can explain this result. First, groundnuts are far more profitable than millet/sorghum, even with substantial increases in the price of that cereal. Second, the expansion of rice cultivation is strongly limited by a land constraint, both for irrigated land in the Senegal River Basin and for lowland in the Casamance.

6.2.2 - <u>Implications for the production of major crops</u>

A general cereal prices increase results in changes in the production of major crops (see Table 29). The most striking change is that most of the increase in cereal production comes from an increase in maize production. When prices increase 40%, millet/sorghum and rice production increase only 0.2% while maize production increases 101%. Maize production goes up from 58,680 tons to 117,840 tons. When prices increase 80%, rice production goes up 0.2%, millet/sorghum 0.8% and

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[1]Interview with ISRA/BAME researchers.

TABLE 29

PRODUCTION OF THE MAJOR CROPS IN SENEGAL ACCORDING TO SEVERAL LEVELS OF CEREALS PRICE INCREASES

(in tons)

Product	Production[1]				
	Present prices	40% price increase	% change	80% price increase	% change
Millet/sorghum	362,370	362,991	0.2	365,261	0.8
Maize	58,680	117,841	101	138,788	137
Rice	72,720	72,884	0.2	72,864	0.2
Groundnuts	518,850	431,344	-16	389,271	-24
Cotton	13,166	13,166	0	13,166	0
Cowpeas	14,970	14,970	0	14,970	0

[1]For cereals, this is net production equal to gross production multiplied by a coefficient that takes into account storage losses, seed stock reconstitution and milling into consumable products. For the other crops, this is gross production.

Source: Supply curves derived by the author.

maize 137%. The share of maize in cereal production measured in billion calories rises from 12% with present prices to 22% with a 40% price increase, and to 25% with an 80% cereal price increase. Conversely, groundnut production goes down 16% with a 40% cereal price increase and 24% with an 80% price increase.

The maize supply response might be overestimated somewhat because certain agronomic factors playing against maize could not easily be included in the model. In particular, maize is more subject to bird and animal attacks than other cereals, which might make the farmer expand his maize production less than he would have done in the absence of these potential attacks. This is particularly an issue in Casamance because of the presence of monkeys and wart-hogs (Goetz 1988).

Moreover, some fertilization is required to obtain adequate maize yields. Presently, maize is mainly grown in home gardens which receive manure. However, the expansion of maize production would occur on regular fields which tend to be poor in nutrients. Fertilizers would be required to provide the necessary nutrients. Therefore, the expansion of maize production depends partly on the availability of fertilizers at the farm level on a wide scale (Goetz 1988 and Ndiame 1987). The farm models assume an infinitely elastic supply of inputs, which ignores the possibility of a supply constraint in the input marketing system. However, the implications for the aggregate quantity of inputs used were considered and the increase in inputs quantities required was found realistic (see part 6.2.3).

Cowpeas compete only with one cereal which is not very competitive, millet/sorghum, so cowpea production remains the same in spite of the increase in the price of millet/sorghum. Cotton production also remains at the same level, but this is meaningless since it is forced into the solution. As we already pointed out, cotton is not a profitable crop with present prices; this will not change with an increase in cereal prices.

The major implication of these changes in the production of different crops is that maize would replace groundnuts to a certain extent. This situation would potentially create a maize surplus problem because maize is not a major part of the diet of the Senegalese population, which eats mainly rice in the cities and millet/sorghum in the countryside. Assuming present food habits would not change, the present maize deficit of 29,430 tons would change to a surplus of 29,730 tons with a 40% cereal prices increase and to a surplus of 50,680 tons with an 80% price increase.[1]

In the long run, one might expect food habits to change in favor of maize. The agricultural sector model was used to calculate the required increase in maize consumption necessary to avoid a surplus. With a 40% price increase, maize consumption would have to increase 25%, and with an 80% price increase, 65%. A 25% increase in maize consumption seems reasonable, but a 65% increase does not seem attainable in the near future.

When marginal land is considered, the changes in the pattern of

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[1]Assuming an industrial use of maize of 15,000 tons, which are mainly imported so far.

production are minimal compared to a case where marginal land is excluded (see Table 30). Most of the marginal land goes to millet/sorghum. This might seem a paradox, but groundnut production does increase going from the scenario with just a 40% cereal price increase to the scenario with a 40% price increase plus marginal land. What is happening is that millet/sorghum grown on marginal land can help satisfy some cereal needs, so that less millet/sorghum is grown on "regular" land for food consumption. The "regular" land area made available this way goes to the most profitable crop, in this case groundnuts.

When optimistic assumptions are made about the development of irrigated agriculture in the Senegal River Basin until the year 2000[1] apart from marginal rainfed land, rice production increases substantially, going from 72,720 to 218,379 tons, i.e., a 200% increase (see Table 30). However, the relatively low share of rice in cereal production and a slightly lower caloric content of rice explain that the total increase in the CSS rate is only about 17 percentage points (see Table 27).

6.2.3 - Implications for the level of technology and the quantity of inputs used

In general, the increase in cereals prices results in an increase in the share of the cultivated area planted to high intensity technical modules. In zones where maize is grown, the intensification effect is combined with the substitution effect from groundnuts to maize. Maize

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[1]See footnote 1 at the bottom of page 204.

TABLE 30

PRODUCTION OF THE MAJOR CROPS IN SENEGAL WITH A 40% INCREASE IN THE LEVEL OF CEREALS PRICES AND SEVERAL ASSUMPTIONS ABOUT LAND USE

(in tons)

Product	Production[1]					
	40% price increase	% change versus product. under current prices	40% price increase + Marginal land	% change versus product. under current prices	40% price increase + Marginal land + Irrigated land in 2000	% change versus product. under current prices
Millet/sorghum	362,991	0.2	373,103	3	370,314	2
Maize	117,841	101	111,270	90	111,270	90
Rice	72,884	0.2	74,387	2	218,379	200
Groundnuts	431,344	-16	453,608	-12	453,413	-12
Cotton	13,166	0	13,166	0	13,166	0
Cowpeas	14,970	0	14,873	-1	14,873	-1

NB: Produc. means production.

[1]For cereals, this is the net production equal to gross production multiplied by a coefficient that takes into account storage losses, seed stock reconstitution and milling into consumable products. For the other crops, this is gross production.

Source: Supply curves derived by the author.

is mainly grown in module 2 while groundnuts, millet/sorghum and rice are grown mainly in modules 3, 5 and a little bit of module 1. Therefore, the cereals price increase results in a large increase of module 2 and small decreases in module 1, 3 and 5.

In zones where maize is not grown, there is either no change in the solution (zones 1 and 10) or an increase in intensification (zone 2). In irrigated areas where two levels of intensification are distinguished, the models switch to the more intensive modules.

When marginal land is taken into account, the models use technical modules corresponding to low levels of intensification on that extra land. This seems logical since the farmer is not likely to invest his scarce capital on far away and low-yielding marginal land.

The changes in the quantities of inputs used reflect the changes in the production of the major crops and in the level of production intensification. When the prices of all cereals increase 80%, the amount of NPK fertilizer used goes up 237% for maize (14-7-7), up 30% for rice and irrigated crops (18-46-0), up 1% for millet/sorghum (14-7-7), but down 97% for groundnuts (6-10-20). It does not change for cotton (6-14-35). Overall, the amount of NPK used increases 4% from 44,900 tons to 46,900 tons. The amount of urea goes up 45% from 21,970 tons to 31,820 tons. The amount of groundnut seed used goes down 17%.

When optimistic assumptions for irrigated cultivation development are adopted, the amount of NPK fertilizer used goes up 27% for rice and irrigated crops (18-46-0) and the amount of urea 42%. Other inputs are not affected.

When marginal land is taken into account with a 40% cereals price increase, there is not much change in inputs used for cereals compared to the effect of a 40% price increase alone since low intensity technical modules are used on marginal land. However, as noted above, groundnut production increases a little and so do the amounts of inputs used for groundnuts. NPK fertilizer for groundnuts (6-20-10) goes up 34% and groundnut seed 3%.

6.2.4 - Cost implications

The cost implications of alternative levels of food self-sufficiency can be estimated in two ways. First, there is the social cost of meeting a given level of CSS valuing all resources at their shadow prices. The value of the objective function in the agricultural sector model, which is defined as the cost of meeting the population's cereal needs less the value of exports, provides one estimate of this cost. This value increases 20% with a 40% cereal price increase and 39% with an 80% price increase (see Table 31).

Second, there is the cost for the public budget. It is hard to evaluate precisely the impact of different levels of CSS on the state budget because the higher producer prices can be paid either by the consumers in the form of higher consumer prices or by the state in the form of producer or consumer subsidies. Given the low standard of living of many consumers, it makes sense to assume that the state would pay for the extra costs of higher levels of self-sufficiency. The state would have to pay a subsidy only for the marketed production to guarantee the producer the higher cereal prices. This subsidy or extra cost is estimated 1) by multiplying the marketed production for each crop at the farm level by its price 2) by aggregating across all

TABLE 31

ESTIMATION OF THE COST IMPLICATIONS OF ALTERNATIVE LEVELS OF CEREALS SELF-SUFFICIENCY IN SENEGAL

	Present prices	40% price increase	80% price increase
1 - Level of cereals self-sufficiency (%)	47.3	53.2	55.6
2 - Increase in the cereals self-sufficiency in percentage points		5.9	8.3
3 - Cost of meeting population food needs minus the value of exports (million CFAF)	125,500	150,230	174,862
4 - Increase in the cost of meeting population food needs minus the value of exports in %		20	39
5 - Extra cost for the state (million CFAF)		6,261	15,112
6 - Extra cost as % of the state deficit in 1983		11	27

Source: Agricultural sector model results.

farms, crops and zones to get the marketed production cost and 3) by subtracting the marketed production cost at a given price level, e.g., the present price level, from the marketed production cost at a higher price level, e.g., a 40% cereal price increase. The extra cost is estimated at 6.3 billion CFAF with a 40% price increase, which would increase the CSS rate by 5.9 percentage points above the present level. It is estimated at 15.1 billion CFAF with an 80% price increase, which would increase the CSS rate by 8.3 percentage points (see Table 31). These subsidies amount to 11% and 27% respectively of the state deficit in 1983.

Apart from these price subsidies, a major burden on the public budget is the cost of developing irrigated agriculture in the Senegal River Basin. Given the different supply responses mentioned earlier in this chapter, this public investment appears to be the only way of really increasing the CSS rate in Senegal. However, the cost of such a scheme was estimated in Chapter 3 at 57 billion CFAF, i.e., a little more than the total public deficit of 1983.

6.2.5 - Implications for the agricultural trade balance

An agricultural trade balance is calculated in the agricultural sector model through an inventory row that tracks the uses and sources of foreign exchange. Uses of foreign exchange include agricultural equipment and crop protection products, fertilizers, interregional product transfers and cereal imports. The source of foreign exchange is cash crop exports. Table 32 shows the importance of each of them with three levels of cereals prices. The figures presented are rough approximations since obtaining precise figures would require a separate

TABLE 32

AGRICULTURAL TRADE BALANCE FOR SENEGAL ACCORDING TO SEVERAL LEVELS OF CEREALS PRICE INCREASES

(in millions of CFA Francs)

Foreign exchange uses and sources	Present prices	% of total use	40% price increase	% of total use	80% price increase	% of total use
1 - Uses						
- Agricultural equipment and crop protection products	2,200	4.6	1,850	4.1	1,700	3.9
- Fertilizers						
. Imports of basic chemicals	1,964	4.1	2,417	5.3	2,511	5.8
. Processing cost	719	1.5	764	1.7	750	1.7
. Total	2,683	5.6	3,182	7.0	3,262	7.5
- Interregional product transfers						
. Cereals	1,261	2.6	1,396	3.1	1,345	3.1
. Cash crops	2,152	4.5	1,817	4.0	1,691	3.9
. Total	3,414	7.1	3,213	7.0	3,035	7.0
- Processing						
. Cereals	4,190	8.7	4,132	9.1	4,039	9.3
. Cash crops	6,456	13.4	5,409	11.9	4,881	11.2
. Total	10,646	22.1	9,541	20.9	8,921	20.5
- Cereal imports						
. Sorghum	2,621	5.4	2,262	5.0	2,178	5.0
. Maize	717	1.5	0	0.0	0	0.0
. Rice	20,384	42.3	20,157	44.2	19,210	44.0
. Wheat	5,503	11.4	5,427	11.9	5,305	12.2
. Total	29,225	60.7	27,846	61.0	26,693	61.2
- Total uses	48,167	100.0	45,632	100.0	43,611	100.0

TABLE 32 (CONT'D.)

Foreign exchange uses and sources	Present prices	% of total use	40% price increase	% of total use	80% price increase	% of total use
2 - Sources						
- Cash crop exports						
. Groundnut products	17,944	97.5	15,033	97.0	13,567	96.7
. Cotton	459	2.5	459	3.0	459	3.3
. Total	18,403	100.0	15,492	100.0	14,026	100.0
3 - Deficit	29,764		30,139		29,585	

Source: Agricultural sector model results.

study.

The most striking observation is that the overall agricultural trade deficit does not seem to change much when cereal prices are increased. This results from several counterbalancing effects. When cereal prices increase, groundnut production and exports fall, reducing sources of foreign exchange. Fertilizer use increases slightly, increasing uses of foreign exchange.

However, the use of foreign exchange for agricultural equipment and crop protection products goes down slightly. This results from the reduction in groundnut production which is the most mechanized among the rainfed crops and which uses fungicides for seed storage. Another result of the reduction in groundnut production is the reduced quantity of this product which is transported and processed. Cereal processing costs decrease very slightly as a result of a smaller industrial wheat processing activity, which uses imported equipment. Most locally produced cereals are processed manually, without any foreign exchange cost.

Finally, cereal imports go down since domestic production goes up. The figures presented in Table 32 are taken from the results of the agricultural sector models run to see how much maize consumption had to increase in order to have a zero surplus when cereals prices are increased. This explains why there are no imports of maize with a 40% or an 80% cereal price increase.

6.3 - Analysis of other price policies

Two other price policies were considered. The first one would involve raising rice and wheat consumer prices and the producer price for rice. The second one would consist of moving towards economic prices or border prices.

6.3.1 - Analysis of a policy raising only rice and wheat prices

This price policy is currently discussed following one recommendation of the CILSS-Club du Sahel conference in 1986 at Mindelo arguing in favor of the creation of a regional protected agricultural market in West Africa (CILSS-Club du Sahel 1987, Gabas et al. 1987). Only the prices of cereals which are not produced (wheat) or still not very much produced (rice) would be increased. Consumer prices for those cereals would be raised to favor the consumption of millet/sorghum and maize. The producer price of rice would be increased as well to promote the local production of that cereal and the substitution of local production for imports.

The methodology used in this research is ill-equipped to handle changes on the demand side. However, it can offer insights on the probable supply response to an increase in the producer price of rice. The assumption made was a 50% increase in the price of rice. The supply response was minimal. The CSS rate increased only by 0.6 percentage point. The other performance variables considered were affected to a similarly slight degree.

The major reason for the absence of response to an increase in the price of rice is the land constraint. Irrigated perimeters already produce mainly rice and the only real solution to expanding rice production is to expand the irrigated area. The area available for lowland rice and transplanted rice in Casamance is constrained by climatic factors. As mentioned in Chapter 4, several years of relative drought have lowered the water table and increased the salt content of many lowland areas. Upland rainfed rice is not the most profitable upland crop, even after the increase in the price of rice. Moreover, upland rice is a very risky crop.

The other component of this price policy involves raising the consumer prices of rice and wheat to favor the consumption of millet /sorghum and maize. The state would benefit from higher consumer prices. In 1986, the state earned 21 billion CFAF in revenues from taxes on the consumer price of rice.

However, the impact on income distribution could be harmful. An increase in the consumer price of wheat would hurt mainly well-off urban residents, who can afford to pay a higher price for this luxury good. But an increase in the consumer price of rice would reduce the real income of poor consumers, whose diet involves mainly rice. Consumers in Senegal are already paying a significant tax on rice. The CIF price of rice in Dakar varies roughly between CFAF 55 and 100 per kilo while the consumer price in Dakar is currently CFAF 160 per kilo.

Raising consumer and producer prices 35% or 40% above the import parity price can be justified by the overvaluation of the CFA Franc of the same magnitude. However, raising prices above that level penalizes consumers and might cause an inefficient allocation of resources.

Overall, the effects of such a price policy could be minimal on the supply, but, at first glance, could strongly affect the demand side and the real income of consumers, especially that of the poor urban consumers.

6.3.2 - Analysis of an economic prices policy

Another price policy option is to move toward economic prices. Economic prices are defined as import parity prices for cereals and agricultural inputs, and export parity prices for cash crops. For nontraded inputs, the economic price is the domestic market price. The advocates of this price policy argue that these economic prices provide a true indication of the opportunity cost of production of different crops and therefore give correct signals for an optimal allocation of resources to the microeconomic agents.

The estimated economic prices are compared to the current financial prices for major products in several zones of Senegal in Table 33. Three observations can be made on this table. First, Senegalese agriculture is already well protected. The economic prices for all crops except cotton are substantially lower than the financial prices. Second, the economic prices are relatively much lower than the financial prices in the case of cereals compared to the case of groundnuts. In the Center of the Groundnut Basin, the ratio groundnut price / millet price is 1.45 using financial prices and 1.73 using economic prices.

Third, the economic price of tomato seems much higher than its current financial price. One must be cautious here because the economic price calculated is based on the import parity price of fresh tomatoes while most of the tomatoes produced in the Senegal River Basin seem to be processed into tomato paste for domestic consumption. However, the little data available on the import parity prices of canned tomatoes and tomato paste were consistent with that economic

TABLE 33

COMPARISON OF FINANCIAL AND ECONOMIC PRICES FOR MAJOR AGRICULTURAL PRODUCTS IN SEVERAL ZONES OF SENEGAL

(in CFA Francs per kilo)

Product	Zone name	Financial price	Economic price[1]	Difference in % of financial price
Millet/ Sorghum	. Center of Groundnut Basin	62	39	-37
	. Center of Eastern Senegal	62	27.4	-56
	. Middle Casamance	62	26.5	-57
Maize	. South-East Groundnut Basin	75	26.3	-65
	. Center of Eastern Senegal	72	21.5	-70
	. Lower Casamance	67	23.2	-65
Rice (paddy)	. Large perimeters of the Lower Senegal River Valley	85	37.5	-56
	. Middle Senegal River Valley	85	32.1	-62
	. Upper Senegal River Valley and North Eastern Senegal	85	31.4	-63
Groundnut (shells)	. Center of Groundnut Basin	90	67.3	-25
	. Middle Casamance	90	66.7	-26
Cotton	. Middle Casamance	95	122.3	+29
Tomato	. Large perimeters of the Lower Senegal River Valley	25	80[2]	+220

[1]For sorghum, import parity price with the Center of the Groundnut Basin as the consumption point. For maize, rice and tomato, import parity price with Dakar as the consumption point. For groundnuts and cotton, export parity price. The CIF or FOB prices came from Customs statistics. See complete calculations in Tables 57 to 62 in Appendix A.

[2]This is the fresh tomato price.

Source: Calculations made by the author.

price. Given the lack of adequate data and to avoid overestimating the economic profitability of tomatoes, the financial price of CFAF 25 was used in the farm models rather than the estimated economic price of CFAF 80 per kilo.

The implications of these observations are obvious when running the farm models and the agricultural sector model with economic prices. The net margins per hectare are considerably lower with economic prices than with financial prices (see Table 34). The greatest income losses are for the large irrigated perimeters of the Lower Senegal Valley which are hurt by the decrease in the price of rice. The net margin in the North of the Groundnut Basin goes up slightly because the farm benefits from lower purchase prices for cereals while cowpea sales are not affected.

The net margins including cereal purchases are also lower with economic prices than with financial prices for most zones. The two exceptions are the North of the Groundnut Basin (zone 2) and the Middle Senegal River Basin (zone 4). In those two zones with low levels of CSS, the decrease in the value of cereal purchases more than compensates for the loss of output sale, which results in higher net margins including cereal purchases (respectively +69% and +4%).

Then, the production of groundnuts increases while that of cereals decreases when producers are faced with economic prices (see Table 35). This would support the argument that Senegal has a comparative advantage in the production of groundnuts rather than in the production of cereals.

Another interesting finding is that cotton enters in the solution

TABLE 34

COMPARISON OF NET MARGINS PER HECTARE BY ZONE IN SENEGAL USING FINANCIAL AND ECONOMIC PRICES

(in CFA Francs per hectare)

Zone number	Zone name	Farm model's net margin per ha[1]		
		Financial prices	Economic prices	Difference in % of financial price
	Groundnut Basin			
1	. Center of Groundnut Basin	26,326	23,712	-10
2	. North Groundnut Basin	4,684	5,030	+7
10	. Southwest Groundnut Basin	53,205	41,977	-21
11	. Southeast Groundnut Basin	51,928	36,713	-29
	Eastern Senegal and Casamance			
6	. Center Eastern Senegal	43,216	26,687	-38
7	. Upper Casamance	22,473	17,968	-20
8	. Middle Casamance	18,034	13,846	-23
9	. Lower Casamance	50,076	40,813	-18
	Senegal River Basin			
3	. Large perimeters of the Lower Senegal River Valley	144,400	25,950	-82
4	. Middle Senegal River Valley	-13,372	-17,335	-30
5	. Upper Senegal River Valley and North Eastern Senegal	45,790	28,070	-39

[1]The net margin is equal to gross revenue minus expenses for purchased inputs. Since the objective function of the farm model is the net margin minus the value of cereal purchases, the net margin is calculated by adding the value of cereal purchases to the objective function value in the solution.

Source: Farm models built by the author.

TABLE 35

COMPARISON OF THE PRODUCTION OF MAJOR CROPS IN SENEGAL

USING FINANCIAL AND ECONOMIC PRICES

(in tons)

Product	Production with financial prices	Production with economic prices	% change
Millet/sorghum	362,373	366,980	+1
Maize	58,680	45,825	-22
Rice	72,718	65,187	-10
Groundnuts	514,849	588,694	+14
Cotton	13,166	23,565	+79
Cowpeas	14,970	14,970	0
Tomato	0	29,255	

NB: For cereals, this is the net production equal to gross production multiplied by a coefficient that takes into account storage losses, seed stock reconstitution and milling into consumable products. For the other crops, this is gross production.

Source: Supply curves derived by the author.

without any constraint, contrary to the solution with financial prices. Also cotton does not enter in the solution in the traditional producing zones for that crop (Eastern Senegal and Upper Casamance), but in a zone where cotton is presently a marginal crop (Middle Casamance).

On irrigated perimeters, tomato replaces rice as the most profitable crop, even when the economic price of tomato is estimated at CFAF 25 per kilo rather than CFAF 80. In the initial run of the economic farm models and of the agricultural sector model, tomato production reached 118,000 tons. This was not realistic since the domestic market for tomato is around 30,000 tons. There is a potential for exporting tomatoes, but the past experience of Senegal in that field indicates that this requires many preconditions to be successful. At least for the short run, exporting large quantities of tomatoes does not seem a feasible option. To reflect this marketing constraint, a ceiling was set on tomato acreage in the economic models which results in tomato production of less than 30,000 tons.

The cost of meeting the population's cereal needs minus the value of exports drops 27% when economic prices are used instead of financial prices. This comes from the lower prices paid to the producers. The estimated deficit of the agricultural trade balance goes up 35%. One reason is lower cereals production, which results in more cereal imports. The other reason is larger groundnut production which increases the sources of foreign exchange, but which also uses more foreign exchange for production, transportation and processing.

Overall, an economic price policy would permit Senegal to benefit from its comparative advantage in groundnut production and would favor a more efficient allocation of resources. This conclusion is made using the present level of world prices. To validate this conclusion in the long run, one must consider the evolution of world prices over a long period rather than at a given point of time. Some economists argue that the terms of trade deteriorate over time for developing countries, which argues against an integration of these countries in world trade. This argument is debatable in the case of Senegal and depends partly on the years chosen as the start and end of the period over which the evolution of the terms of trade is considered. The terms of trade index for Senegal was 112 in 1960, 123 in 1970, 159 in 1975, 100 in 1980 and 98 in 1985 (World Bank 1979, 1982, 1984, 1987b).

The World Bank (1987a) projects that world prices for agricultural products and inputs traded by Senegal are going to increase slightly over the low level of 1986-87 until year 2000, but will probably stay well below the high level of 1983-84. Therefore, the economic prices calculated for 1986-87 would remain more or less valid in the long run, and the comparative advantage of Senegal in groundnut production as well. However, the zero growth in the world market for groundnut products projected by the World Bank means that Senegal is facing a stagnant source of foreign exchange while the demand for foreign exchange to pay for cereal imports goes up as a result of rapid population growth. This raises the issue of the sustainability in the long run of a development strategy financed on groundnut products exports.

6.4 - Identification of key policy variables affecting the food system performance

An experimental design procedure was set up to identify key policy variables affecting the food system performance. A variance decomposition method was used to provide a systematic way of looking at the impact of each of several key variables, while controlling for the effects of the other variables (Casey 1974, Crawford 1982, Low 1974, Zuckerman 1977 and 1979, Zusman and Amiad 1965). Three policy variables were considered: the cereal production level (or equivalently a level of CSS desired), food habits and world prices.

Three levels of cereal production were chosen: the present production level (or a level of CSS desired of 47.3%), the production level corresponding to a 40% increase in cereal prices (or a level of CSS desired of 53.2%), and the production level corresponding to an 80% increase in cereal prices (or a level of CSS desired of 55.6%). Two levels were chosen for food habits: one with no food habits constraints and another with the present food habits constraints. Two levels of world prices were chosen: the low level of 1986/87 and the high level of 1983/84.[1]

Two performance indicators were chosen: the cost of meeting the population's cereal needs minus the value of exports (the value of the objective function of the agricultural sector model), and the

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[1]World prices for inputs and products traded by Senegal tend to fluctuate more or less similarly in the long run (see Figures 23 and 24 (pp. 89-90), Table 52 (p. 269) and World Bank 1987c). Therefore, it made sense to consider two levels for all prices: high and low.

agricultural trade balance deficit. The values for these two indicators are presented in Table 36 for the twelve possible combinations of the three policy variables.

As expected, the cost of meeting the population's food needs minus the value of exports increases with the level of production and with the inclusion of food habits. It decreases with an increase in world prices. A possible explanation for that result is that Senegal benefits more from an increase in world prices through an increase in the value of exports than it is hurt by an increase in the value of its imports. It is worth pointing out that the objective function of the agricultural sector model values groundnut production as if it was all exported.

The agricultural trade balance deficit does not change much with the level of production as a result of counterbalancing effects mentioned in Section 6.2.5. The impact of the introduction of food habits in the model is clearly to raise the trade deficit. The cheapest cereal on the world market is sorghum. To meet food habits, in particular of the urban population, Senegal has to import more expensive cereals such as rice and wheat.

The evidence for an increase in world prices is less clear-cut. The agricultural trade deficit goes down when world prices increase and no food habits are considered. It goes up when world prices increase and food habits are considered. A possible explanation for this result is that, when food habits are not considered, Senegal imports the cheapest cereal, i.e., sorghum. When world prices go up, the prices go up relatively more for exported products, which command a higher price,

TABLE 36

DATA USED FOR THE EXPERIMENTAL DESIGN PROCEDURE

1 - The total cost of meeting the population's food needs minus the value of exports in Senegal (in billions of CFA Francs)

Production level (level of CSS desired in %)	Low world prices 1986/87		High world prices 1983/84	
	No food habits constraint	Food habits constraint	No food habits constraint	Food habits constraint
Present production level (47.3)	100.6	125.5	74.5	112.3
Production level with a 40% increase in cereal prices (53.2)	124.4	150.2	103.2	141.6
Production level with an 80% increase in cereal prices (55.6)	149.8	174.9	131.3	168.4

TABLE 36 (CONT'D.)

2 - The agricultural trade balance deficit (in billions of CFA Francs)

Production level (level of CSS desired in %)	Low world prices 1986/87		High world prices 1983/84	
	No food habits constraint	Food habits constraint	No food habits constraint	Food habits constraint
Present production level (47.3)	6.5	29.8	-0.3	35.9
Production level with a 40% increase in cereal prices (53.2)	6.8	30.1	2	37.9
Production level with an 80% increase in cereal prices (55.6)	7	29.6	3.5	38

Source: Agricultural sector model results.

than for cheap imported sorghum. The net result is an improvement in the trade balance. When food habits are considered, more expensive cereals are imported such as wheat and rice. When world prices go up, the value of imported products goes up relatively more than the value of exported products, resulting in a deterioration of the trade balance.

A variance decomposition analysis was conducted to estimate the importance of the impact of each of the three policy variables on the two performance indicators (see Tables 37 and 38). The variables affecting the cost of meeting the population's food needs minus the value of exports are in order of importance: food habits and the production level (or level of CSS desired), and world prices. The variables affecting the agricultural trade balance deficit are in order of importance: food habits (by far), the production level or level of CSS desired, and world prices.

Several observations can be made on the basis of these results. First, food habits seem the policy variable that has the biggest impact on the performance indicators identified, especially the agricultural trade balance. This result would support the emphasis put by the Senegalese government on promoting millet/sorghum and maize to substitute for rice and wheat. Improvements in millet/sorghum and maize processing and marketing could contribute significantly to changing food habits in favor of those cereals and reducing the cost of meeting food needs.

Second, the production level (or the level of CSS desired) is the next important policy variable to consider. This variable has a major

TABLE 37

VARIANCE DECOMPOSITION TABLE FOR THE COST OF MEETING THE POPULATION'S FOOD NEEDS MINUS THE VALUE OF EXPORTS IN SENEGAL

(in billions of CFA Francs)

	Degrees of freedom	Sum of squares	Share of total (%)	Mean square	Share of total (%)
Food habits	1	2984	31.6	2984	44.9
Production level	2	5591	59.1	2795	42.0
World prices	1	739	7.8	739	11.1
Cross-effect (food habits X world prices)	1	118	1.2	118	1.8
Cross-effect (production level X world prices)	2	27	0.3	13	0.2
Cross-effect (production level X food habits)	2	1	0.0	0	0.0
Cross-effect (production level X food habits X world prices)	2	0	0.0	0	0.0
Total	11	9459	100.0	6650	100.0

Note: The zeros indicated in the table correspond to positive small numbers rounded to the nearest integer for numbers and to the nearest first decimal for percentages.

Source: Agricultural sector model results and calculations by the author.

TABLE 38

VARIANCE DECOMPOSITION TABLE FOR THE AGRICULTURAL TRADE

BALANCE DEFICIT IN SENEGAL

(in billions of CFA Francs)

	Degrees of freedom	Sum of squares	Share of total (%)	Mean square	Share of total (%)
Food habits	1	2572	95.1	2572	95.3
World prices	1	4	0.2	4	0.2
Production level	2	5	0.2	3	0.1
Cross-effect (food habits X world prices)	1	117	4.3	117	4.3
Cross-effect (production level X world prices)	2	4	0.1	2	0.1
Cross-effect (production level X food habits)	2	1	0.0	0	0.0
Cross-effect (production level X food habits X world prices)	2	0	0.0	0	0.0
Total	11	2703	100.0	2698	100.0

Note: The zeros indicated in the table correspond to positive small numbers rounded to the nearest integer for numbers and to the nearest first decimal for percentages.

Source: Agricultural sector model results and calculations by the author.

impact on the cost of meeting food needs, suggesting that higher CSS rates can be reached in Senegal through higher producer prices for cereals, but at a high social cost. However, the CSS level has little impact on the agricultural trade balance. Increased CSS does not seem to improve the balance of trade.

Third, world prices do not seem to matter much in the long run since some counterbalancing effects are at work to reduce the impact of their variations on the performance indicators considered. This does not mean however that short run fluctuations in the relative prices of inputs and outputs do not affect the performance variables considered.

To review this chapter, the results of the empirical modelling exercise were presented. To start with, the CSS level, the profitability and the most binding constraints at the farm level were analyzed. Then, the implications of three price policies were considered: a general cereals prices increase policy, a policy raising only rice and wheat prices, and an economic price policy. Finally, key policy variables affecting the food system performance were identified. The next chapter sums up the findings of this research and draws some policy implications.

CHAPTER 7

SUMMARY OF FINDINGS AND POLICY IMPLICATIONS

This chapter reviews the methodology and the major findings of this research, draws some policy implications, and suggests possible topics for further research. First, a conceptual framework and a theoretical model were proposed to analyze the interactions between food security and comparative advantage at the micro and at the macro level.

Then a methodology was proposed for an empirical analysis of these relations. It starts with a macro analysis of the food situation using food balances, which concludes that the agricultural situation in Senegal has deteriorated over the last decade. The cereals self-sufficiency rate decreased while the shares of commercial imports and especially food aid in total cereals supply increased. On the basis of the projections made under alternative scenarios about the cereals supply and demand conditions in Senegal until the year 2000, the Senegalese government's new objective of 80% cereals self-sufficiency by that date does not seem attainable. The only apparent hope for improving the level of food self-sufficiency in the very long run is to reduce the very rapid population growth.

Then the present financial profitability of major crops in the agricultural zones of Senegal was analyzed on the basis of several types of margins calculated from a number of detailed crop budgets. This analysis concludes that the present price policy does not especially favor rainfed cereals. Millet/sorghum is clearly not an interesting cash crop, and is grown mainly for home-consumption. Maize is much more profitable and can be competitive with groundnuts in some cases, although overall, groundnuts remain the most profitable rainfed crop. This does not seem consistent with the Senegalese government's objective of significantly increasing the level of cereals self-sufficiency.

The present price structure strongly favors irrigated rice in the Senegal River Valley, which is consistent with the very high priority given by the Senegalese government to increasing domestic rice production. Cotton is less profitable than most crops, and quite often, not profitable at all. It is not grown because it is profitable, but because it is one way for farmers to get access to credit and fertilizers supplied by the parastatal initially created to foster cotton cultivation.

To incorporate food security considerations at the micro level and look at their interactions with the profit objective, a number of typical farm models were built. These models provide insights on the possible rates of cereals self-sufficiency at the farm level, the profitability of agriculture, and the key binding constraints in different zones of Senegal. The possible cereals self-sufficiency rates are rather high in an average year (although only one zone achieves a rate of 80%), but are much lower in a very bad rainfall year. For rainfed cultivation zones, the rates are lower in the north than in the south of the country. In the zones of irrigated perimeters in the Senegal River Basin, individual plots in the large perimeters of the Lower Valley are big enough to meet a high level of self-sufficiency. On small perimeters in the Middle Valley, the small size of the individual plots and the high population density prevent the farm model from reaching high self-sufficiency levels.

A ranking of the agricultural zones according to the farm models' net margin per hectare was made. The large irrigated perimeters come first by far. However, the margins for the small perimeters of the Middle and the Upper Valley of the Senegal River are smaller, due to the irrigated land constraint mentioned above. The regions that grow a lot of groundnuts are highly ranked in the model's margin ranking.

The most binding constraints vary from zone to zone. However, land for rice cultivation (irrigated land in the Senegal River Basin, lowland in Casamance) and capital are the most important constraints overall.

The farm models were run with several output price vectors to derive cereal supply curves. These supply curves serve as an interface between the micro farm models and the macro agricultural sector model. The latter considers the trade-offs between the benefits of comparative advantage and food security.

This methodology was used to analyze three price policies that could be considered to improve the food situation. The first one would involve establishing a regional protected cereal market in West Africa by raising the consumer prices for rice and wheat and the producer price of rice. The second policy would involve raising all cereal prices in a similar way. The third policy would involve moving toward economic or border prices.

The first price policy involves raising the producer price of rice to develop rice production, which could substitute for imports. This policy is estimated to have a minimal impact on rice production and thus on the level of cereals self-sufficiency, the allocation of resources, the public deficit and the trade deficit. This results from a major constraint on irrigated land in the Senegal River Basin and on lowland in Casamance, which severely limits the expansion of rice production. While the impact on the supply side would probably be limited, an increase in the consumer price of rice would hurt the poor urban consumers, whose diet is mainly composed of rice.

The second price policy, which involves raising the prices of all cereals, would result in an increase of production, although not as great as might have been anticipated. The estimated cereal price supply response is low. Apart from the land constraint on rice production mentioned above, the other factor limiting the expansion of cereal production is that groundnuts remain often the most profitable rainfed crop, even after the cereals price increase.

Another potential problem with a general increase in cereals prices is that most of the increase in cereal production would be in maize. Given the present food habits in Senegal, a large increase in maize production could result in the creation of a surplus.

A key determinant of the possibility of changing the food habits of urban consumers in favor of maize is the transformation of maize into a convenient form which is as easy to store and to prepare as rice. This activity would have to be profitable and the maize supply would have to be stable enough from year to year to attract private milling companies. Both conditions would probably require the intervention of the state, first to subsidize the difference between the high producer price and the import parity price and, second, to help set up some kind of buffer stock.

Another potential outlet for the surplus would be to export it to neighboring countries. However, it is hard to see how Senegal could be competitive with major world maize producers, especially if the producer price has been raised.

Another problem with this price policy would be the increased costs of meeting the population's food needs. Either the consumers would have to pay more for their cereals or the state would have to pay for a consumer subsidy. Neither alternative is attractive. Many consumers have very low incomes. The state is already experiencing a high budget deficit. It is hard to imagine how the state could generate additional revenues to pay for this subsidy, except by asking for additional foreign aid. The end result might be an increase in Senegal's dependence vis-à-vis the rest of the world.

Finally, a general cereals price increase would have a limited impact on the trade balance. The effect of lower cereal imports would be offset by lower groundnut exports.

The third price policy considered would involve moving toward economic or border prices. This policy would permit Senegal to benefit from its comparative advantage in groundnut production and would favor a more efficient allocation of resources.

However, this policy would increase Senegal's dependence on international markets to meet its food needs. This runs counter to the desire of national independence, which is clearly an important objective for the Senegalese government. Also the sustainability of the past development strategy, based on the specialization in groundnut production and exports to pay for rice imports, is becoming questionable. The world market for oil products will experience very little growth until the end of the century, especially for groundnut products. Senegal is facing at best a stagnant source of foreign exchange while the demand for foreign exchange to pay for cereal imports goes up as a result of population growth. Therefore, in the long run, Senegal has to find an alternative development strategy.

Another potential issue with an economic price policy is finding an outlet for the large increase in tomato production on irrigated perimeters. Estimated tomato production with economic prices would be around four times the size of the domestic market in the short run. Such an increase in tomato supply would probably depress the price and reduce supply in the longer run, but the small domestic market size and the limited tomato marketing system could create potential problems.

The impact of an economic price policy on the state budget would be positive since the state would eliminate most subsidies. However, the impact on the trade balance would be negative since more cereals would be imported, and since groundnut production is a user as well as a source of foreign exchange.

Finally, in terms of income distribution, the typical farmers in most zones would probably lose more from the reduced value of their sales than they would gain from the reduced value of cereal purchases. However, a number of small farmers, who are net purchasers of cereals, could gain from an economic price policy, at least in the short run. Consumers would clearly be the big gainers of this policy.

It is clear that none of these policies is perfect. One key dimension of the policy choice appears to be time. In the short run, if the government wants to increase the cereals self-sufficiency rate, a sensible approach would be to implement a moderate general increase in cereals prices. This would limit the additional costs to the state and to consumers. It would avoid the creation of a large maize surplus. And in any case, the effect of a price increase on the cereals self-sufficiency rate would be limited.

In the longer run, certain disadvantages of a higher cereals price policy would become less important. Food habits would have time to change in favor of maize. More irrigated perimeters would be available, so that the land constraint on the expansion of rice production would be less binding. However, a comparative advantage strategy could also become more attractive if other economic sectors such as fisheries and tourism could replace groundnuts as the major source of foreign exchange. Given the population growth prospects, the limited public resources, and the hard living conditions of a large part of the Senegalese population, this might well be the only way for Senegal to avoid becoming an international welfare state. An economic price policy would also result in lower food prices, making it possible to reduce urban wages and potentially improve Senegal's comparative advantage in labor intensive activities.

All these conclusions depend partly on the institutional environment. For example, the price elasticity of cereals supply might be greater than estimated if changes in the inputs marketing system occurred, in particular in the availability of agricultural credit. Current institutional reforms are going to affect Senegal's comparative advantage and it is hard to tell now in what direction.

Finally, some key policy variables affecting food system performance were identified using experimental design techniques. A variance decomposition analysis was conducted to estimate the importance of the impact of three policy variables on two performance indicators. The three policy variables are: the cereal production level (or equivalently a level of cereals self-sufficiency desired by the government), the inclusion or exclusion of food habits constraints, and the level of world prices. The two performance indicators are the cost of meeting the population's cereals needs minus the value of exports (the value of the objective function of the agricultural sector model), and the agricultural trade balance deficit.

Food habits seem the policy variable that has the biggest impact on the performance indicators identified, especially the agricultural trade balance. This result would support the emphasis put by the Senegalese government on promoting cheaper millet/sorghum and maize to substitute for more expensive rice and wheat. Improvements in millet/sorghum and maize processing and marketing could contribute significantly to changing food habits in favor of those cereals and reducing the cost of meeting food needs.

The production level (or the level of cereals self-sufficiency desired) is the next important variable to consider. This variable has a major impact on the cost of meeting food needs, suggesting that higher cereals self-sufficiency rates can be reached in Senegal through higher prices for cereals, but at a high social cost. However, the cereals self-sufficiency level has little impact on the agricultural trade balance. Increasing cereals self-sufficiency does not seem to improve the balance of trade.

Finally, world prices do not seem to matter much in the long run since some counterbalancing effects are at work to reduce the impact of their variations on the performance indicators considered.

<u>Suggestions for further research:</u>

This research could be complemented in several ways:

- This research concentrated on the supply side. The scope of the study could be enlarged to include a more elaborate analysis of demand than the simple demand system used;
- This research focuses on agriculture. The livestock sector could also be included in the analysis. Livestock budgets could be elaborated to evaluate the profitability of alternative livestock activities. Livestock models could be built to analyze the herders' objectives and constraints. The focus should be put on the interrelationships between the farm models and the livestock models, especially the provision of organic fertilizer by the herd to the farm and the provision of feed grain and forage by the farm to the

herd;

- Each farm model could include more details about the local conditions of production. In particular, several farm models could be built in each zone to reflect the structural diversity of farming systems;
- The decision-makers' aversion to variations in world prices or in domestic yields could be incorporated in the agricultural sector model. A system of food security constraints could potentially be introduced in the agricultural sector model as was introduced in the farm models;
- This research does not address the empirical problem of enforcing official producer prices. There are a variety of enforcing mechanisms whose pros and cons should be studied;
- The most promising follow-ups to this research in Senegal are studies on maize and tomato production, marketing and consumption. Maize seems to be the cereal with the highest price elasticity of supply, but its consumption is currently quite limited. Tomato seems a profitable irrigated crop, especially with economic prices, but its expansion is limited by the size of the domestic market.

The research presented here provides some insights into the complex policy issues of food security and comparative advantage from theoretical, methodological and empirical points of view. Its main emphasis is on the need to consider the micro perspective in looking at macro issues, and on the necessary consistency between the two perspectives for a successful food strategy.

APPENDICES

APPENDIX A

Other data tables

TABLE 39

EVOLUTION OF THE NATIONAL SUPPLY OF CEREALS FOR SENEGAL FROM 1974 TO 1985

(TONS OF MILLED PRODUCT)

YEARS	NATIONAL NET PRODUCTION (1)				COMMERCIAL IMPORTS (2)					FOOD AID (2)					TOTAL				
	MILLET SORGHUM	MAIZE	RICE	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS
1974	345916	20348	33898	400162	7200	26900	207200	61557	302857	29756	27131	3218	3142	63247	382871	74379	244317	64699	766266
1975	539824	26006	62598	628428	2500	9600	102100	72349	186549	5052	4387	0	4457	13896	547375	39993	164698	76806	829873
1976	417919	26729	67694	512342	48200	15100	244500	85129	392929	16574	13760	775	3997	35106	482693	55589	312969	89126	940376
1977	344153	26187	65510	435850	49300	13800	248000	68160	379260	28587	7195	969	6729	43480	422039	47182	314479	74889	858589
1978	244216	19986	32755	296957	60300	12000	239000	101104	412404	73796	18461	8790	813	101860	378311	50447	280545	101917	811221
1979	509856	32568	76116	618540	19900	9400	351900	87239	468459	27735	4422	5009	619	37785	557491	46390	433025	87878	1124785
1980	352967	27812	50224	431003	28900	23200	302500	69012	423612	52804	9664	30539	11915	104919	434667	60676	383263	80927	959535
1981	369510	34314	33639	437463	21700	4500	339800	86478	452478	52427	33935	22319	29636	138317	443637	72749	395758	116114	1028258
1982	499279	40936	62390	602606	7785	5735	329380	70408	413328	8281	6246	31161	23143	68831	515345	52937	422931	93551	1084765
1983	396400	49500	55500	501400	48777	8428	374329	82724	514258	31357	11728	20308	17395	80788	476534	69656	450137	100119	1096446
1984	238500	36500	57300	332300	143536	19970	336600	52641	552747	80853	24547	30570	45440	181410	462889	81017	424470	98081	1066457
1985	319700	59200	71700	450600	60136	28445	300513	87654	476748	145470	10592	10528	22365	188955	525306	98237	382741	110019	1116303
AVERAGE	381520	33341	55777	470638	41520	14758	281319	77040	414636	46057	14339	13682	14138	88216	469097	62438	350778	91177	973489

NOTES: (1) THE NET NATIONAL PRODUCTION IS EQUAL TO THE GROSS PRODUCTION MULTIPLIED BY A COEFFICIENT OF 67.8% FOR MILLET/SORGHUM, 52.8% FOR RICE AND 60.2% FOR MAIZE. THESE COEFFICIENTS INCLUDE THE EFFECTS OF THE RECONSTITUTION OF CEREAL SEED STOCKS, WASTE, FEED AND INDUSTRIAL USE AND THE MILLING RATE. THE RECONSTITUTION OF THE CEREAL SEED STOCKS ACCOUNT FOR 2.3% OF GROSS PRODUCTION FOR MILLET/SORGHUM, 2% FOR MAIZE AND 5.75% FOR RICE. THE WASTE, FEED AND INDUSTRIAL USE ACCOUNT FOR 15% OF GROSS PRODUCTION FOR ALL CEREALS. THE MILLING RATE IS 0.82 FOR MILLET/SORGHUM, 0.666 FOR RICE AND 0.725 FOR MAIZE.

(2) THE COMMERCIAL IMPORTS AND THE FOOD AID IN WHEAT ARE GENERALLY IN GRAINS WHICH ARE THEN MILLED INTO FLOUR. THE FIGURE INDICATED FOR WHEAT IS FOR FLOUR USING A CONVERSION COEFFICIENT OF 0.71 FROM GRAIN TO FLOUR TO ACCOUNT FOR MILLING AND STORAGE LOSSES.

SOURCES: DIRECTION DE L'AGRICULTURE FOR NATIONAL PRODUCTION.
DIRECTION DE LA STATISTIQUE FOR COMMERCIAL IMPORTS.
CSA FOR FOOD AID.
USAID FOR THE COEFFICIENTS FROM GROSS TO NET PRODUCTION AND FROM WHEAT GRAIN INTO FLOUR.

TABLE 40

EVOLUTION OF THE NATIONAL SUPPLY OF CEREALS FOR SENEGAL

IN PERCENTAGE BY ORIGIN FROM 1974 TO 1985

YEARS	NATIONAL PRODUCTION	COMMERCIAL IMPORTS	FOOD AID	TOTAL SUPPLY
1974	52%	40%	8%	100%
1975	76%	23%	2%	100%
1976	54%	42%	4%	100%
1977	51%	44%	5%	100%
1978	37%	51%	13%	100%
1979	55%	42%	3%	100%
1980	45%	44%	11%	100%
1981	43%	44%	13%	100%
1982	56%	38%	6%	100%
1983	46%	47%	7%	100%
1984	31%	52%	17%	100%
1985	40%	43%	17%	100%
AVERAGE	49%	42%	9%	100%

NOTE: THE PERCENTAGES ARE ROUNDED TO FULL UNITS WHICH EXPLAINS WHY THE SUM OF NATIONAL PRODUCTION, COMMERCIAL IMPORTS AND FOOD AID PERCENTAGES FOR 1975 AND 1978 DO NOT ADD UP TO 100%.

SOURCE: TABLE 39

TABLE 41

EVOLUTION OF THE NATIONAL SUPPLY OF CEREALS FOR SENEGAL IN PERCENTAGE BY PRODUCT FROM 1974 TO 1985

YEARS	NATIONAL NET PRODUCTION				COMMERCIAL IMPORTS					FOOD AID					TOTAL				
	MILLET SORGHUM	MAIZE	RICE	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS
1974	86.4%	5.1%	8.5%	100.0%	2.4%	8.9%	68.4%	20.3%	100.0%	47.0%	42.9%	5.1%	5.0%	100.0%	50.0%	9.7%	31.9%	8.4%	100.0%
1975	85.9%	4.1%	10.0%	100.0%	1.3%	5.1%	54.7%	38.8%	100.0%	36.4%	31.6%	0.0%	32.1%	100.0%	66.0%	4.8%	19.9%	9.3%	100.0%
1976	81.6%	5.2%	13.2%	100.0%	12.3%	3.8%	62.2%	21.7%	100.0%	47.2%	39.2%	2.2%	11.4%	100.0%	51.3%	5.9%	33.3%	9.5%	100.0%
1977	79.0%	6.0%	15.0%	100.0%	13.0%	3.6%	65.4%	18.0%	100.0%	65.7%	16.5%	2.2%	15.5%	100.0%	49.2%	5.5%	36.6%	8.7%	100.0%
1978	82.2%	6.7%	11.0%	100.0%	14.6%	2.9%	58.0%	24.5%	100.0%	72.4%	18.1%	8.6%	0.8%	100.0%	46.6%	6.2%	34.6%	12.6%	100.0%
1979	82.4%	5.3%	12.3%	100.0%	4.2%	2.0%	75.1%	18.6%	100.0%	73.4%	11.7%	13.3%	1.6%	100.0%	49.6%	4.1%	38.5%	7.8%	100.0%
1980	81.9%	6.5%	11.7%	100.0%	6.8%	5.5%	71.4%	16.3%	100.0%	50.3%	9.2%	29.1%	11.4%	100.0%	45.3%	6.3%	39.9%	8.4%	100.0%
1981	84.5%	7.8%	7.7%	100.0%	4.8%	1.0%	75.1%	19.1%	100.0%	37.9%	24.5%	16.1%	21.4%	100.0%	43.1%	7.1%	38.5%	11.3%	100.0%
1982	82.9%	6.8%	10.4%	100.0%	1.9%	1.4%	79.7%	17.0%	100.0%	12.0%	9.1%	45.3%	33.6%	100.0%	47.5%	4.9%	39.0%	8.6%	100.0%
1983	79.1%	9.9%	11.1%	100.0%	9.5%	1.6%	72.8%	16.1%	100.0%	38.8%	14.5%	25.1%	21.5%	100.0%	43.5%	6.4%	41.1%	9.1%	100.0%
1984	71.8%	11.0%	17.2%	100.0%	26.0%	3.6%	60.9%	9.5%	100.0%	44.6%	13.5%	16.9%	25.0%	100.0%	43.4%	7.6%	39.8%	9.2%	100.0%
1985	70.9%	13.1%	15.9%	100.0%	12.6%	6.0%	63.0%	18.4%	100.0%	77.0%	5.6%	5.6%	11.8%	100.0%	47.1%	8.8%	34.3%	9.9%	100.0%
AVERAGE	80.7%	7.3%	12.0%	100.0%	9.1%	3.8%	67.2%	19.9%	100.0%	50.2%	19.7%	14.1%	15.9%	100.0%	48.5%	6.4%	35.6%	9.4%	100.0%

SOURCE: TABLE 39

TABLE 42

EVOLUTION OF RAINFALL AND GROSS CEREALS PRODUCTION

IN SENEGAL FROM 1974 TO 1985

YEARS	GROSS CEREALS PRODUCTION (THOUSAND TONS)	NATIONAL RAINFALL INDEX (IN MM'S OF RAIN)
1974	609	565
1975	958	583
1976	789	645
1977	675	573
1978	455	415
1979	950	600
1980	662	482
1981	666	436
1962	923	563
1983	772	491
1984	521	313
1985	706	613

SOURCE: DIRECTION DE L'AGRICULTURE

TABLE 43

EVOLUTION OF THE CEREALS SUPPLY PER CAPITA BY PRODUCT FOR SENEGAL

FROM 1974 TO 1985

(KILOS OF MILLED PRODUCT PER CAPITA)

YEARS	MILLET SORGHUM	MAIZE	RICE	WHEAT	ALL CEREALS
1974	78.9	15.3	50.4	13.3	158.0
1975	110.0	8.0	33.1	15.4	166.5
1976	96.6	11.1	62.6	17.8	188.2
1977	80.9	9.0	60.3	14.4	164.6
1978	70.7	9.4	52.4	19.0	151.5
1979	101.2	8.4	78.6	16.0	204.2
1980	76.7	10.7	67.6	14.3	169.3
1981	75.6	12.4	67.4	19.8	175.2
1982	85.3	8.8	70.0	15.5	179.6
1983	76.7	11.2	72.4	16.1	176.4
1984	72.5	12.7	66.5	15.4	167.1
1985	80.0	15.0	58.3	16.7	169.9
AVERAGE	83.7	11.0	61.6	16.1	172.5

SOURCES: DIRECTION DE L'AGRICULTURE FOR NATIONAL PRODUCTION.
DIRECTION DE LA STATISTIQUE FOR COMMERCIAL IMPORTS AND POPULATION.
CSA FOR FOOD AID.

TABLE 44

REGIONAL DISTRIBUTION OF THE CEREALS SUPPLY FOR SENEGAL IN 1983-1985

(TONS OF MILLED PRODUCT)

REGIONS	REGIONAL NET PRODUCTION				COMMERCIAL IMPORTS					FOOD AID					TOTAL				
	MILLET SORGHUM	MAIZE	RICE	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS
CAP VERT	0	0	0	0	0	0	158733	49293	208026	490	0	4790	0	5279	490	0	163523	49293	213306
CASAMANCE	49000	22600	25200	96800	39293	8847	37699	2599	88439	3066	3999	15679	0	22745	91359	35447	78578	2599	207984
DIOURBEL	33700	0	0	33700	0	0	22487	5260	27747	5841	0	0	3181	9022	39541	0	22487	8440	70468
LOUGA	14400	0	0	14400	0	0	12566	2186	14753	14945	0	0	7583	22528	29345	0	12566	9769	51681
FLEUVE	2700	1400	34100	38200	2434	548	15212	6016	24210	11424	8342	0	1903	21669	16558	10290	49312	7919	84079
EASTERN SENEGAL	27800	14000	2200	44000	24341	5481	6581	1093	37496	1108	3234	0	1233	5574	53249	22715	8781	2326	87070
SINE SALOUM	142000	10400	0	152400	18082	4071	36046	2798	60997	10479	0	0	7637	18116	170561	14471	36046	10435	231513
THIES	48700	0	0	48700	0	0	37038	7201	44239	9620	0	0	7412	17032	58320	0	37038	14614	109972

SOURCES:
- DIRECTION DE L'AGRICULTURE FOR NATIONAL PRODUCTION.
- CPSP FOR THE REGIONAL DISTRIBUTION OF RICE COMMERCIAL IMPORTS.
- CSA FOR THE REGIONAL DISTRIBUTION OF FOOD AID.
- CONTROLE ECONOMIQUE AND SURVEY OF THE 10 MOST IMPORTANT WHEAT FLOUR WHOLESALERS IN DAKAR FOR THE REGIONAL DISTRIBUTION OF WHEAT COMMERCIAL IMPORTS.
- HYPOTHESIS MADE FOR THE REGIONAL DISTRIBUTION OF MAIZE AND MILLET/SORGHUM COMMERCIAL IMPORTS: REGIONAL DISTRIBUTION IDENTICAL TO THE SUM OF THE REGIONAL PRODUCTION AND FOOD AID OF THOSE PRODUCTS.
- USAID FOR THE COEFFICIENTS FROM GROSS TO NET PRODUCTION AND FROM WHEAT GRAIN TO WHEAT FLOUR.

TABLE 45

REGIONAL DISTRIBUTION OF THE CEREALS SUPPLY FOR SENEGAL BY ORIGIN IN 1983-1985

REGIONS	REGIONAL PRODUCTION	COMMERCIAL IMPORTS	FOOD AID	TOTAL
CAP VERT	0.0%	97.5%	2.5%	100.0%
CASAMANCE	46.5%	42.5%	10.9%	100.0%
DIOURBEL	47.8%	39.4%	12.8%	100.0%
LOUGA	27.9%	28.5%	43.6%	100.0%
FLEUVE	45.4%	28.8%	25.8%	100.0%
EASTERN SENEGAL	50.5%	43.1%	6.4%	100.0%
SINE SALOUM	65.8%	26.3%	7.8%	100.0%
THIES	44.3%	40.2%	15.5%	100.0%

SOURCE: TABLE 44

TABLE 46

REGIONAL DISTRIBUTION OF CEREALS SUPPLY FOR SENEGAL IN PERCENTAGE BY PRODUCT IN 1983-1985

REGIONS	REGIONAL NET PRODUCTION				COMMERCIAL IMPORTS					FOOD AID					TOTAL				
	MILLET SORGHUM	MAIZE	RICE	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS
CAP VERT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	76.3%	23.7%	100.0%	9.3%	0.0%	90.7%	0.0%	100.0%	0.2%	0.0%	76.7%	23.1%	100.0%
CASAMANCE	50.6%	23.3%	26.0%	100.0%	44.4%	10.0%	42.6%	2.9%	100.0%	13.5%	17.6%	68.9%	0.0%	100.0%	43.9%	17.0%	37.8%	1.2%	100.0%
DIOURBEL	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	81.0%	19.0%	100.0%	64.7%	0.0%	0.0%	35.3%	100.0%	56.1%	0.0%	31.9%	12.0%	100.0%
LOUGA	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	85.2%	14.8%	100.0%	66.3%	0.0%	0.0%	33.7%	100.0%	56.8%	0.0%	24.3%	18.9%	100.0%
FLEUVE	7.1%	3.7%	89.3%	100.0%	10.1%	2.3%	62.8%	24.9%	100.0%	52.7%	38.5%	0.0%	8.8%	100.0%	19.7%	12.2%	58.6%	9.4%	100.0%
EASTERN SENEGAL	63.2%	31.8%	5.0%	100.0%	64.9%	14.6%	17.6%	2.9%	100.0%	19.9%	58.0%	0.0%	22.1%	100.0%	61.2%	26.1%	10.1%	2.7%	100.0%
SINE SALOUM	93.2%	6.8%	0.0%	100.0%	29.6%	6.7%	59.1%	4.6%	100.0%	57.8%	0.0%	0.0%	42.2%	100.0%	73.7%	6.3%	15.6%	4.5%	100.0%
THIES	100.0%	0.0%	0.0%	100.0%	0.0%	0.0%	83.7%	16.3%	100.0%	56.5%	0.0%	0.0%	43.5%	100.0%	53.0%	0.0%	33.7%	13.3%	100.0%

SOURCE: TABLE 44

TABLE 47

ESTIMATION OF THE CONSUMPTION OF CEREALS PER CAPITA FOR SENEGAL IN URBAN AND RURAL AREAS

BY REGION IN 1983-1985

(KILOS OF MILLED PRODUCT PER CAPITA)

REGIONS	MILLET/SORGHUM		RICE		MAIZE		WHEAT		TOTAL	
	URBAN	RURAL	URBAN	RURAL	URBAN	RURAL	URBAN	RURAL	URBAN	RURAL
CAP VERT	12	42	110	110	6	6	41	15	169	173
CASAMANCE	11	51	102	79	24	33	19	1	156	164
DIOURBEL	52	132	69	24	6	6	25	3	152	165
LOUGA	52	132	69	24	6	6	25	3	152	165
FLEUVE	24	57	78	86	8	9	43	11	153	163
EASTERN SENEGAL	42	130	87	25	15	20	18	1	162	176
SINE SALOUM	49	131	80	24	12	11	18	1	159	167
THIES	52	132	69	24	6	6	25	3	152	165

NOTE: (1) IN ORDER TO GET COMPARABLE QUANTITIES OF EACH CEREAL CONSUMED, THE GROSS QUANTITIES CONSUMED ARE MULTIPLIED BY THE FOLLOWING MILLING COEFFICIENTS: MILLET/SORGHUM: 0.82; MAIZE: 0.725; RICE: 1; WHEAT: 0.71.

SOURCES: - FAO (1985) APPENDIX F P.24 BASED ON SONED AND ORANA SURVEYS.
- NATIONAL FOOD BALANCE SHEET (TABLE 39).
- ISRA/BAME FARM MODELS RESULTS.

TABLE 48

REGIONAL CEREALS BALANCE SHEETS FOR SENEGAL ESTIMATED BY PRODUCT IN 1983-1985

(TONS OF MILLED PRODUCT)

REGIONS	REGIONAL NET PRODUCTION					REGIONAL NET CONSUMPTION					REGIONAL BALANCE					REGIONAL BALANCE AS % OF REGIONAL CONSUMPTION				
	MILLET/ SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET/ SORGHUM	MAIZE	RICE	WHEAT	TOTAL CEREALS	MILLET/ SORGHUM	MAIZE	RICE	WHEAT	NET BALANCE	MILLET/ SORGHUM	MAIZE	RICE	WHEAT	NET BALANCE
CAP VERT	0	0	0	0	0	21473	8718	159821	56070	246082	-21473	-8718	-159821	-56070	-246082	-100	-100	-100	-100	-100
CASAMANCE	49300	22600	25200	0	96800	38317	27361	72277	3608	141563	10683	-4761	-47077	-3608	-44763	28	-17	-65	-100	-32
DIOURBEL	33[illegible]0	0	0	0	33700	56938	2997	17047	3972	80953	-23238	-2997	-17047	-3972	-47253	-41	-100	-100	-100	-58
LOUGA	144[illegible]	0	0	0	14400	55863	2957	16994	4005	79819	-41463	-2957	-16994	-4005	-65419	-74	-100	-100	-100	-82
FLEUVE	2700	1400	34100	0	38200	28721	5315	51078	12653	97767	-26021	-3915	-16978	-12653	-59567	-91	-74	-33	-100	-61
EASTERN SENEGAL	27800	14000	2200	0	44000	42706	6993	12124	1204	63028	-14906	7007	-9924	-1204	-19028	-35	100	-82	-100	-30
SINE SALOUM	142000	10400	0	0	152400	147824	14121	42471	4947	209363	-5824	-3721	-42471	-4947	-56963	-4	-26	-100	-100	-27
THIES	48700	0	0	0	48700	83962	5112	36488	10397	135959	-35262	-5112	-36488	-10397	-87259	-42	-100	-100	-100	-64
TOTAL	318300	40400	61500	0	420200	475804	73575	408299	96857	1054534	-157504	-25175	-346799	-96857	-626334	-33	-34	-85	-100	-59

NOTE: THE REGIONAL BALANCE TOTAL PER CEREAL CORRESPONDS APPROXIMATIVELY TO THE SUM OF COMMERCIAL IMPORTS AND FOOD AID FOR EACH CEREAL FOR 1983-85 IN TABLE 39.

SOURCES: TABLE 44 FOR REGIONAL NET PRODUCTION.
TABLE 47 FOR PER CAPITA REGIONAL CEREALS NET CONSUMPTION.
"DIRECTION DE LA STATISTIQUE" FOR REGIONAL POPULATION.

TABLE 49

PROJECTION OF THE CEREALS BALANCE SHEET FOR SENEGAL BY FAO

TABLE 49.1

PROJECTION OF THE DEMAND FOR CEREALS FOR SENEGAL FROM 1982/84 TO 1995

HYPOTHESES:
- FOR THE ANNUAL POPULATION GROWTH RATES, 5.5% IN DAKAR, 4.5% IN THE OTHER CITIES AND 1.97% IN RURAL AREAS, I.E. 3.18% FOR THE TOTAL POPULATION.
- FOR THE DEMAND FOR CEREALS IN URBAN AREAS IN 1995, 33 KILOS OF MILLET/SORGHUM, 110 KILOS OF RICE, 7 KILOS OF MAIZE, 54 KILOS OF WHEAT, I.E. 204 KILOS OF CEREALS PER CAPITA.
- FOR THE DEMAND OF CEREALS IN RURAL AREAS IN 1995, 147 KILOS OF MILLET/SORGHUM, 51 KILOS OF RICE, 13 KILOS OF MAIZE, 4 KILOS OF WHEAT, I.E. 215 KILOS OF CEREALS PER CAPITA.
- FOR THE DEMAND OF CEREALS IN 1982/84, AVERAGE NATIONAL SUPPLY OF CEREALS OVER THREE YEARS (SUM OF PRODUCTION PLUS COMMERCIAL IMPORTS PLUS FOOD AID).

YEARS	URBAN POPULATION (THOUSAND PEOPLE)	RURAL POPULATION (THOUSAND PEOPLE)	TOTAL POPULATION (THOUSAND PEOPLE)	DEMAND FOR CEREALS (THOUSAND TONS)				
				RICE	WHEAT	MAIZE	MILLET SORGHUM	TOTAL
1982/84 (1)	2434	4085	6519	445	133	79 (2)	649	1306
1995	3965	4967	8933	689	234	117 (3)	861	1901

NOTES: (1) POPULATION FIGURES IN THE LINE 1982/84 ARE FOR 1985.
(2) THIS AMOUNT INCLUDES 10000 TONS OF MAIZE FOR ANIMAL FEEDING.
(3) THIS AMOUNT INCLUDES 25000 TONS OF MAIZE FOR ANIMAL FEEDING.

SOURCES: FAO (1985) APPENDIX F TABLE F4 P.24, TABLE F6 P.28 AND TABLE F7 P.30

TABLE 49.2

PROJECTION OF THE CEREALS PRODUCTION FOR SENEGAL FROM 1982-84 TO 1995

HYPOTHESES: - FOR THE RAINFED CULTIVATION OF MILLET/SORGHUM AND MAIZE, 3 LEVELS ARE PROPOSED: F0: PRESENT LEVEL, F1: MODERATE INTENSIFICATION, F2: AVERAGE INTENSIFICATION, GOING TO A HIGHER LEVEL OF INTENSIFICATION IMPLIES AN INCREASE IN YIELDS AND CULTIVATED AREAS. THE FORECASTED SCENARIO IS AN OPTIMISTIC SCENARIO WHICH IS BASED ON A MIX OF F0, F1 AND F2 LEVELS.
- FOR THE CULTIVATION OF RAINFED RICE, LOWLAND RICE, TRANSPLANTED RICE, IRRIGATED RICE ON THE ANAMBE AND THE GAMBIA RIVERS, IRRIGATED MAIZE ON THE ANAMBE RIVER, AN OPTIMISTIC HYPOTHESIS FOR PRODUCTION IS ADOPTED.
- FOR ALREADY CREATED PERIMETERS IN THE FLEUVE REGION, YIELD OF 6 TONS PER HECTARE; CULTURAL INTENSITY COEFFICIENTS OF 1.8 (O/W 1.6 OF RICE AND 0.2 OF MAIZE FOR SAED PERIMETERS AND 1.8 OF RICE FOR THE OTHER PERIMETERS).
- FOR THE NEW PERIMETERS TO CREATE IN THE FLEUVE REGION, VERY OPTIMISTIC HYPOTHESES ARE ALSO ADOPTED: 3000 HECTARES TO BE CREATED ANNUALLY (O/W 300 FOR TOMATO); AVERAGE YIELD OF 5 TONS PER HECTARE FOR RICE AND 4.5 TONS FOR MAIZE; CULTURAL INTENSITY COEFFICIENT OF 1.68 (1.5 OF RICE AND 0.18 OF MAIZE).
THE NUMBER OF HECTARES TO CREATE IS CALCULATED SO THAT THE CEREALS SELF-SUFFICIENCY LEVEL IS 75% IN COMPLIANCE WITH THE GOVERNMENT'S OBJECTIVES.

CROP	AVERAGE PRODUCTION 1982/84 (THOUSAND TONS)	AREA 1995 (THOUSAND HECTARES)	YIELD 1995 (1) (KGS/HA)	PRODUCTION 1995 (2) (THOUSAND TONS)
MILLET/SORGHUM	577			656
- RAINFED MAIZE				204
- IRRIGATED MAIZE (ANAMBE)				6
- IRRIGATED MAIZE (FLEUVE; EXISTING PERIMETERS IN 1984)		24.5	100 (3)	22
- IRRIGATED MAIZE (FLEUVE; NEW PERIMETERS)		35	810 (4)	25.5
TOTAL MAIZE	72			337.5
- RAINFED RICE		5	650	3
- LOWLAND RICE		20	1300	26
- FRESH WATER AQUATIC RICE		30	1625	49
- MANGROVE RICE		4	975	4
- IRRIGATED RICE:				
- ANAMBE		5	3900	19.5
- GAMBIA		0.6	5200	3.1
- IRRIGATED RICE (FLEUVE; EXISTING PERIMETERS):				
-SAED		24.5	6240 (5)	153
-OTHERS		1.5	7020 (6)	11
- IRRIGATED RICE (FLEUVE; NEW PERIMETERS)		35	4875 (7)	171
TOTAL RICE	66			439.6
TOTAL CEREALS	715			1433.1

NOTES: (1) THE YIELD FOR RICE IS IN PROCESSED RICE USING A PROCESSING RATE OF 65%.
(2) THE PRODUCTION OF MILLET/SORGHUM AND MAIZE IS NET OF LOSSES ESTIMATED AT 10% OF GROSS PRODUCTION.
(3) CULTURAL INTENSITY COEFFICIENT OF 0.2; YIELD OF 5 TONS/HA.
(4) CULTURAL INTENSITY COEFFICIENT OF 0.18; YIELD OF 4.5 TONS/HA.
(5) CULTURAL INTENSITY COEFFICIENT OF 1.6; YIELD OF 6 TONS/HA FOR THE SAED PERIMETERS.
(6) CULTURAL INTENSITY COEFFICIENT OF 1.8; YIELD OF 6 TONS/HA FOR THE OTHER EXISTING PERIMETERS.
(7) CULTURAL INTENSITY COEFFICIENT OF 1.5; YIELD OF 5 TONS/HA FOR THE NEW PERIMETERS.

SOURCES: FAO (1985) APPENDIX 8 TABLE 06 P.21, APPENDIX 1 PP. 7,18,19,26,27,64

TABLE 49.3

PROJECTION OF THE CEREALS BALANCE SHEET FOR SENEGAL FROM 1982-84 TO 2005

(THOUSAND TONS)

CEREALS	1982-84				2005			
	DEMAND	PRODUCTION	BALANCE (1)	LEVEL OF SELF SUFFICIENCY	DEMAND	PRODUCTION	BALANCE (1)	LEVEL OF SELF SUFFICIENCY
RICE	445	66	-379	15%	689	440	-249	64%
MILLET/ SORGHUM	649	577	-72	89%	861	656	-205	76%
WHEAT	133	0	-133	0%	234	0	-234	0%
MAIZE	79 (2)	715	-7	91%	117 (2)	337	220	288%
TOTAL	1306	715	-591	55%	1901	1433	-468	75%

NOTES: (1) THE BALANCE IS THE DIFFERENCE BETWEEN PRODUCTION AND DEMAND.
A NEGATIVE BALANCE IS A DEFICIT; A POSITIVE BALANCE A SURPLUS.
(2) INCLUDES 10000 TONS OF MAIZE FOR ANIMAL FEEDING.

SOURCES: FAO (1985) APPENDIX O TABLE 06 P.21, APPENDIX I PP. 7, 18, 19, 26, 27, 64

TABLE 50

PROJECTION OF THE GRAIN BALANCE SHEET FOR SENEGAL IN THE ABT ASSOCIATES REPORT

TABLE 50.1

PROJECTION OF THE DEMAND FOR GRAINS FOR SENEGAL FROM 1985 TO 2000

(POPULATION IN MILLION PEOPLE)
(DEMAND IN THOUSAND TONS)

HYPOTHESES: - ANNUAL GROWTH RATE OF 2.4% FOR THE RURAL POPULATION AND OF 3.7% FOR THE URBAN POPULATION.
- DEMAND FOR PROCESSED GRAINS (MILLET/SORGHUM, MAIZE, COWPEAS) PER CAPITA OF 247.8 KGS IN RURAL AREAS AND OF 119.3 KGS IN URBAN AREAS.

YEARS	URBAN POPULATION	RURAL POPULATION	TOTAL POPULATION	GRAINS DEMAND
1985	4.38	2.12	6.50	1338.30
1990	4.92	2.54	7.46	1522.20
1995	5.52	3.05	8.57	1731.80
2000	6.19	3.65	9.84	1969.30

SOURCE: ABT ASSOCIATES (1984) TABLE 3-15

TABLE 50.2

PROJECTION OF THE GRAINS PRODUCTION FOR SENEGAL FROM 1985 TO 2000

(AREA IN THOUSAND HECTARES)
(YIELD IN KILOS/HECTARE)
(PRODUCTION IN THOUSAND TONS)

HYPOTHESES: - FOR MILLET/SORGHUM, DECREASE OF 102,400 HECTARES FROM 1985 TO 2000, I.E., - 6,287 HA PER YEAR; YIELD INCREASE OF 1% ANNUALLY.
- FOR MAIZE, INCREASE OF 75,000 HECTARES FROM 1985 TO 2000, I.E., + 5,000 HA/YEAR; YIELD INCREASE OF 3.5% ANNUALLY.
- FOR TRADITIONALLY CULTIVATED RICE (RAINFED, LOWLAND AND TRANSPLANTED), DECREASE OF 5,500 HECTARES FROM 1985 TO 2000, I.E., - 1% ANNUALLY; YIELD UNCHANGED.
- FOR IRRIGATED RICE, INCREASE OF 7,500 HECTARES FROM 1985 TO 2000, I.E., + 5,000 HA/YEAR; YIELD INCREASE OF 3% ANNUALLY.
- FOR COWPEAS, INCREASE OF 32,300 HECTARES FROM 1988 TO 2000, I.E., + 2,475 HA/YEAR; YIELD INCREASE OF 2% ANNUALLY FROM 1988 TO 1989 AND 5% THEREAFTER.

CROP	1985			1990			1995			2000		
	A	Y	P	A	Y	P	A	Y	P	A	Y	P
- MILLET/SORGHUM	1000	470	470	873	493	479	935	517	483	898	540	485
- MAIZE	75	721	54	100	866	87	125	1010	126	150	1154	173
- RICE												
. RAINFED, LOWLAND AND TRANSPLANTED RICE	37	498	18	35	498	18	33	498	17	32	498	16
. IRRIGATED RICE	33	1412	47	58	1624	94	83	1835	152	108	2048	221
. TOTAL RICE	70		65	93		112	116		169	140		237
TOTAL CEREALS	1145		589	1066		678	1176		778	1188		895
COWPEAS	40	288	12	48	315	15	60	402	24	72	513	37
TOTAL GRAINS	1185		601	1114		693	1236		802	1260		932

NOTE: A MEANS AREA.
Y MEANS YIELD.
P MEANS PRODUCTION.

SOURCE: ABT ASSOCIATES (1984) TABLES 3-13, 3-14, 3-15

TABLE 50.3

PROJECTION OF THE GRAINS BALANCE SHEET FOR SENEGAL FROM 1985 TO 2000

(THOUSAND TONS)

YEARS	DEMAND	PRODUCTION	DEFICIT	LEVEL OF SELF-SUFFICIENCY
1985	1338	600	738	45.0%
1990	1522	693	829	46.0%
1995	1732	802	930	46.0%
2000	1969	932	1037	47.0%

SOURCE: ABT ASSOCIATES (1984) TABLE 3-15

TABLE 51

PROJECTION OF THE CEREALS BALANCE SHEET FOR SENEGAL BY THE "SCHEMA NATIONAL D'AMENAGEMENT DU TERRITOIRE"

TABLE 51.1

PROJECTION OF THE DEMAND FOR CEREALS FROM 1980 TO 2005

HYPOTHESES: - FOR THE POPULATION GROWTH, SLOW DECREASE OF MORTALITY, SLOW DECREASE OF FECUNDITY AND SLOW EVOLUTION OF THE SOCIO-ECONOMIC SITUATION - AVERAGE GROWTH RATE OF 3% PER YEAR.
- DEMAND FOR CEREALS IN 1980: 90.4 KGS OF RICE, 19.5 KGS OF WHEAT, 11.7 KGS OF MAIZE 98.9 KGS OF MILLET/SORGHUM, I.E. 220.5 KGS OF CRERALS PER CAPITA.
- DEMAND OF CEREALS IN 2005: 83.6 KGS OF RICE, 17.4 KGS OF WHEAT, 10.9 KGS OF MAIZE, 99.1 KGS OF MILLET, I.E. 211 KGS OF CEREALS PER CAPITA. CONSUMPTION IN 2005 ASSUMES A FALL OF PER CAPITA INCOME OF 0.5% AND THE FOLLOWING PRICE-ELASTICITIES OF DEMAND: 0.4 FOR RICE, 0.7 FOR WHEAT, 0.3 FOR MAIZE ET -0.2 FOR MILLET.

YEARS	POPULATION (THOUSAND PEOPLE)	DEMAND FOR CEREALS (THOUSAND TONS)				
		RICE	WHEAT	MAIZE	MILLET SORGHUM	TOTAL
1980	5625	508.5	109.9	65.7	556.1	1240.2
2005	12373	1034.1	214.8	135.3	1226.6	2610.8

SOURCE: SECRETARIAT D'ETAT CHARGE DE LA DECENTRALISATION (1984) P.117, P.291

TABLE 51.2

PROJECTION OF THE CEREALS PRODUCTION FOR SENEGAL FROM 1980 TO 2005

(PRODUCTION IN THOUSAND TONS)
(AREA IN THOUSAND HECTARES)
(YIELD IN KILOS/HA)

HYPOTHESES: - FOR MILLET/SORGHUM, PRODUCTION GROWTH RATE OF 2.5% ANNUALLY.
- FOR RICE, PRODUCTION GROWTH RATE OF 6.0% ANNUALLY.
- FOR MAIZE, PRODUCTION GROWTH RATE OF 3.0% ANNUALLY.

CROP	AVERAGE PRODUCTION AROUND 1980	AREA 2005	YIELD 2005	PRODUCTION 2005
MILLET/SORGHUM	600	1430	700	1000
RICE	100			450
O/W:				
- DELTA SENEGAL RIVER		20	3000	60
- SENEGAL RIVER VALLEY		40	5600	225
- CASAMANCE		100	1500	150
- OTHERS				15
MAIZE	47	140	900	125
TOTAL	747			1575

SOURCE: SECRETARIAT D'ETAT CHARGE DE LA DECENTRALISATION (1984) P.254

TABLE 51.3

PROJECTION OF THE CEREALS BALANCE SHEET FOR SENEGAL FROM 1980 TO 2005

(THOUSAND TONS)

CROP	1980				2005			
	DEMAND	PRODUCTION	BALANCE (1)	LEVEL SELF SUFFICIENCY	DEMAND	PRODUCTION	BALANCE (1)	LEVEL SELF SUFFICIENCY
RICE	508	100	-408	19.7%	1034	450	-584	43.5%
MILLET/SORGHUM	556	600	44	107.9%	1227	1000	-227	81.5%
WHEAT	110	0	-110	0.0%	215	0	-215	0.0%
MAIZE	66	47	-19	71.2%	135	125	-10	92.6%
TOTAL	1240	747	-493	60.2%	2611	1575	-1036	60.3%

NOTE: (1) THE BALANCE IS THE DIFFERENCE BETWEEN PRODUCTION AND DEMAND.
A NEGATIVE BALANCE IS A DEFICIT; A POSITIVE BALANCE IS A SURPLUS.

SOURCE: SECRETARIAT D'ETAT CHARGE DE LA DECENTRALISATION (1984) P.254

TABLE 52

EVOLUTION OF THE WORLD PRICES OF SELECTED AGRICULTURAL PRODUCTS TRADED BY SENEGAL FROM 1970 TO 1984

PRODUCT	DENOMINATION	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	AVERAGE	STANDARD DEVIATION	COEF. OF VARIATION
RICE (1)	U.S. DOLLARS	144	129	147	350	542	363	255	272	368	334	434	483	293	277	257	310	116	0.38
	NOMINAL CFA FRANCS	40032	35733	37044	78050	130622	77703	60826	66961	83055	71185	91553	131322	94607	105499	112353	81103	29730	0.37
	1980 CFA FRANCS	104796	90008	87782	166418	238797	107772	83552	82566	99111	77375	91553	124005	76112	76063	72439	105223	42612	0.40
WHEAT (2)	U.S. DOLLARS	55	62	70	140	180	149	133	103	128	160	173	175	160	157	153	133	40	0.30
	NOMINAL CFA FRANCS	15290	17174	17640	31220	43380	31886	31787	25338	28928	34080	36503	47600	51680	59817	66861	35946	14833	0.41
	1980 CFA FRANCS	40026	43259	41801	66567	79305	44225	43663	31243	34520	37043	36503	44948	41577	43127	43108	44728	11929	0.27
SORGHUM (3)	U.S. DOLLARS	52	56	56	93	121	112	105	88	94	108	129	126	109	129	121	100	26	0.26
	NOMINAL CFA FRANCS	14400	15429	14112	20739	29161	23947	25143	21746	21199	23025	27198	34381	35046	49073	52877	27165	11160	0.41
	1980 CFA FRANCS	37697	38864	33441	44220	53311	33213	34537	26814	25297	25027	27198	32465	28194	35381	34092	33983	7339	0.22
MAIZE (4)	U.S. DOLLARS	58	58	56	98	132	120	112	95	101	116	125	131	108	136	136	105	27	0.26
	NOMINAL CFA FRANCS	16124	16066	14112	21854	31812	25680	26768	23370	22826	24708	26375	35632	34884	51816	59432	28764	12245	0.43
	1980 CFA FRANCS	42209	40469	33441	46597	58157	35617	36769	28816	27239	26857	26375	33647	28064	37358	38319	35996	8364	0.23
SHELLED GROUNDNUT (5)	U.S. DOLLARS	228	251	254	391	739	433	423	547	631	563	486	623	383	349	350	443	147	0.33
	NOMINAL CFA FRANCS	63384	69527	64008	87193	178099	92662	101097	134562	142606	119919	102546	169456	123709	132969	152950	115646	35498	0.31
	1980 CFA FRANCS	165927	175131	151678	185913	325592	128519	138870	165921	170174	130347	102546	160015	98525	95868	98614	152976	54760	0.36
GROUNDNUT MEAL (6)	U.S. DOLLARS	102	98	122	266	174	140	176	218	205	211	241	239	189	196	158	182	49	0.27
	NOMINAL CFA FRANCS	28356	27146	30744	59318	41934	29960	42064	53628	46330	44943	50851	65008	61047	74676	69046	48337	14851	0.31
	1980 CFA FRANCS	74230	68378	72853	126478	76662	41553	57780	66125	55286	48851	50851	61386	49113	53840	44517	63194	19988	0.32
GROUNDNUT OIL (7)	U.S. DOLLARS	379	441	426	546	1077	778	691	846	1079	889	859	1043	585	711	1017	758	235	0.31
	NOMINAL CFA FRANCS	105251	122074	107327	121803	259509	166492	165149	208116	243899	189293	181207	283696	188923	270853	444429	203868	85542	0.42
	1980 CFA FRANCS	275526	307491	254329	259707	474422	230918	226853	256617	291049	205753	181207	257890	151989	195280	286544	257705	71703	0.28
COTTON (8)	U.S. DOLLARS	138	136	144	224	339	285	301	333	296	338	338	335	275	307	360	277	76	0.27
	NOMINAL CFA FRANCS	38364	37672	36162	49907	81603	61054	71915	82016	66886	72058	71297	91147	88954	117043	157451	74897	30856	0.41
	1980 CFA FRANCS	100429	94892	85692	106412	149182	84680	98784	101130	79720	78324	71297	86069	71564	84386	101516	92939	18501	0.20

NOTES: (1) 100% BROKEN RICE PRICE CIF DAKAR PAID BY THE CPSP, THE PARASTATAL IN CHARGE OF IMPORTING RICE.
(2) U.S. WHEAT, GULF PORTS.
(3) U.S. SORGHUM # 2 MILO YELLOW, FOB GULF PORTS.
(4) U.S. MAIZE # 2 YELLOW, FOB GULF PORTS.
(5) SHELLED GROUNDNUT FROM NIGERIA, CIF EUROPEAN PORTS.
(6) ORIGIN: NIGERIA, PRICE ON THE LONDON MARKET.
(7) ORIGIN: NIGERIA, GAMBIA, OTHER ORIGINS 3-5% IN BULK, CIF EUROPEAN PORTS.
(8) EGYPTIAN COTTON, CIF LIVERPOOL.

SOURCES: - F.MARTIN (1986) LA REFORME DE LA POLITIQUE CEREALIERE DANS LE SAHEL - LE SENEGAL, CILSS - CLUB DU SAHEL - ELLIOT BERG ASSOCIATES, TABLES 24 TO 28 FOR THE WORLD PRICES OF RICE, WHEAT, SORGHUM, MAIZE AND GROUNDNUT PRODUCTS.
- WORLD BANK (1985) COMMODITY TRADE AND PRICE TRENDS FOR THE PRICE OF COTTON.
- IMF (1985) ANNUAIRE, P.F577 AND IMF (1987) STATISTIQUES FINANCIERES INTERNATIONALES, MARCH, P. F452 FOR THE CONSUMER PRICE INDEX FOR SENEGAL (1980 = 100).

TABLE 53

EVOLUTION OF YIELDS FOR MAJOR CROPS IN SENEGAL FROM 1970 TO 1985

(KILOS PER HECTARE)

AREA	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	AVERAGE	STANDARD DEVIATION	COEF. OF VARIATION
SENEGAL																			
MILLET/SORGHUM	612	395	601	344	460	700	640	535	445	760	540	490	830	590	425	458	552	131	0.24
MAIZE	883	652	770	623	960	890	885	895	615	960	685	730	1219	950	859	1191	860	174	0.20
PADDY RICE	1351	1043	1280	711	1005	1410	1390	1420	995	1605	1225	960	1675	1395	1974	2055	1343	353	0.26
COWPEAS	316	281	365	125	287	395	408	256	205	292	339	315	420	250	234	308	300	75	0.25
GROUNDNUT	819	554	929	532	640	930	1095	855	440	910	640	490	850	995	530	779	749	197	0.26
COTTON	1172	852	1154	1145	1160	1070	785	1030	790	700	870	700	1280	1120	1110	1284	1014	193	0.19
CASAMANCE																			
MILLET/SORGHUM	779	1002	812	986	789	843	1067	817	833	740	298	779	565	804	949	1042	819	183	0.22
MAIZE	953	734	831	746	986	1078	1096	1213	713	838	911	783	801	894	1034	1527	946	205	0.22
PADDY RICE	1248	919	1118	791	990	1354	1374	1358	814	1510	983	550	1348	1095	1129	933	1095	253	0.23
COWPEAS	444	391	301	200	379	510	433	402	386	495	266	347	463	503	483	688	418	110	0.26
GROUNDNUT	776	997	1031	1148	1055	943	1081	1156	858	1008	840	472	1099	1256	1180	1222	1008	192	0.19
COTTON	1506	1303	1321	1449	1449	1084	665	1160	1168	755	993	779	686	1355	1120	792	1099	281	0.26
DIOURBEL																			
MILLET/SORGHUM	511	269	597	423	400	639	529	623	253	794	555	363	555	447	542	542	503	135	0.27
COWPEAS	194	252	283	286	339	337	445	400	310	560	614	189	552	275	0	187	326	155	0.47
GROUNDNUT	536	311	851	338	530	851	1194	978	492	870	713	306	931	697	336	769	669	263	0.39
																	0	0	
LOUGA																			
MILLET/SORGHUM	337	210	462	60	240	526	498	301	283	550	330	427	284	283	124	33	304	154	0.51
COWPEAS	287	230	367	116	290	438	497	285	218	428	352	370	400	233	225	370	314	101	0.32
GROUNDNUT	804	248	918	94	505	742	1009	600	273	958	420	717	850	782	157	1313	649	332	0.51

TABLE 53 (CONTINUED)

AREA	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	AVERAGE	STANDARD DEVIATION	COEF. OF VARIATION
FLEUVE																			
MILLET/SORGHUM	612	318	417	22	317	441	434	231	113	410	312	323	474	140	284	355	325	143	0.44
MAIZE	686	631	653	500	587	740	0	0	480	732	1250	797	682	375	424	2160	669	481	0.72
PADDY RICE	1962	1456	2385	565	1225	1830	1238	2178	2218	2884	3143	3258	3583	3365	4330	4773	2525	1133	0.45
SENEGAL ORIENTAL																			
MILLET/SORGHUM	785	382	754	545	454	611	861	308	584	869	446	641	845	849	512	706	635	177	0.28
MAIZE	879	536	768	544	818	779	863	456	475	982	682	568	2308	1076	630	900	825	421	0.51
PADDY RICE	1059	737	977	875	1200	1623	1769	1155	919	1114	842	800	3368	952	769	1028	1199	625	0.52
GROUNDNUT	862	384	740	642	464	1044	985	1189	787	1023	601	469	923	914	525	1006	785	238	0.30
COTTON	1110	712	1200	1053	1054	1071	877	960	576	672	799	610	1126	905	0	1077	863	293	0.34
SINE SALOUM																			
MILLET/SORGHUM	631	465	618	440	468	787	683	710	498	809	585	575	712	651	483	594	607	112	0.18
MAIZE	857	667	857	500	1429	1667	1931	1264	781	1426	191	800	1909	1085	556	930	1053	493	0.47
GROUNDNUT	957	670	911	754	648	1010	1150	977	419	784	683	509	835	1110	586	1046	816	212	0.26
COTTON	1038	734	824	784	704	1027	838	880	329	606	799	635	1066		559	950	785	194	0.25
THIES																			
MILLET/SORGHUM	471	219	506	85	589	676	763	406	211	1070	548	422	722	687	334	400	507	238	0.47
COWPEAS	257	242	281	95	310	433	361	235	213	258	820	251	410	400	826	181	273	87	0.32
GROUNDNUT	758	531	1088	118	611	975	977	747	244	1297	656	342	693	990	556	1201	736	327	0.44

SOURCE: DIRECTION DE L'AGRICULTURE

TABLE 54

PERCENTAGE OF SELF-SUFFICIENT FARMS IN CEREALS IN SENEGAL

ACCORDING TO SEVERAL SURVEYS

SOURCE	YEARS OF THE SURVEY	REGION SURVEYED	NUMBER OF FARMS SURVEYED
ROSS (1979)	1977-78	DIOURBEL	30
BA (1982)	1979	SINE-SALOUM	177
BENOIT-CATTIN (1984)	1981	SINE-SALOUM	10
SODEVA QUOTED BY YOUNG (1984)	1981-82	LOUGA	94
		DIOURBEL	195
		THIES	179
		SINE-SALOUM	189
JOLLY ET AL. (1984)	1982-83	LOWER CASAMANCE	237
JOLLY ET AL. (1984)	1983-84	LOWER CASAMANCE	150

TABLE 55

TRADE BALANCE FOR AGRICULTURAL PRODUCTS PROJECTED FROM 1985

TO 2000 FOR SENEGAL BY THE ABT ASSOCIATES REPORT

(BILLIONS OF CONSTANT CFAF OF 1985)

CATEGORY	1985	1990	1995	2000
EXPORTS				
. GROUNDNUT PRODUCTS	56	56	56	56
. COTTON	8	8	8	8
. TOTAL	64	64	64	64
IMPORTS				
. RICE	39.2	44.1	49.4	55.2
. WHEAT	8.8	10	11.1	12.4
. SUGAR	2.7	3.1	3.6	4.2
. OTHERS	30	34.2	40	46.4
. TOTAL	80.7	91.4	104.1	118.2
BALANCE	-16.7	-27.4	-40.1	-54.2

SOURCE: ABT ASSOCIATES (1984) TABLE 3.5

TABLE 56

TRADE BALANCE OF AGRICULTURAL PRODUCTS PROJECTED FROM 1982 TO 1992

TO 1992 FOR SENEGAL BY THE SENEGALESE GOVERNMENT

(BILLIONS OF CONSTANT CFAF OF 1982)

CATEGORY	1982	1985	1990	1992
EXPORTS				
. GROUNDNUT PRODUCTS	54	47.3	47.3	47.3
. COTTON	5.5	5	6.6	7.5
. TOTAL	59.5	52.3	53.9	54.8
IMPORTS				
. RICE	24.7	26.3	26.3	26.3
. WHEAT	5.6	5.9	5.9	5.9
. TOTAL	30.3	32.2	32.2	32.2
BALANCE	29.2	20.1	21.7	22.6

SOURCE: GOUVERNEMENT DU SENEGAL (1984) P.112

TABLE 57

ESTIMATION OF ECONOMIC PRICES FOR FERTILIZERS IN SENEGAL IN 1986-87

(CFA FRANCS PER KILO)

HYPOTHESIS: - THE FOREIGN EXCHANGE COMPONENT OF THE COST OF FERTILIZERS IS 100%. EVEN THOUGH COMPLEX FORMULAS ARE MANUFACTURED LOCALLY, THE LOCAL COST COMPONENT IS MINIMAL.

	TRANSPORTATION COST	FERTILIZER NAME						
		14-7-7	8-18-27	18-46-0	6-20-10	6-14-35	UREA	KCL
DAKAR FACTORY PRICE		47.8	51.3	60.3	39.8	51.3	40.0	29
80% PRICE (NO TAX)		38.2	41.0	48.2	31.8	41.0	32.0	23.2
PRICE AFTER CORRECTION FOR OVERVALUATION OF THE CFAF		51.6	55.4	65.1	43.0	55.4	43.2	31.3
MARKETING MARGINS		8.0	8.0	8.0	8.0	8.0	8.0	8
ECONOMIC PRICE IN ZONE:								
1	2.5	62.1			53.5		53.7	
2	3.2	62.8					54.4	
3	6.0			73.1			57.2	45.3
4	10.8			83.9			62.0	50.1
5 IRRIGATED	14.2			87.3	65.2		65.4	53.5
5 RAINFED	9.0	68.6			60.0		60.2	
6	8.1	67.7	71.5		59.1	71.5	59.3	
7	9.0	68.6	72.4	82.1	60.0	72.4	60.2	
8	8.5	68.1	71.9	81.6	59.5	71.9	59.7	
9	7.1	66.7	70.5	80.2	58.1		58.3	
10	3.6	63.2			54.6		54.8	
11	5.3	64.9	68.7		56.3		56.5	

SOURCE: CALCULATIONS BY THE AUTHOR.

TABLE 58

ESTIMATION OF IMPORT PARITY PRICES FOR CEREALS TO BE BOUGHT BY FARMERS IN SENEGAL IN 1986-87

(CFA FRANCS PER KILO)

HYPOTHESES: - PROCESSING COEFFICIENT FROM GRAIN TO FLOUR: 71%.
THE COST OF ONE KILO OF GRAIN IS 53.2 F.
THE COST OF ONE KILO OF MILLED FLOUR IS 53.2 / 0.71 = 74.9 F.
- ECONOMIC COST OF PROCESSING: 3.7 F/KG OF GRAIN.
- TOTAL COST OF FLOUR: 78.6 F/KG.
- 370 GRAMS OF FLOUR TO MAKE ONE KILO OF BREAD.
- 20 F/KG OF BREAD FOR BAKER'S COSTS AND PROFITS.
- 2 F/KG FOR TRANSPORTATION FROM THE ZONE TO THE FARM.

	TRANSPORTATION COST	MARKETING MARGIN	SORGHUM	MAIZE	RICE	WHEAT GRAIN	WHEAT FLOUR	WHEAT BREAD
CIF PRICE DAKAR			19.0	21.0	55.7	39.4		
PRICE AFTER CORRECTION FOR OVERVALUATION OF THE CFAF			25.7	28.4	75.2	53.2	74.9	
STORAGE, HANDLING AND TRANSPORTATION TO DAKAR			9.0	9.0	9.0		9.0	
PROCESSING COST							3.7	
ECONOMIC PRICE IN ZONE 12			34.7	37.4	84.2		87.6	256.8
ECONOMIC PRICE IN ZONE:								
1	2.5	1.8	41.0	43.7	90.5		91.9	270.4
2	3.2	2.3	42.2	44.9	91.7		93.1	273.7
3	6.0	4.3	47.0	49.7	96.5		97.9	286.6
4	10.8	7.7	55.2	57.9	104.7		106.1	308.8
5	11.4	8.2	56.3	59.0	105.8		107.2	311.8
6	8.1	5.8	50.6	53.3	100.1		101.5	296.4
7	9.0	6.5	52.2	54.9	101.7		103.1	300.7
8	8.5	6.1	51.3	54.0	100.8		102.2	298.3
9	7.1	5.1	48.9	51.6	98.4		99.8	291.8
10	3.6	2.6	42.9	45.6	92.4		93.8	275.6
11	5.3	3.8	45.8	48.5	95.3		96.7	283.4

SOURCE: CALCULATIONS BY THE AUTHOR.

TABLE 59

ESTIMATION OF IMPORT PARITY PRICES FOR MILLET/SORGHUM

TO BE SOLD BY FARMERS IN SENEGAL IN 1986-87

(CFA FRANCS PER KILO)

HYPOTHESES: - THE CONSUMPTION CENTER IS ASSUMED TO BE THE CENTER OF THE GROUNDNUT BASIN (ZONE 1).
- 2 F/KG OF TRANSPORTATION COST FROM THE FARM TO THE ZONE.

	TRANSPORTATION COST	MARKETING MARGIN	SORGHUM
CIF PRICE DAKAR			19.0
PRICE AFTER CORRECTION FOR OVERVALUATION OF THE CFAF			25.7
STORAGE, HANDLING AND TRANSPORTATION TO DAKAR			9.0
PRICE IN ZONE 12			34.7
TRANSPORTATION COST TO ZONE 1			2.5
MARKETING COST TO ZONE 1			1.8
ECONOMIC PRICE IN ZONE 1			39.0
ECONOMIC PRICE IN ZONE:			
2	2.8	2.0	32.2
3	5.5	4.0	27.5
4	10.4	7.4	19.2
5	9.0	6.5	21.5
6	5.6	4.0	27.4
7	6.6	4.7	25.7
8	6.1	4.4	26.5
9	4.7	3.4	28.9
10	1.1	0.8	35.1
11	2.9	2.1	32.0

SOURCE: CALCULATIONS BY THE AUTHOR.

TABLE 60

ESTIMATION OF IMPORT PARITY PRICES FOR MAIZE AND RICE

TO BE SOLD BY FARMERS IN SENEGAL IN 1986-87

(CFA FRANCS PER KILO)

HYPOTHESES: - RICE MILLING RATE OF 66%.
- MILLING COST OF 15 CFAF PER KILO OF PADDY OR 22.7 CFAF PER KILO OF MILLED RICE.

	TRANSPORTATION COST	MARKETING MARGIN	MAIZE	RICE (MILLED)	RICE (PADDY)
CIF PRICE DAKAR			21.0	55.7	
PRICE AFTER CORRECTION FOR OVERVALUATION OF THE CFAF			28.4	75.2	
STORAGE, HANDLING AND TRANSPORTATION TO DAKAR			9.0	9.0	
PRICE IN ZONE 12			37.4	84.2	
PROCESSING COST PER KILO OF MILLED RICE				14	
ECONOMIC PRICE IN ZONE:					
3	6.0	4.3	25.1	59.9	37.5
4	10.8	7.7	16.9	51.7	32.1
5	11.4	8.2	15.8	50.6	31.4
6	8.1	5.8	21.5		
7	9.0	6.5	19.9	54.7	34.1
8	8.5	6.1	20.8	55.6	34.7
9	7.1	5.1	23.2	58.0	36.3
11	5.3	3.8	26.3		

SOURCE: CALCULATIONS BY THE AUTHOR.

TABLE 64

ESTIMATION OF EXPORT PARITY PRICES FOR GROUNDNUT SHELLS

TO BE SOLD BY FARMERS IN SENEGAL IN 1986-87

(CFA FRANCS PER KILO)

HYPOTHESES: - GROUNDNUTS FROM ZONES 1, 5, 6, 10, AND 11 GOING TO ZONE 12.
- GROUNDNUTS FROM ZONES 7, 8, AND 9 GOING TO ZONE 12.
- 35% CRUDE OIL AND 42% PEANUT MEAL OUT OF 100% UNSHELLED GROUNDNUTS.
- ECONOMIC PROCESSING COST OF 3 F PER KILO OF SHELLS.
- TRANSPORTATION COST OF 3 F PER KILO OF SHELLS FROM FARM TO ZONE CENTER.

	TRANSPORTATION COST	MARKETING MARGIN	GROUNDNUT OIL	GROUNDNUT MEAL	VALUE OF SHELLS FROM OIL	VALUE OF SHELLS FROM MEAL	TOTAL VALUE OF SHELLS
FOB PRICE DAKAR			134.0	39			
PRICE AFTER CORRECTION FOR OVERVALUATION OF THE CFAF			180.9	52.7			
STORAGE, HANDLING AND TRANSPORTATION FROM DAKAR PLANT TO SHIP			9.0	9.0			
PRICE IN ZONE 12			171.9	43.7	60.2	18.3	78.5
PROCESSING COST PER KILO OF SHELLS							3
PRICE IN SHELLS							75.5
ECONOMIC PRICE IN ZONE:							
1	3.8	1.4					67.3
5	18.4	5					49.1
6	12.9	4.6					55.0
7	8.2	2.9					61.4
8	4.3	1.5					66.7
9	0	0					72.5
10	5.7	2					64.8
11	8.5	3.1					60.9

SOURCE: CALCULATIONS BY THE AUTHOR.

TABLE 62

ESTIMATION OF EXPORT PARITY PRICES FOR COTTON

TO BE SOLD BY FARMERS IN SENEGAL IN 1986-87

(CFA FRANCS PER KILO)

HYPOTHESES:
- COTTON GINNED IN EACH PRODUCTION ZONE AT A COST OF 6.9 CFAF PER KILO OF GINNED COTTON.
- GINNED COTTON FROM ZONES 6, 7, AND 8 GOING TO ZONE 12.
- GINNING COEFFICIENT OF 39%.
- FARM TO ZONE TRANSPORTATION COST OF 3 CFAF PER KILO OF UNGINNED COTTON.

	TRANSPORTATION COST	MARKETING MARGIN	GINNED COTTON	UNGINNED COTTON
FOB PRICE DAKAR			285.0	
PRICE AFTER CORRECTION FOR OVERVALUATION OF THE CFAF			384.8	
STORAGE, HANDLING AND TRANSPORTATION FROM DAKAR PLANT TO SHIP			9.0	
PRICE IN ZONE 12			375.8	
PROCESSING COST PER KILO OF GINNED COTTON			6.9	
PRICE TAKING INTO ACCOUNT PROCESSING			368.9	143.9
ECONOMIC PRICE IN ZONE:				
6	12.9	4.6		123.4
7	14.5	5.2		121.2
8	13.7	4.9		122.3

SOURCE: CALCULATIONS BY THE AUTHOR.

APPENDIX B

Crop budget sample for millet/sorghum
in the Center of the Groundnut Basin

CROP BUDGET

ZONE: CENTER OF THE GROUNDNUT BASIN (ZONE 1)
CROP: MILLET/SORGHUM
VERSION 1.1

INCOME AND COSTS (CFAF)	UNIT OF QUANTITY PER HA	UNIT PRICE	MODULE 1		MODULE 2		MODULE 3		MODULE 4		MODULE 5	
			QUANTITY	VALUE	QUANTITY	VALUE	QUANTITY	VALUE	QUANTITY	VALUE	QUANTITY	VALUE
INCOME												
(11) BAD YEAR	KILO	90	250	22500	200	18000	150	13500	250	22500	0	0
(12) AVERAGE YEAR	KILO	70	700	49000	550	38500	400	28000	700	49000	250	17500
(13) GOOD YEAR	KILO	60	900	54000	800	48000	600	36000	900	54000	400	24000
VARIABLE COSTS												
(21) SEEDS	KILO	80	6	480	6	480	6	480	6	480	6	480
(31) NPK (14-7-7)	KILO	81.5	100	8150	100	8150	0	0	0	0	0	0
(32) UREA	KILO	72.5	50	3625	0	0	0	0	0	0	0	0
LABOR												
(51) BAD YEAR	MAN-DAY	500	35	17500	32	16000	25	12500	41	20500	19	9500
(52) AVERAGE YEAR	MAN-DAY	500	46	23000	42	21000	32	16000	52	26000	26	13000
(53) GOOD YEAR	MAN-DAY	500	52	26000	48	24000	37	18500	58	29000	30	15000
TOTAL VARIABLE COSTS WITH LABOR												
(61) BAD YEAR (21+31+32+51)				29755		24630		12980		20980		9980
(62) AVERAGE YEAR (21+31+32+52)				35255		29630		16480		26480		13480
(63) GOOD YEAR (21+31+32+53)				38255		32630		18980		29480		15480
(64) TOTAL VARIABLE COSTS WITHOUT LABOR				12255		8630		480		480		480
ANNUAL FIXED COSTS												
(71) TOOLS	UNIT	231	1	231	1	231	1	231	1	231	1	231
(72) "SUPER-ECO" SEEDER	UNIT	461	1	461	1	461	1	461	1	461	1	461
(73) SPRING TOOTH ARARA	UNIT	294	2	588	2	588	2	588	2	588	1	294
(74) HORSE CART	UNIT	481	1	481	1	481	1	481	1	481	1	481
(75) CART	ANIMAL-DAY	302	4.5	1359	4.5	1359	4.5	1359	3.5	1057	3.5	1057
(80) TOTAL FIXED COSTS				3120		3120		3120		2818		2524
TOTAL COST WITH LABOR												
(91) BAD YEAR (61+80)				32875		27750		16100		23798		12504
(92) AVERAGE YEAR (62+80)				38375		32750		19600		29298		16004
(93) GOOD YEAR (63+80)				41375		35750		22100		32298		18004
(94) TOTAL COST WITHOUT LABOR (64+80)				15375		11750		3600		3298		3004

CROP BUDGET

ZONE: CENTER OF THE GROUNDNUT BASIN (ZONE 1)
CROP: MILLET/SORGHUM
VERSION 1.1

MARGINS (CFAF)	MODULE 1	MODULE 2	MODULE 3	MODULE 4	MODULE 5
IN A BAD YEAR PER HECTARE					
(101) GROSS WITH LABOR COST (11-61)	-7255	-6630	520	1520	-9980
(102) GROSS WITHOUT LABOR COST (11-64)	10245	9370	13020	22020	-480
(103) NET WITH LABOR COST (11-91)	-10375	-9750	-2600	-1298	-12504
(104) NET WITHOUT LABOR COST (11-94)	7125	6250	9900	19202	-3004
IN AN AVERAGE YEAR PER HECTARE					
(105) GROSS WITH LABOR COST (12-62)	13745	8870	11520	22520	4020
(106) GROSS WITHOUT LABOR COST (12-64)	36745	29870	27520	48520	17020
(107) NET WITH LABOR COST (12-92)	10625	5750	8400	19702	1496
(108) NET WITHOUT LABOR COST (12-94)	33625	26750	24400	45702	14496
IN A GOOD YEAR PER HECTARE					
(109) GROSS WITH LABOR COST (13-63)	15745	15370	17020	24520	8520
(110) GROSS WITHOUT LABOR COST (13-64)	41745	39370	35520	53520	23520
(111) NET WITH LABOR COST (13-93)	12625	12250	13900	21702	5996
(112) NET WITHOUT LABOR COST (13-94)	38625	36250	32400	50702	20996
IN A BAD YEAR PER WORKDAY					
(113) GROSS (102/290.1)	293	293	521	537	-25
(114) NET (104/290.1)	204	195	396	468	-158
IN AN AVERAGE YEAR PER WORKDAY					
(115) GROSS (106/290.2)	799	711	860	933	655
(116) NET (108/290.2)	731	637	763	879	558
IN A GOOD YEAR PER WORKDAY					
(117) GROSS (110/290.3)	803	820	960	923	784
(118) NET (112/290.3)	743	755	876	874	700
UNIT COST OF PRODUCTION					
(119) BAD YEAR (91/CORRESPONDING YIELD)	132	139	107	95	INFINI
(120) AVERAGE YEAR (92/CORRESPONDING YIELD)	55	60	49	42	64
(121) GOOD YEAR (93/CORRESPONDING YIELD)	46	45	37	36	45

CROP BUDGET

ZONE: CENTER OF THE GROUNDNUT BASIN (ZONE 1)
CROP: MILLET/SORGHUM
VERSION 1.1

LABOR USE CALENDAR (MAN-DAYS)	MODULE 1	MODULE 2	MODULE 3	MODULE 4	MODULE 5
PERIOD P0 (8 WEEKS BEFORE THE FIRST USEFUL RAIN)					
(201) FIELD CLEARING	6	6	6	8	6
(202) PLANTING	1	1	1	1	0
(210) TOTAL P0	7	7	7	9	6
PERIOD P1 (WEEKS 1 TO 2 AFTER THE FIRST USEFUL RAIN)					
(211) FIELD CLEARING	0	0	0	0	2
(212) WEEDING-THINNING-NPK OR MANURE SPREADING	5.5	0	0	8	0
(220) TOTAL P1	5.5	0	0	8	2
PERIOD P2 (WEEKS 3 TO 4 AFTER THE FIRST USEFUL RAIN)					
(221) PLANTING	0	0	0	0	1
(222) WEEDING-THINNING-NPK OR MANURE SPREADING	7.5	13	7	10	0
(230) TOTAL P2	7.5	13	7	10	1
PERIOD P3 (WEEKS 5 TO 6 AFTER THE FIRST USEFUL RAIN)					
(231) WEEDING-THINNING-UREA SPREADING	3	2	2	2	5
(240) TOTAL P3	3	2 *	2 *	2 *	5

CROP BUDGET

ZONE: CENTER OF THE GROUNDNUT BASIN (ZONE 1)
CROP: MILLET/SORGHUM
VERSION 1.1

LABOR USE CALENDAR (MAN-DAYS)	MODULE 1	MODULE 2	MODULE 3	MODULE 4	MODULE 5
PERIOD P4 (WEEKS 7 TO 8 AFTER THE FIRST USEFUL RAIN)					
(241) WEEDING	0	0	0	0	2
(250) TOTAL P4	0	0	0	0	2
PERIOD P5 (WEEKS 9 TO 24 AFTER THE FIRST USEFUL RAIN)					
(251.1) HARVESTING IN A BAD YEAR	3	2	2	3	1
(251.2) HARVESTING IN AN AVERAGE YEAR	5	5	4	5	3
(251.3) HARVESTING IN A GOOD YEAR	7	6	5	7	4
(252.1) THRESHING-WINNOWING - BAD YEAR	9	8	7	9	4
(252.2) THRESHING-WINNOWING - AVERAGE YEAR	18	15	12	18	9
(252.3) THRESHING-WINNOWING - GOOD YEAR	22	20	16	22	12
(260.1) TOTAL P5 IN A BAD YEAR	12	10	9	12	5
(260.2) TOTAL P5 IN AN AVERAGE YEAR	23	20	16	23	12
(260.3) TOTAL P5 IN A GOOD YEAR	29	26	21	29	16
TOTAL LABOR USE					
(290.1) BAD YEAR	35	32	25	41	19
(290.2) AVERAGE YEAR	46	42	32	52	26
(290.3) GOOD YEAR	52	48	37	58	30

CROP BUDGET

ZONE: CENTER OF THE GROUNDNUT BASIN (ZONE 1)
CROP: MILLET/SORGHUM
VERSION 1.1

ANIMAL USE CALENDAR (ANIMAL-DAYS)	MODULE 1	MODULE 2	MODULE 3	MODULE 4	MODULE 5
PERIOD P0 (8 WEEKS BEFORE THE FIRST USEFUL RAIN)					
(301) PLANTING	0.5	0.5	0.5	0.5	0
(310) TOTAL P0	0.5	0.5	0.5	0.5	0
PERIOD P1 (WEEKS 1 TO 2 AFTER THE FIRST USEFUL RAIN)					
(311) MANURE TRANSPORTATION AND SPREADING	0	0	0	0.5	0
(320) TOTAL P1	0	0	0	0.5	0
PERIOD P2 (WEEKS 3 TO 4 AFTER THE FIRST USEFUL RAIN)					
(321) PLANTING	0	0	0	0	0.5
(322) MANURE TRANSPORTATION AND SPREADING	0	0	0	0.5	0
(323) WEEDING	1	1	1	1	0
(330) TOTAL P2	1	1	1	1.5	0.5
PERIOD P3 (WEEKS 5 TO 6 AFTER THE FIRST USEFUL RAIN)					
(331) WEEDING	1	1	1	1	0
(340) TOTAL P3	1	1	1	1	0
PERIOD P4 (WEEKS 7 TO 8 AFTER THE FIRST USEFUL RAIN)					
(341) WEEDING	0	0	0	0	1
(350) TOTAL P4	0	0	0	0	1
PERIOD P5 (WEEKS 9 TO 24 AFTER THE FIRST USEFUL RAIN)					
(351.1) HARVEST TRANSPORT. IN A BAD YEAR	2	2	2	0	1
(351.2) HARVEST TRANSPORT. IN AN AVERAGE YEAR	2	2	2	0	2
(351.3) HARVEST TRANSPORT. IN A GOOD YEAR	3	3	2	0	2
(360.1) TOTAL P5 IN A BAD YEAR	2	2	2	0	1
(360.2) TOTAL P5 IN AN AVERAGE YEAR	2	2	2	0	2
(360.3) TOTAL P5 IN A GOOD YEAR	3	3	2	0	2
TOTAL ANIMAL USE					
(390.1) BAD YEAR	4.5	4.5	4.5	3.5	2.5
(390.2) AVERAGE YEAR	4.5	4.5	4.5	3.5	3.5
(390.3) GOOD YEAR	5.5	5.5	4.5	3.5	3.5

NOTES ON MILLET/SORGHUM CULTIVATION IN THE CENTER OF THE GROUNDNUT BASIN (ZONE 1)

Module 1: high level of intensification

- Mechanized planting.
- High use of fertilizers.
- 2 mechanized weedings with spring-tooth harrow set on a "sine" hoe or on a "western" hoe.
- 1 thinning very well done.

Module 2: average level of intensification

- Mechanized planting.
- Average use of fertilizers.
- 2 mechanized weedings with spring-tooth harrow set on a "sine" hoe or on a "western" hoe.
- 1 thinning well done.

Module 3: low level of intensification

- Mechanized planting.
- No use of fertilizers.
- 2 mechanized weedings with spring-tooth harrow set on a "sine" hoe or on a "western" hoe.
- 1 quick thinning.

Module 4: home gardens ("champs de case")

- Mechanized planting.
- Manure spreading.
- 2 mechanized weedings with spring-tooth harrow set on a "sine" hoe or on a "western" hoe.
- 1 thinning well done.

Module 5: late cultivation

- Mechanized planting. This planting often follows a first planting done according to the optimal crop calendar, but which failed because of a lack of germination or an insect problem. The farmer has to plant again at a later time. The seed cost and the time required for planting are very low and are counted only once.
- No use of fertilizers.
- 1 mechanized weeding with spring-tooth harrow set on a "sine" hoe or on a "western" hoe.
- 1 quick thinning.

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