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EXECUTIVE SUMMARY

Key Findings

Lessons from History. Senegal has experienced a number of spurts in agricultural production and productivity growth since independence, yet average trends from 1960 through 1993 have been either stagnant (in terms of aggregate production and yields), or negative (in terms of real value of production). Key insights gained from a historical review of Senegalese agricultural policy are:

(1) Agricultural intensification and productivity growth are driven by cash crops that have reliable markets and predictable prices;
(2) Crop research has helped maintain productivity despite declining rainfall;
(3) Liberalization has improved cereal marketing efficiency, but the production impact has been small because peanuts still provide greater profits and more predictable markets;
(4) Vertically integrated extension, input distribution, credit, and output marketing systems serve geographically dispersed smallholders well, encouraging agricultural intensification more than the less integrated systems which have recently evolved;
(5) Vertically integrated systems can become costly and inefficient, particularly if management responds more to political pressure than to business logic;
(6) A lack of attention to rural literacy, extension, and farm-level financial analysis has fostered the adoption of technologies, such as animal traction and fertilizer, that farmers now find difficult to sustain;
(7) Senegal's failure during the 1960s and 1970s to monitor farmers' real income, input/output price ratios, and the net financial impact of agricultural subsidies and taxes on stakeholders (farmers, fertilizer manufacturers, the government, etc.) increased the severity of the economic crisis that brought structural adjustment to the forefront in the 1980s.

Current Input Use Patterns and Constraints. Although use of animal traction is ubiquitous, current crop production in the Peanut Basin must be characterized as low external input farming. Farmers are unanimous in their belief that the most important constraint to improving agricultural output is their inability to obtain desired quantities of peanut seed. Inadequate seed has led to lower peanut income and a diminished capacity to purchase productivity-enhancing inputs: aging animal traction equipment is not being replaced, fertilizer use has become virtually nonexistent, the organic matter being returned to the soil is far from adequate, and the use of certified seed is extremely rare, as is the use of chemical inputs to protect seed quality or fight pests. Family labor is under-utilized during slack periods, while wage laborers are rarely hired during peak periods. The key strategies now being used by farmers to increase their yields and/or incomes cannot be sustained in the long-term:

(1) extensification on marginal lands;
(2) increasing peanut seeding rates to compensate for declining soil quality; and
(3) increasing the quantity (but not necessarily the quality) of labor.

Constraints to use of purchased inputs vary, but include the following:

(1) Fertilizer is not being used because farmers consider it too expensive;
(2) Fungicides are not used due to inadequate appreciation of their impact on yields;
(3) Insecticides are not used on seed because their application precludes future consumption;
(4) Day laborers are rarely used because labor markets function poorly;
(5) Seasonal contract laborers are rare because peanut seed constraints have made it more difficult to provide traditional in-kind payments;
(6) Certified seed is not purchased because farmers do not associate it with higher yields; furthermore, marketing locations, timing of sales, and packaging do not meet the farmers' needs;
(7) Organic matter is inadequate because reduced pasture prevents animals from staying in production zones, and multiple uses of crop residues compete with crop production needs; and
(8) Credit fails to ease the liquidity constraint because the system does not support flexible loan repayment schedules following poor harvests.

Two important objectives for the peanut sector are (1) to maintain peanut production at a level that keeps the processing industry running at capacity, and (2) to increase farmers' incomes. Farmers' inability to obtain desired quantities of peanut seed prevents attainment of both these objectives. Although the seed marketing system could be improved, farmers' inadequate cash reserves and poor access to credit are the principal bottlenecks; at present, there is more of a demand-side than a supply-side problem.

Economic Efficiency and Factors Associated with Higher Levels of Productivity. Although the economic efficiency of current production practices varies by farm type and agroclimatic zone, two findings apply in almost all situations:

(1) If farmers continue to cultivate without fertilizer, the primary means of increasing yields and profits will be to increase seeding rates beyond their current levels (which already exceed the rates recommended by extension services); and
(2) The marginal value product of household labor is less than the prevailing wage rate, suggesting that more labor than necessary is being used during most of the cropping season.

Input use patterns, adequacy of caloric intake, location, and access to cash are the principal factors that differentiate high-productivity farms from others.

Higher peanut yields are obtained by farms that use higher seeding densities and employ more household labor per hectare. Higher millet yields are obtained by farms that are diligent about reseeding and use more animal traction per hectare.

Productivity, measured in terms of returns to labor, is higher in households that have better levels of caloric intake, suggesting that food security and health are important "inputs" influencing the quality of agricultural labor.

Farms located in zones with better soils and more rain tend to have better yields. There were, however, notable exceptions during the 1989/90 season:

(1) Cereal yields in the southeastern Peanut Basin were significantly lower than those in less favorable zones; and
(2) Peanut yields in the drier northern and central zones were not statistically different from those in the higher rainfall zones.

Failure to control crop disease appears to have caused the low cereal yields in the southeast. We attribute the latter result to the successful development and extension of shorter-cycle peanuts which are well-adapted to conditions in the drier zones. Had these varieties not been developed, more than half the Peanut Basin would no longer be producing peanuts.

Farms with the best peanut yields have better access to cash at planting time. This access comes from a combination of higher overall incomes, larger prior-year peanut harvests, more livestock which can be converted easily to cash, and better access to credit. Access to cash, however, does not differentiate high-productivity millet producers from others.

Although there is evidence that noncropping income improves food security and is reinvested in cropping activities, we are unable to establish a clear link between high shares of noncropping income and better cropping productivity.

Policy Implications and Recommendations

Senegal needs to encourage farmers to move from the present pattern of increasing yields by mining the soil to an agriculture based on more intensive production technologies that conserve the natural resource base while increasing returns to land and labor. The recent devaluation of the CFA franc has improved the profitability of export crops such as peanuts, and increased the demand for local cereals, yet there is little evidence that farmers are moving toward the type of agricultural intensification needed to meet Senegal's long-term income and food security goals. As this type of intensification is not only in the long-term interests of farmers, but also in the long-term interests of the entire nation, farmers cannot be expected to carry the full financial burden of the transformation. The government has an important role to play in fostering policies and public investments that will induce private farmers and other business people to invest in the production, marketing, and use of more intensive, yet sustainable, agricultural production technologies. In the absence of this "enabling" environment, there is little hope for improving productivity.

We believe the most urgent issues to address are:

(1) the quality and quantity of peanut seed available to farmers;

(2) restoring soil fertility;
(3) renewing animal traction stocks;
(4) land tenure legislation; and
(5) increasing rural cash income to improve food security and input access.

The following paragraphs offer some ideas about remedial actions which are suggested by our research. The next logical step is to evaluate the relative costs and benefits of these suggested options in order to develop policies and programs that are economically feasible and sustainable.

Peanut Seed. There is a need to improve farmers' capacity to pay for seed, as this increases the quantities planted and contributes to improved seed quality through replacement of household stocks. Some options to consider are:

(1) making more credit available;
(2) making reimbursement terms flexible to allow for high inter-annual variability in cropping outcomes; and
(3) promoting alternative cash sources (livestock and nonfarm enterprises).

Seed storage, supply, and marketing systems can also be improved by:

(1) promoting the sale of certified seed through marketing campaigns;
(2) increasing distribution points for certified seed;
(3) encouraging sales of smaller units of seed than the 50-kilogram sacks now used;
(4) making certified seed available for purchase year round;
(5) increasing competition in the production and sale of certified seed; and
(6) fostering extension programs to promote insecticides and fungicides.

Soil Fertility. The profitability of, and access to, fertilizer can be improved by:

(1) cutting the costs of production and distribution through infrastructure investments that reduce transportation costs, reduction of import duties and taxes, and programs that increase fertilizer demand to levels that would foster economies of scale in production and distribution;
(2) conducting analyses to determine the level of subsidy that would be required to increase fertilizer use to a more reasonable level;
(3) judicious use of fertilizer subsidies based on cost-benefit analyses that show a net benefit of the subsidy to society in general;
(4) updating agronomic research on fertilizer response, with particular attention being paid to the use of locally produced phosphates and technologies that combine fertilizer with improved farm management practices (water harvesting, wind breaks, etc); and
(5) greater private sector involvement (extension, demonstration trials, etc.) in the promotion of fertilizer use.

Promotion of organic matter is essential. Measures to encourage this include:

(1) programs that promote livestock fattening to increase manure availability;
(2) feasibility studies for converting urban waste to soil supplements;
(3) research and extension on technologies that increase green manure or animal fodder;
(4) programs that link input use and improved natural resource management practices (tying fertilizer credit to composting, for example); and
(5) programs that increase the availability of crop residues for soil enhancement (replacement of millet-stalk fencing with live fences, for example).

Animal Traction Equipment. Most existing animal traction equipment is fully depreciated. In the next five to ten years there will be a major need for manufacture, sales, and credit programs to encourage recapitalization of the equipment stock. Measures to consider are:

(1) providing credit and technical support to local blacksmiths;
(2) creating a financial analysis unit in the extension services to help farmers evaluate their debt-carrying capacity, particularly for traction equipment; and
(3) reducing the costs of production for industrially manufactured equipment.

Land Tenure Legislation. There is a need for land tenure reform that permits (and legally protects) land transactions so as to ensure better land allocation (i.e., those who need it, get it). This will increase cropping specialization by funneling land to more productive farmers.

At the same time, research suggests that titling land so that it can be used as loan collateral does not have strong farmer support because farmers fear they will lose their land.

Income Diversification. Most farmers do not want to abandon farming but do want to diversify their income sources so as to reduce their risk, improve their access to inputs, and increase their income and food security. Policy options that would help farmers diversify their income sources include:

(1) the promotion of microenterprise programs (credit, training, etc.) in rural areas, particularly in fragile zones;
(2) industrial planning that encourages employment-generating activities in rural areas that have high levels of underemployed labor;
(3) programs that encourage the development of rural enterprises that support agriculture through upstream (input provision, for example) and downstream (output processing, for example) linkages; and
(4) food for work programs targeted at households with the most severe income and food security problems.

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ANOVA	Analysis of variance
BCEAO	Banque Centrale des Etats de l'Afrique de l'Ouest (Central Bank of West African States)
BNDS	Banque Nationale de Développement Sénégalais (BSD initially)
CER	Centre d'Expansion Rurale
CERP	Centres d'Expansion Rurale Polyvalents
CFA	Communaté Financiere Africaine
CNCAS	Caisse Nationale de Credit Agricole du Sénégal
CPSP	Caisse de Péréquation et de Stabilisation des Prix
CRAD	Centres Régionaux d'Assistance au Développement
CSA	Commissariat de Sécurité Alimentaire
DPDA	Declaration de Politique de Développement Agricole
EEC	European Economic Community
FAO	Food and Agriculture Organization of United Nations
GDP	Gross domestic product
GIE	Groupement d'Intérêt Économique
HY88/89	Harvest year 1988 or 1989
IFDC	International Fertilizer Development Center
IFPRI	International Food Policy Research Institute
ISRA	Institut Sénégalais de Recherches Agricoles
MVP	Marginal value product
NPA	Nouvelle Politique Agricole; New Agricultural Policy
OCA	Office de Commercialisation Agricole
OECD	Organization for Economic Cooperation and Development
OLS	Ordinary least squares
ONCAD	Office National de Coopération et d'Assistance pour le Développement
PAS	Projet Autonome Semencier
SIES	Société Industrielle des Engrais du Sénégal
SIP	Société Indigene de Prévoyance; farmers' association
SODEVA	Société de Développement et de la Vulgarisation Agricole
SONACOS	Société Nationale de Commercialisation des Oléagineux du Senégal
SONAGRAINES	Société National d'Approvissionnement en Graines
SONAR	Société Nationale d'Approvisionnement du Monde Rural
SUR	Seemingly unrelated regression estimation
USAID	United States Agency for International Development

1. MOTIVATION OF RESEARCH AND OBJECTIVES

With few exceptions, economic growth and development have come about through agricultural intensification that increased agricultural productivity and stimulated growth in the nonfarm economy (Mellor 1976; Timmer 1988). Analyses of agricultural growth trends from aggregate crop production data for Africa suggest that agricultural intensification is not taking place rapidly, however, and, in some cases, is not occurring at all (see Timmer 1988; or Block 1993). The slow growth in African agricultural productivity has generated substantial pessimism about the prognosis for long-term, sustainable economic growth on the continent.

Compounding this concern is the fact that research on new technologies has not yet produced breakthroughs comparable to those that gave rise to the Green Revolution in parts of Asia and Latin America (Matlon 1990; Pieri 1989). Pessimism about agricultural productivity in Africa has led some governments and donors to invest in other sectors, thereby reducing the funds available to agriculture and further exacerbating the problem (Commander, Ndoye, and Ouédraogo 1989; Kelly and Delgado 1989).

The research reported in this document responds to this growing pessimism with concrete insights about what is driving productivity changes, and how productivity can be improved in Senegal. The underlying premise of the research is that aggregate measures of agricultural productivity can provide insights about a country or a continent, but they are not adequate tools for diagnosing the strengths and weaknesses of different farming systems and for prescribing appropriate cures.

This paper is one of four country case studies designed to identify the determinants of, and constraints to, cropping productivity so as to improve agricultural policy prescriptions in Africa. The other case study countries are Burkina Faso, Rwanda, and Zimbabwe.[1]

This case study covers the Senegalese Peanut Basin—a vast area of rainfed peanut and millet production which represents 33 percent of Senegal's land area, 65 percent of its rural population, 80 percent of its exportable peanut production, and 70 percent of its cereal production.[2] The country-study approach delves beneath the surface of the aggregate data by presenting analyses of recent household data in combination with extensive reviews of complementary research (earlier household studies and macro analyses). The extensive use of household data permits us to develop a keener understanding of the household decision- making process that drives cropping decisions. Combining these micro-level insights with a knowledge of what is concurrently happening with macro indicators provides a more solid foundation for the design and implementation of agricultural policy than is possible with either micro- or macro-level analyses in isolation. We present a historical review of agricultural policy and productivity trends, and then examine recent household survey evidence to further explore certain hypotheses. Among the most important questions addressed by the research are:

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[1] All of the studies were funded by the United States Agency for International Development, AFR/SD/PSGE/FSP as part of the Food Security II Cooperative Agreement with Michigan State University.

[2] Percentages calculated from information in Diallo (1989).

How have farmers historically responded to changes in agricultural technology, prices, and input/output marketing policies? What have been the policy successes and failures?

What do aggregate data tell us about trends in cropping productivity?

What do household data reveal about the current input use and crop production patterns for the average farm?

Which types of zones, crops, and farms currently have higher (lower) levels of productivity?

What are the current determinants of, and constraints to, higher productivity?

What are the factors that condition farmers' input use?

Given past experience and current constraints, what types of policies (price, credit, research, etc.) would be the most likely to encourage higher levels of productivity in the future?

Although this study is country-specific, the analytical methods used and many of the insights gained are relevant for other African countries with similar physical, social, and policy environments. We have attempted to draw out the themes and conclusions from the Senegal case study that we believe have broad policy relevance for other countries. Reardon et al. (1994, 1995) provide a synthesis of the results from all four country case studies included in the overall research effort. The synthesis highlights the authors' interpretation of policy implications and conclusions that cut across a wide spectrum of African countries. Readers with extensive knowledge of agricultural policy and farming systems in countries not directly covered by this research should be able to find cross-cutting themes and conclusions that are of relevance to their countries of interest.

We proceed as follows. Chapter 2 presents the conceptual framework within which productivity is examined, and defines the key concepts used. Chapter 3 begins by discussing the evolution of the agricultural sector and changes in the physical, social, and economic environments that influence productivity. It then reviews major changes in Senegalese agricultural policy from colonial times to the present, paying particular attention to differences between the pre- and post-structural adjustment periods. The premise of Chapter 3 is that one cannot understand current productivity patterns and design future agricultural policies without a thorough knowledge of how the government and the private sector historically performed when providing goods and services to farmers, and how farmers have responded over time to technological and policy changes.

Chapters 4 through 6 present empirical analyses of rural household data collected as part of a collaborative study conducted by the International Food Policy Research Institute (IFPRI) and the *Institut Sénégalais de Recherches Agricoles* (ISRA) from 1988 through 1990.[3] Chapter 4

[3] Kelly, Diagana, and Reardon participated in the IFPRI/ISRA study.

discusses the relationship between input use levels and productivity measured in both physical and value terms. Chapter 5 compares the characteristics of high productivity farms (those ranked in the top 25 percent of the sample with respect to yields and returns to household labor) to less productive farms. In Chapter 6, we examine the determinants of peanut seed acquisition and use. Chapter 7 concludes with a discussion of what the research findings imply for designing agricultural and rural development policies, setting priorities for government and donor investments, and funding future agricultural research.

Although the study was designed and begun before the January 1994 devaluation of the CFA franc, the policy discussion takes into account the substantial agricultural sector benefits to be realized by the devaluation if the constraints identified in the report are resolved, particularly input constraints faced by peanut farmers.

2. CONCEPTS AND DEFINITIONS OF KEY TERMS

2.1. Conceptual Framework of Factors Affecting Cropping Productivity

We regard the rural household as starting from a given asset base comprised of land, investment capital, and human resources. The quantity and quality of the assets owned are influenced by social custom and tradition, as well as by government policies such as land tenure laws, banking and credit institutions, and the availability of educational and health services. Cropping activities represent only one of the three sectors from which most rural Senegalese households earn their livelihood. Livestock and nonfarm enterprises also provide an important share of rural income. Farmers' perceptions of the relative profitability and potential complementarities of activities in these three sectors condition the manner in which household resources are allocated and, therefore, the level of cropping productivity attained. These perceptions are influenced by a wide range of factors which can be loosely classified as either environmental or policy-induced.

The physical environment (rainfall, soil quality, groundwater availability, and tree cover) is considered one of the most important determinants of cropping productivity in Senegal, given that the Sahel is prone to frequent droughts and is characterized by nutrient-poor, fragile soils that are subject to wind and water erosion. Improved technologies and management techniques are the principal means available to compensate for the poor agroclimatic environment. Development of improved techniques could be encouraged by policies that favor investments in applied agricultural research. Farmer adoption of new technologies and management techniques could be encouraged by policies that foster adaptive research and extension programs. The ultimate hurdle which must be passed, however, is that of profitability. Profitability of agricultural inputs and management practices is conditioned by price policies for both inputs and outputs (taxes, subsidies, stabilization programs, or controls on marketing margins, for example); market institutions (regulations, licensing procedures); transportation, communication, and market infrastructure; and environmental regulations. The local and foreign demand for the crops produced are also an extremely important factor in determining the price relationships and the ultimate profitability of farm production.

The brief description in the preceding paragraphs fails to capture the full complexity of the interactions among the many factors that influence agricultural productivity. Quantifying the impact of particular policies on productivity is difficult because the real world is not a controlled experiment; it is rare for a major policy change to occur without other factors that influence productivity also changing. Quantifying the relationship between farmer characteristics and productivity is also difficult. Given the relatively low levels of purchased inputs used in Senegal, it is reasonable to assume that differences in farmers' personal skills, work ethic, and knowledge play an important role in determining productivity. Unfortunately, these characteristics are difficult to measure, and we must frequently use proxies (level of education, or contacts with extension services, for example).

There is also the issue of two-way interactions and causality. The fact that nonfarm income can positively influence cropping productivity if it provides liquidity for purchasing inputs leads us to hypothesize that households with large amounts of nonfarm income are more likely to purchase cropping inputs and to have better yields than those with little nonfarm income. The reverse, however, can also be true: Good farmers earn more cropping income which permits them to invest more in noncropping activities and, therefore, earn more noncropping income. The real sequence of events probably differs from one household to another, making it difficult to produce quantitative models that measure the impact of noncropping income on cropping productivity without some supplementary qualitative and historical information.

Despite the difficulties encountered in quantifying these complex interactions (or perhaps because of them!), we use a variety of approaches to evaluate the productivity impact of the various factors mentioned above. An extensive historical review of agricultural policy and productivity trends in Senegal is used to analyze the impact that changes in prices, policies, and available technologies have had on input use, crop mix, yields, and the real value of agricultural output from the colonial period to the present. Using the IFPRI/ISRA data, we examine the influence of a broad range of factors on crop yields and returns to labor: Environmental factors (represented by agroclimatic zone), household resource endowments (land, labor, and agricultural equipment), levels of inputs used (seed, labor, and other purchased inputs), and factors that affect access to and use of inputs (for example, education, nonfarm income, access to credit).

This study focuses on farm-level productivity. It is outside our scope of work to evaluate how changes in agricultural policies or farm-level productivity affect the rest of the economy, although some reference is made to these issues in the historical review. In practice, these economy-wide effects can be complex—for example, government support programs can spur peanut farmers' adoption of inputs that raise yields, which can in turn increase the efficiency of downstream markets and processing plants—but subsidy outlays to spur input use can also increase fiscal deficits and general price levels. These effects are indeterminate *a priori* and are thus an empirical knowledge gap that needs to be addressed elsewhere.

2.2. Concepts

In empirical work, one seldom encounters the word "productivity" without a series of modifying adjectives clarifying exactly what aspect of productivity is being measured. Most measures of productivity fall into two broad groups: average and marginal. Average productivity is a simple ratio: Output produced divided by the quantity of inputs used. Marginal productivity is a measure of efficiency that provides valuable information about how to increase output and profits.

2.2.1. Average Productivity Indicators

There are two types of average productivity measures: partial and total. The quantity of output produced divided by the amount of a single input used is a measure of partial factor productivity. Partial productivity measures do not control for the level of other inputs employed. For example, average yields per hectare reported in aggregate national statistics come from fields cultivated with different amounts of labor, fertilizer, and seed.[4] Partial productivity measures are reported in either physical units or value terms.

Total factor productivity measures attempt to control for the full range and intensity of all inputs used.[5] Total factor productivity is the ratio of an index of aggregate output to an index of aggregate input. Indices are based on monetary values; therefore, accurate price data are a *sine qua non* for reliable estimates of total factor productivity.

The reliability of average productivity indicators depends on the quality of the data in both the numerator and the denominator, as well as on the appropriateness of the indexing procedures used to aggregate dissimilar outputs and inputs. Thin markets for many inputs (land and labor in particular) and outputs (nontradable cereals such as millet) make it difficult to obtain the price data required to report partial productivity measures in value terms, or to create the indices needed for total factor productivity estimates. This study deals exclusively with partial productivity measures.

2.2.2. Marginal Productivity Indicators

Average productivity indicators provide little information on how to improve productivity; yet, this is the question that donors and policy makers want answered. Estimation of production, profit, or cost functions permits one to examine the efficiency of resource allocation using marginal physical or value products. A marginal product shows how much more gross output (or value) a producer obtains by adding one more unit of an input if the levels of all the other inputs remain constant. By comparing the marginal value product of an input to its unit cost, one can evaluate allocative efficiency and identify production constraints. If the marginal value product exceeds the unit cost of an input, producers can increase profits (i.e., become more efficient) by increasing their use of the input. The challenge is to understand what prevents producers from employing more of the "constrained" input, and develop policies that will alleviate the constraint.

To fully understand production constraints and predict how farmers will respond to various policies, one needs information on the marginal productivity of such key inputs as land and labor for different types of farms. African agriculture has traditionally been considered land abundant and labor constrained. There is already substantial evidence that these relationships are changing, particularly in the semi-arid tropics and highlands. Given the high population growth rates now found in most of Africa, monitoring changes in the relative importance of land and labor constraints is crucial to developing policies that will encourage African productivity growth.

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[4] Although there are methods to control for levels of other inputs when calculating partial productivity ratios, this is seldom done.

[5] Given gaps in available data, it is clearly never possible to control for <u>all</u> inputs.

2.2.3. Allocative versus Technical Efficiency

There are two principal ways of improving efficiency in crop production—allocative and technical.[6] Allocative efficiency is achieved when marginal value products are equal to per unit factor costs (as described in Section 2.2.2. above). Allocative inefficiency has two dimensions: (1) errors due to misallocation within a given budget constraint (movement to the expansion path), and (2) a failure to use profit maximizing levels of inputs (errors of scale). The first type of misallocation can be caused by inadequate farmer information, poor input supply systems, or land tenure laws that distort incentives. Failure to attain profit maximizing levels of output can be the result of input access constraints or risk avoidance behavior.

Technical efficiency concerns the optimal application of inputs with respect to timing, techniques of application, and environmental factors (i.e., failure to be on the production frontier). Technical efficiency is usually considered to be independent of prices. Common causes of technical inefficiency are inadequate farmer information, poor technical skills, or untimely input supply. This type of inefficiency tends to be more prevalent in situations where farmers are learning about and adopting new technologies.

To separate production inefficiencies into their technical and allocative components, one must estimate production functions that have a separate variable for the quantity used of all inputs that are not perfect substitutes. This means one must be able to quantify environmental variables such as soil quality and rainfall at a disaggregated level (preferably farm- or village-specific), and have information on the timing and methods of input used by individual farmers. Failure to account for environmental factors in a production function can lead to erroneous conclusions about an individual farm's efficiency. This is particularly true in those farming systems where soil quality and rainfall are highly variable. Use of overly aggregated input categories (fertilizer, for example, rather than nitrogen and phosphate individually) results in attributing allocative inefficiency (failure to be on the nitrogen/phosphate expansion path) to technical inefficiency.

Unfortunately, it is rare to have the full range of information needed to completely separate technical and allocative aspects of efficiency when using farm-level survey data.

2.3. Methods

Although information about average productivity can be easily obtained with simple calculations, marginal analyses are usually based on coefficients obtained from econometric estimations of production functions.

The production function is output explained by use of variable inputs (for example, labor or fertilizer), capital inputs (for example, land or equipment), and environmental factors such as rainfall. Given an estimate from the production function of the marginal effect of an input on the

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[6] This discussion of technical and allocative efficiency draws heavily on Ali and Byerlee (1991).

quantity of output, one can examine how this marginal impact changes when different levels of other inputs are utilized (such as how much more productive an extra unit of labor is when fertilizer use increases).

One can then ask what determines a farmer's use of inputs using policy and other household-level determinants, such as education or nonfarm income, to estimate the levels of inputs used. It is also common to include conditioning factors (education and access to markets or credit, for example) directly in the production function. This permits one to test the effect of these factors on productivity, and examine the interactions between inputs and conditioning factors. We use both approaches in this study.

There are many diverse ways of evaluating cropping productivity. Some of the key analytical issues which must be addressed are:

(1) Degree of aggregation across crops: Should one examine the productivity of individual crops or of some aggregated "crop" representing the total farm output?
(2) Units of analysis: Should one examine physical input/output relationships comparing kilograms of output to units of inputs, or look at financial returns comparing, for example, the total value of net income to the units of inputs?
(3) Choice of denominator: Should one examine productivity in terms of returns to land (as is usually done when looking at yields per hectare) or should other key inputs (labor, for example) also be examined?
(4) Allocative versus technical efficiency: What is the relative importance of each type of inefficiency, the feasibility of analyzing each type given the available data, and the relative costs of reducing each inefficiency?

This list is not exhaustive, but these are the principal issues we dealt with when analyzing data for this study.

Aggregating across all crops by using a numeraire, for example, helps one examine how well the farm is doing overall, but does not permit one to examine the relative productivity of each individual crop or whether the farm could be more productive by changing the crop mix. In this study we disaggregate the analyses by crop.

Looking at ways to maximize the total output (in kilograms) is important for government planners who want to increase domestic production so that it meets estimated demand. A production system which maximizes output, however, may not be profitable to the farmer if net returns are low. In other words, measuring productivity in only physical terms is unlikely to provide much insight regarding farmer behavior and potential supply of agricultural products. We evaluate a mix of physical and value measures of productivity, as both are relevant to the design of agricultural policies.

With respect to the denominator, one usually wants to measure productivity of limited or constrained inputs. Land is the input most often selected, but not necessarily the most appropriate input to use. Delgado and Ranade (1987), for example, argue that labor has traditionally been more constraining in Africa than land. Because it is not always clear *a priori* which inputs are most constraining, a variety of denominators should be examined and the results compared. We did a thorough analysis of land, labor, seed, and other purchased inputs; however, more attention is given to reporting details of land productivity analyses because evidence suggests that land is becoming more constraining than labor in Senegal at the present time.

Differentiating between allocative and technical efficiency can be useful, because reducing different types of inefficiency requires policies and programs with different time horizons and costs. Removing technical inefficiencies by improving farmers' skills may be a slower, more costly process than reducing those allocative inefficiencies associated with capital constraints due to poorly functioning credit markets. Although the Senegal data set used for the empirical analyses in this report contains excellent information on quantities of principal inputs used, it lacks the precision on timing, application methods, and environmental factors required to do separate analyses of allocative and technical efficiency; hence, most of our empirical work deals with issues of allocative efficiency (see Chapter 4). There is ample evidence in the descriptive sections of the report, however, that technical inefficiencies need to be examined more carefully (Chapter 5).

3. EVOLUTION OF AGRICULTURAL POLICY AND PERFORMANCE: 1800-1980

3.1. Historical Overview and Broad Trends

In June 1994 the Senegalese government issued the *Declaration de Politique de Developpement Agricole* (DPDA), which describes the prevailing agricultural situation:

> The agricultural sector occupies 70 percent of the population and acts as one of the principal motors of the Senegalese economy in terms of household income, government revenue, and foreign exchange generated. For two decades, however, the sector has been in crisis ... and the growth in agricultural production has not exceeded the population growth rate.
>
> The contribution of the agricultural sector to the gross domestic product was 18.75 percent from 1960-66 but was no more than 11 percent between 1987 and 1993.... The decline in the gross domestic product of agriculture finds its source in lower world prices for key export products and a progressive reduction in subsidies that has diminished real incomes of rural households; but inadequacies in agricultural policies and a lack of competition in the sector have also contributed (Government of Senegal, Ministry of Agriculture 1994, page 1).

To understand what is happening in the agricultural sector, one must look at the evolution of the physical, social, economic, and policy environments in which it operates. During the last 30 years there have been radical changes in this environment. These changes have substantially modified the way in which Senegalese farmers earn their livelihood, and how the government deals with the agricultural sector and issues of national food security.

Changes in the physical environment include declining rainfall, shorter growing seasons, deteriorating soils, and growing land and water constraints.[7] These changes have raised concerns about the environmental sustainability of agricultural production under rainfed conditions in much of Senegal. Agricultural research has responded in limited ways (shorter- cycle peanut varieties, for example), but technical innovations have—at best—only prevented yields per hectare from declining in response to the adverse environment.

The most notable social change is the rapid rate of population and urbanization growth. Annual population growth from 1976 to 1988 was 2.7 percent overall; 2.1 percent in rural areas, and 3.8 percent in urban areas (United States Agency for International Development [USAID] 1991). During the same period the economic growth rate was 2 percent, and growth in cereal production 2.7 percent. Senegal has been importing about half of its cereal needs for more than a decade. Although agricultural research in the 1960s and 1970s (Tourte et al. 1971; or Benoit-Cattin 1986,

[7] See LeBorgne (1988) for evidence of declining rainfall, and Charreau (1974) for a discussion of the poor structural quality of the Peanut Basin soils and problems of nutrient loss associated with the disappearance of the traditional wooded fallow system of cultivation.

for example) showed that the potential existed to increase crop productivity using modern inputs, Senegal has not experienced anything close to a Green Revolution, particularly in food crops.

Economic change has been ubiquitous, with both rural households and the government significantly adjusting their *modus operandi* during the last several decades. Rural households have become much more involved in off-farm and market economies, as they progressively moved from subsistence to cash crop production during the 1960s and 1970s and, more recently, into nonfarm activities and migration. Survey results (Kelly et al. 1993) show that although rural households throughout the Peanut Basin rely on home production for 50 to 80 percent of their staple foods, most participate in the cash economy by selling crops (peanuts in particular), other home-produced goods, and labor. The share of noncropping income in rural household income ranges from a low of 20 percent to a high of 80 percent, depending on the zone and the adequacy of the harvest. Agriculture alone no longer provides an adequate livelihood for most.

While rural households have become more involved in the broader economy, the government—in response to rising external debt and fiscal deficits—has been decreasing its direct involvement in the economy as a whole. In 1984, the government launched a New Agricultural Policy (Nouvelle Politique Agricole; NPA), designed to improve macro economic indicators by decreasing direct government financing of agriculture, and stimulating farmer and private sector initiatives. Among the principal changes affecting the agricultural sector were (1) the privatization of input distribution and output marketing functions previously performed by parastatals, and (2) the elimination of direct subsidies for agricultural inputs, particularly fertilizer. Although these reforms have reduced government outlays for agriculture, it has become increasingly difficult for farmers to obtain the productivity-enhancing inputs which they were encouraged to adopt in the 1960s and 1970s. The DPDA assesses the impact of these adjustments:

> These policies, responding to the logic of internal economic adjustment, have facilitated the suppression of important market distortions associated with the massive and ineffective intervention of the government. They have not, however, provided an adequate response for assuring strong growth in the agricultural sector and an improvement in productivity (Government of Senegal, Ministry of Agriculture 1994, page 3).

Human beings, like the institutions they create, are creatures of habit; any attempt to radically change long-established behavior patterns in a short period of time is likely to be met with resistance. The pattern of heavy government involvement in the agricultural sector, and farmers' reliance on the government for inputs as well as for output marketing, dates back to the introduction of peanuts as a cash crop during the colonial period. This history did little to prepare Senegal for the rapid withdrawal of government support from the agricultural sector in the 1980s. An historical review of Senegalese agricultural policy gives one a better perspective on the magnitude of the transformation being undertaken by the NPA and a better appreciation for why many of the government's objectives have not yet been achieved.

Senegal's agricultural history can be divided into four periods: (1) the colonial period, which established the government as the "prime mover" in the agricultural sector and peanuts as the principal cash crop, (2) an early post-colonial period of government expansion and productivity growth, (3) a period of "growing pains" which led to economic crisis, and (4) a period of structural adjustment, characterized by government withdrawal from the agricultural sector.

3.2. The Colonial Period: 1800-1960

Senegal inherited a government-managed agricultural sector characterized by the production of a dominant cash crop (peanuts) in conjunction with a subsistence crop (millet/sorghum). The high level of government involvement in agriculture began even before the technological imperative associated with the introduction of peanuts in the late 1800s. Governor Roger, in the early 1800s, described his vision of the colonial government's role in agriculture: The government is to conduct agricultural research, provide economic incentives encouraging private farmers to increase productivity, provide monetary advances for equipment and animals, distribute seeds and plants free of charge, give food aid in the hungry season, offer farmer training by government agents, and finance community improvements (wells, dikes, village fences, etc.).[8]

Once peanut production was introduced, the government became more concerned than ever with providing inputs—particularly peanut seed—which farmers were thought incapable of storing or purchasing on their own, given the large quantities required. This concern led the government to create farmers' associations (Sociétés Indigene de Prévoyance; SIPs), which evolved over time into the post-independence cooperative movement. The initial role of the associations was to facilitate distribution of inputs; the provision of credit for "hungry season" food and agricultural inputs was soon added. The SIPs' role later expanded to marketing peanuts in competition with the French commercial houses.

Senegal benefitted from substantial agricultural research on peanut fertilizer during the colonial period. Research began in 1947 and fertilizer marketing in 1949. Multi-rate trials designed to identify zone-specific recommendations continued during the 1950s. Research on different types of animal traction equipment was often combined with the fertilizer trials. A network of *Centres d'Expansion Rurale* (CER) was created in 1954 to extend research findings to farmers. By independence in 1960, the colonial government was the primary actor in all aspects of input supply, extension, credit, and research. The one activity in the agricultural sector that remained primarily in the private sector was the first-handler peanut marketing function carried out by the prominent French trading houses (Buhan and Teisseire, Deves and Chaumet, Maurel and Prom).

In many ways Senegal represents a success story for the rapid transformation of a subsistence economy into an export-oriented, cash crop economy. The colonial government's desire to speed up this transformation led it to perform many functions carried out by farmers or private firms in more developed, market-oriented economies. Of particular note was the government's provision of inputs and credit, import of rice from Asia, and guaranteed purchasing of cash crops.

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[8] Our translation and paraphrase from Ly (1958), p. 24.

Although it is unlikely that the Senegalese economy would have developed as rapidly without this intervention, it is also true that more attention should have been given to gradually transferring all of these functions to private farmers and firms once the initial goal of introducing cash cropping and modern inputs had been achieved.

3.3. The Period of Government Expansion: 1960-1965

After independence, the French concept of government involvement in agriculture prevailed. The *Centre de Recherches Agronomiques* continued research on improved technologies (primarily fertilizer, animal traction, and crop rotation practices) under the supervision of the French. The *Centres d'Expansion Rurale Polyvalents* (CERP) provided extension services. The *Office de Commercialisation Agricole* (OCA) coordinated peanut marketing and input distribution activities. The *Centres Régionaux d'Assistance au Développement* (CRAD) provided liaison between the OCA and farmers' cooperatives, training and assisting the latter with record keeping and other administrative functions. The *Programme Agricole*, funded by the Senegalese Development Bank (BSD, later Banque Nationale de Développement Sénégalais; BNDS), provided input credit for peanut seed, animal traction equipment, and fertilizer to farmers through cooperatives established by the government.

The main difference between the colonial and the early post-independence periods was the gradual replacement of the French trading houses with a government peanut and input marketing parastatal. In 1966 the *Office National de Coopération et d'Assistance pour le Développement* (ONCAD) was given the combined functions of the OCA and CRAD; at this time, peanut marketing by anyone but ONCAD became illegal. This latter development was more a reaction against the colonial past than a continuation of it. Colonial marketing was dominated by the French commercial houses because they were the only ones with access to the necessary commercial bank credit. Some historical accounts suggest that calculated efforts by the French and Lebanese to restrict Senegalese participation in the colonial peanut trade were responsible for the post-independence proclivity toward nationalization of commerce (Amin 1969). Most accounts, however, blame the usurious practices of Lebanese and Senegalese *traitants*, licensed traders who acted as intermediaries between commercial houses and farmers.

This anti-business sentiment fostered the creation of ONCAD and the nationalization of peanut marketing activities. The government's objectives were to (1) give farmers a fair price, thereby freeing them from their cycle of indebtedness; and (2) ensure that peanut- sector profits went either to farmers or the government, thereby eliminating the transfer of these revenues to "unproductive" middlemen. Farmers were guaranteed the official price (which they had not always received from the *traitants*). This was often less than the world market equivalent, but the profit was now going to the government, which reinvested a substantial share in the agricultural sector by funding the cooperative movement, the *Programme Agricole* credit program, and input subsidies (particularly fertilizer).

A desire to use agriculture as a source of investment capital for the newly independent government, as well as African Socialist ideals, led to a scorn of "middlemen" and fostered heavy government intervention. The result is that at an early stage in the agricultural history of Senegal there was a failure to appreciate the positive role that "middlemen" could play in facilitating agricultural production and marketing activities. Much of the animosity toward, and mistrust of, traders appears to be linked to a failure on the part of both farmers and the government to recognize that the margins going to traders included not only profits, but also covered remuneration for services that have substantial costs and value—storage, transportation, and risk taking, for example.

Beginning in 1964, efforts were devoted to improving aggregate peanut production to diminish the anticipated impact of the French decision (driven by European Economic Community [EEC] membership conditionalities) to stop paying preferential peanut prices to Senegal by 1967. It was hoped that by improving extension services and access to modern inputs, aggregate peanut production could be increased by 25 percent in four years.

Through the mid-1960s, the availability of credit and price subsidies were judged by the government to be having a favorable effect—the use of fertilizer and purchases of modern equipment surged forward. The impact on peanut production appeared to be positive, as production increased from 892,000 tons in 1960/61 to 1,168,000 tons in 1965/66, and marketed peanuts went from 786,000 tons to 1,089,000 tons—meeting the established target of increasing output by 25 percent. Much of the gain was through increased planting (1114 thousand hectares in 1965 versus 977 thousand hectares in 1960), but increased productivity per hectare was also evident (1007 kilograms per hectare in 1965 versus 913 kilograms in 1960).

Aggregate millet production increased steadily from 392,000 tons in 1960/61 to 514,000 tons in 1964/65. This increase was due to expansion of the area cultivated, as yields per hectare declined from 574 kilograms in 1960/61 to 508 kilograms in 1964/65. Although the Government of Senegal had substantial legislation concerning trade in millet and sorghum (official prices, restrictions on trade across administrative boundaries, licensing fees for traders, for example), its capacity to enforce these prices and rules was limited. The government was continuing a policy introduced during the colonial period, in which little attention was paid to the development of local cereal production and marketing because cereal deficits were easily satisfied by rice imports from Asia. This attitude meant that farmers and traders faced relative certainty with respect to peanut prices and demand, but great uncertainty with respect to cereal prices and demand. The net impact was that farmers grew cereals for home consumption and peanuts for sale.

The overall impact of these policies is reflected in the average annual growth in agricultural gross domestic product for 1960-65, estimated to be 4.4 percent (Frelastre 1982, p. 50, citing the Senegalese Fifth Development Plan).

3.4. Growing Pains and Economic Crisis: 1965-1980

3.4.1. Slowdown in Agricultural Growth: 1965-1974

The latter half of the 1960s and the beginning of the 1970s were problematic, as farmers had to adjust to lower peanut prices and a period of recurrent droughts. High levels of credit defaults in 1970 led the government to "forgive" agricultural debts. This began a pattern of debt defaults that progressively worsened during the decade. In 1972, 56 percent of the seed credit and 49 percent of the fertilizer and equipment credit were not reimbursed. In 1973, farmers defaulted on 42 percent of their seed credit and 26 percent of their other credit (reimbursement rates from Casswell 1984, page 47, using Banque Centrale des Etats de l'Afrique de l'Ouest [BCEAO] sources).

Performance indicators for the late 1960s and early 1970s were less favorable than those for the early post-independence period. The average annual growth in agricultural production was only 1.1 percent between 1965 and 1970, and 1.6 percent from 1970-74 (Frelastre 1982, p. 50). Peanut production for five of the ten years between 1966/67 and 1975/76 was lower than the 1960 levels. The decline in millet production was less dramatic; in only two years did production fall below 1960 levels. The 1965-75 period witnessed a sharp increase in the percent of fertilizer going to cereal crops; this could partially explain why millet production did relatively better than that for peanuts. The increase in the use of cereal fertilizer came largely from the Food and Agriculture Organization of the United Nations (FAO) fertilizer program that conducted on-farm demonstration trials for cereal fertilizer. The total quantities of purchased inputs declined, however, during this same period. Unfavorable changes in farm-gate prices (following France's change in preferential pricing) and poor rains are the most commonly cited causes of this decline. Given the difficulty of determining to what extent this poor performance was due to policy rather than exogenous price and weather effects, there was a tendency to place most of the blame on the latter, ignoring important signs that the parastatal system supporting agriculture was not performing efficiently.

3.4.2. Performance Indicators on the Rise Again: 1974-1978

The 1974/75 harvest seemed to signal a turning point. Peanut production was on the rise, and the World Bank's estimate of annual agricultural growth for the 1974-77 period was 7.1 percent (Frelastre 1982, p. 50). Earlier research had already shown that farmers who adopted the recommended packages of animal traction, fertilizer, and crop rotation practices could improve both yields per hectare and economic returns (Tourte et al. 1971). The extension services were apparently getting the news of these improvements to farmers, while credit and distribution programs were making it possible for the farmers to acquire the productivity-enhancing inputs.

Peanut Seed. The role of the post-independence government was to ensure that supplies of the key inputs—particularly the all-important peanut seed—continued to be available at affordable prices and credit terms. Maintaining an adequate stock of high-quality seed is a much more difficult task for peanuts than for millet and sorghum, because peanut seed has a very low reproduction rate.[9] The sheer magnitude of the national seed stocks required, and the importance of peanuts in the gross value of Senegalese agricultural production, made it unrealistic for the under-capitalized private sector to assume responsibility for the production and distribution of peanut seed in the early post-independence period. The government, therefore, played an active role in peanut seed production, distribution, and quality control from the time of Senegal's independence through the mid-1980s.

The cornerstone of the country's seed policy was the distribution of seed on credit to every adult for whom the annual head tax had been paid. Seed was usually distributed on the basis of 100 kilograms per taxable man and 50 kilograms per taxable woman. The household head who paid the taxes was most often the recipient of the seed, which was distributed through government-sponsored cooperatives. At the household level, seed was redistributed to other household members or contract laborers in exchange for labor performed in the household heads' fields. At marketing time, production was sold to the cooperative, which deducted an in-kind payment plus interest (ranging from 12.5 to 25 percent—a range considered reasonable by farmers) for the seed credit before paying the official producer price for the remaining production.

Animal Traction Equipment. Senegalese farmers began using animal traction during the colonial period, but it was not until credit was widely available under the *Programme Agricole* that virtually all farmers in the Peanut Basin adopted the technology. The rapid adoption of animal traction favored extensification (expansion of area) more than intensification (using more labor and/or non-labor inputs per given unit of land) for both peanut and cereal production. This is illustrated by data from the southern Peanut Basin which shows that households having adopted the animal traction and fertilizer recommendations of the *Unités Expérimentales* research and extension program doubled the number of hectares they cultivated per active worker between 1969 and 1975, but their gross income per hectare increased only 47 percent (Benoit-Cattin 1986). Of all the new technologies introduced by the research and extension services (animal traction, fertilizer, improved seeds, and crop rotation practices), animal traction was probably the most important single cause of growth in aggregate production and labor productivity after 1960, and the only new technology that was universally adopted throughout the Peanut Basin.

The success of animal traction in the Peanut Basin is due in large part to the fact that it alleviates one of the major constraints to peanut production—timely seeding. Agronomic research shows that peanut yields decline substantially for each day that seeding is delayed beyond the first useful rain. Seeding is much more rapid when done with animal traction (particularly with horse-drawn equipment, which is the most popular type in the Peanut Basin) and therefore, more area can be planted at the optimal time.

The introduction of short-cycle peanut varieties in the 1970s provided another opportunity for animal traction to speed up a critical operation—harvesting. During the 1960s and 1970s, animal traction was not commonly used for harvesting peanuts. Unlike their longer-cycle predecessors,

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[9] While it takes only 1 kilogram of seed to produce 100 kilograms of millet, it requires at least 10 kilograms of seed to produce 100 kilograms of peanuts.

however, short-cycle peanuts can be destroyed by regermination if they are rained on once they have matured. As a result, rapid harvesting has become important, and one now finds widespread use of animal traction for peanut harvesting. Local blacksmiths contributed to this transformation by producing an inexpensive harvesting blade which easily attaches to existing animal traction equipment.

Thus, we find that the rapid and extensive adoption of animal traction in Senegal resulted from the convergence of three factors: (1) farmers produced a cash crop that permitted them to pay for the equipment, (2) credit was made available on reasonable terms, and (3) the equipment served to overcome important bottlenecks associated with the production of the cash crop. The growth in the number of credit defaults, however, suggests that research and extension services had not given enough attention to analyses of the financial returns for animal traction used in different types of farming situations, and the debt-carrying capacity of individual farmers. A research and extension program was introduced in the 1970s to provide farmers with some guidance on the financial aspects of adopting new technologies, but the extension services' resources were not adequate and only a small share of farmers benefitted (see Benoit-Cattin 1977).

Fertilizer. Fertilizer, like animal traction, was introduced to the Peanut Basin during the colonial period, but was more cautiously adopted by farmers despite the liberal credit and subsidy programs that prevailed from 1960 through 1980. Although Senegal's fertilizer consumption rate was one of the highest in Africa in the mid-1970s, it represented an average application of only 11 kilograms per hectare (Kelly 1988).

Despite these low levels (as measured by world standards), an International Fertilizer Development Center (IFDC) evaluation mission in the mid-1970s gave both fertilizer policy and performance of the fertilizer sector high marks. Understanding the evolution of fertilizer demand and supply in Senegal is more complex than in most African countries because Senegal has local deposits of phosphates and a fertilizer manufacturing industry. The country's fertilizer policy included (1) an industrial subsidy to the *Société Industrielle des Engrais du Sénégal* (SIES), motivated by a desire to increase domestic employment and provide a hedge against fluctuating world market supplies and prices; and (2) a fertilizer subsidy to farmers that was intended to increase crop production, particularly cereals, thereby reducing dependence on imported foods. The IFDC report also notes that between 1962 and 1976, the fertilizer applied to millet increased from 9.3 to 30.4 percent of Senegal's fertilizer consumption. For Senegal as a whole, fertilizer use increased at an annually compounded rate of 20 percent between 1964 and 1967, then declined from 1968-70 due to drought and producer price effects, and subsequently climbed at an annual compound rate of 40 percent between 1970 and 1976 (IFDC 1977, p. 33). National consumption of fertilizer attained an all-time high of 87,000 tons in 1975. More than 80 percent of this fertilizer was used for peanut and millet production.

3.4.3. Advent of Crisis: 1978-1980

From 1970/71 through 1973/74, the government's price stabilization board (*Caisse de Péréquation et de Stabilisation des Prix*, or CPSP) realized 24 billion CFA francs in net revenues from the agricultural sector (revenue from the sale of peanuts bought by ONCAD minus the costs of agriculture sector subsidies), while rice consumers were subsidized by 17.5 billion (Abt 1985, p. 13, citing the Organization for Economic Cooperation and Development [OECD] sources). In short, until the mid-1970s, the government was realizing a net gain through agricultural taxes. The tax weighed most heavily on those farmers who sold their peanuts through official channels but purchased few of the subsidized inputs.

Although criticism of the pervasive government involvement in agriculture was a topic of conversation during the 1965-75 period, and farmers' defaults on agricultural debts were becoming more frequent, the relatively good harvests of 1975 and 1976 fostered a general belief that all was going well.

Unfortunately, more debt defaults occurred in 1977 (72 percent of the seed credit was not reimbursed) and again in 1979 (67 percent of seed and 92 percent of other credit were not reimbursed). Non-democratic practices and an absence of solidarity among members of the government-sponsored farmers' cooperative movement were increasingly cited as causes for the poor credit reimbursement rates. This partly contributed to what was then called the *malaise paysanne*. At the same time, the cumulative effects of over-centralization, inefficiency, and corruption in the input distribution and marketing parastatal (ONCAD) and the agricultural extension parastatal (Société de Développement et de la Vulgarisation Agricole, SODEVA) were having a more noticeable impact on the economic performance of the agricultural sector (see Schumacher 1975; Casswell 1984; Government of Senegal, Ministry of Rural Development 1984; Frelastre 1982; and Waterbury and Gersovitz 1987).

Beginning in 1978, the government entered a prolonged period of severe economic crisis that exposed many of the previously hidden weaknesses in the system. By 1980, the government was subsidizing the peanut sector rather than taxing it, and the era of structural adjustment was imposed.

3.5. The Era of Structural Adjustment: 1980 to the Present

In response to its own assessment of the fiscal situation, but also due to pressure from major donors (France, the United States, the World Bank, and the International Monetary Fund), the Senegalese Government began a series of fairly drastic agricultural sector reforms in 1980. The underlying principals of the reforms were to:

(1) curtail direct government intervention in the agricultural sector while encouraging private sector actors (both commercial and cooperative) to fill the gap; and
(2) eliminate government subsidies and taxes to the greatest extent possible.

Changes were introduced incrementally during the 1980s; many of them were not implemented until the middle of the decade. The "New Agricultural Policy" was published by the government in 1984 and the "Cereals Policy" in 1986. Some of the changes introduced called for a radical departure from the long-established behavior patterns for the three major participants in the agricultural sector—farmers, the government, and private sector input manufacturers and distributors. In many cases, the farmers and the private sector have not responded to these policy initiatives in the anticipated fashion.

3.5.1. Liberalizing and Privatizing Output Markets

Peanuts. ONCAD, the peanut marketing parastatal, was dissolved in 1980. The oil processing company, SONACOS (a mixed firm owned by both government and private interests), was forced to assume the added responsibility of supervising first-handler peanut marketing activities in collaboration with the cooperatives. In 1985, efforts to expand private sector participation in cash crop marketing led the government to authorize a limited number of private traders (*organismes privés stockeurs*) to buy peanuts directly from farmers. The government continued to administer producer prices and commercial margins. Producer prices were increased to compensate for the reduction in input subsidies and distribution services (see Section 3.5.2.). Unfortunately, when the government increased producer prices from 60 to 90 CFA francs/kilogram in 1986, the export price fell. After subsidizing the producer price for 3 years, the government brought it more in line with international prices by declaring a 70 CFA franc/kilogram price in 1989.

In general, rules concerning the private peanut traders were similar to those that applied to the *traitants* (licensed traders) during the early 1960s before peanut marketing was nationalized; many of the "new" private traders had been *traitants* formerly. One important difference, however, was that private traders were not guaranteed assignment to the same location from one year to the next. This significantly diminished their leverage for collecting credit reimbursements from producers and, therefore, reduced their enthusiasm for extending credit. Offering credit to farmers was a tactic used extensively by the earlier *traitants* to guarantee their peanut supply ahead of the harvest. Given the limited access that farmers had to formal credit during the 1980s, Gaye (1992a) suggests that rules permitting private traders to return annually to the same location might have improved producers' access to informal credit.

Coarse Grains. One of the key agricultural policy goals of the 1980s was to increase production and consumption of local cereals, thereby reducing rice imports. This was to be accomplished by liberalizing cereal marketing for locally produced coarse grains. Market liberalization was accompanied by research and extension activities to reduce millet processing costs and improve consumer acceptance of industrially processed millet. The belief was that more liberal markets and less expensive processing would reduce consumer prices, thereby increasing the demand for local cereals without significantly reducing producer prices.

Legal restrictions on transportation of agricultural products and rules governing licensing fees were simplified in the mid-1980s. The government declared floor and ceiling prices, rather than fixed producer prices, for millet. The *Commissariat de Sécurité Alimentaire* (CSA) was authorized to maintain emergency cereal stocks and intervene in markets when actual prices differed substantially from declared floor and ceiling prices. Resources were generally not adequate for effective market intervention. With the assistance of agricultural research, however, the CSA developed a market information system that reports weekly grain prices in newspapers and on the radio. By the late 1980s, the government withdrew completely from price interventions in millet and sorghum markets.[10]

Rice. Although rice is not produced in the Peanut Basin, consumer price policy concerning rice imports plays a significant role in determining the demand for, and producer prices of, coarse grains. Imported rice markets continued to be government controlled through 1994.[11] Licenses to sell rice are restricted and difficult to obtain. Consumer prices are set by the government and are strictly controlled.[12] Although imported rice was subsidized during the colonial and early post-independence periods, it has been highly taxed since the 1980s, with the tax representing a major source of government revenue. Despite the tax, imported rice is quite competitive with coarse grains when the processing costs of the latter are taken into account. In urban areas and millet deficit zones, rice has frequently been less expensive than millet per consumable calorie. Given strong preferences for rice, and its ready availability throughout the country, both urban and rural households do not hesitate to purchase rice instead of millet when the price of millet, plus its processing costs, approach that of rice. Hence, the price controls on imported rice serve as a fairly effective ceiling on the consumer price of millet.

3.5.2. Liberalizing and Privatizing Input Marketing

Following the 1980 dissolution of ONCAD, the government created the *Société Nationale d'Approvisionnement du Monde Rural* (SONAR) to assume input distribution functions. SONAR's role was defined to a large extent by changes in the credit program and mechanisms for financing input distribution. The *Programme Agricole*, which had provided input credit to farmers since 1960, was radically changed in 1980, when all equipment and most fertilizer credit was discontinued. By the middle of the decade, public seed credit was also stopped and the *Programme Agricole* was completely phased out. The credit program was temporarily replaced by a *retenue à la source* before a new credit program began in 1987.[13]

During SONAR's short life (1980-1985), a different set of rules about credit, subsidies, and input distribution policies evolved for each of the three major categories of inputs: seed, fertilizer, and animal traction equipment. Rules changed with little warning, as the government and donors

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[10] Newman, Ndoye, and Sow (1985) provide a good review of cereal marketing policies and their impacts during the 1970s and early 1980s.

[11] At present (1995), even rice marketing is being liberalized and privatized.

[12] Rice is produced at a relatively high cost in irrigated areas of the Senegal River Valley and Upper Casamance. Producer prices were subsidized through 1994, further complicating the price policy for rice in Senegal.

[13] The *retenue à la source* was a tax imposed on farmers when they marketed their peanuts. Revenues from the tax were used to cover seed and fertilizer for the following season. There was little correlation between the amount of tax paid by farmers and the quantities of inputs they received.

jumped from one stop-gap measure to another. This continues to the present day as the government tries to fine-tune those policies that have failed to elicit the desired response from various participants in the agricultural sector. Because these changes in input policies have so profoundly altered many aspects of agricultural production in the Senegalese Peanut Basin, we present a detailed review of the changes for each type of input, discussing farmers' responses to the changes, and the apparent impact the policies have had on aggregate productivity.

Animal Traction Equipment. Changes in credit and distribution policies for animal traction were the most straightforward and least subject to subsequent revisions. *Programme Agricole* credit for equipment was stopped entirely in 1980. Although a new credit program was launched by the *Caisse Nationale de Credit Agricole du Sénégal* (CNCAS) in 1987, it got off to a slow start. The program began in the lower potential areas of the central Peanut Basin, where the profitability of improved inputs and the capacity to reimburse were problematic. Expansion of CNCAS services to other regions took several years. Even when equipment credit was available, farmers' demand was for seed credit.

Although some concern has been expressed about the impact on productivity that the aging equipment stock might have (Havard 1987, in particular), up through the end of the 1980s farmers seldom mentioned agricultural equipment as an important constraint, even though most equipment was at least 15 to 20 years old.[14] This is a result of the high adoption rate permitted by the *Programme Agricole* up to 1980—farm surveys in 1989 found that virtually all households in the Peanut Basin owned some animal traction equipment—and the fact that equipment proved to have a much longer lifetime than anticipated. Since the dissolution of *Programme Agricole* equipment credit, there have been few purchases of new factory-made equipment. There has, however, been a strong response from local blacksmiths who recondition old equipment and sell it as "new." Farmers consider the quality of the reconditioned equipment adequate, with the exception of the seeders. Apparently, factory-made seeder disks are much better than their local substitutes (Kelly 1986).

There is a large differential in the prices of factory-made versus locally-made equipment. For example, a factory-made hoe cost about 60,000 CFA francs in the late 1980s, while the local reconditioned variety was 10-15,000 CFA francs. Without credit, farmers earning an average annual income of 30-50,000 CFA francs per adult equivalent would be unlikely to purchase factory-made equipment.[15] Even if the credit program were revived, it remains to be seen if farmers would willingly switch back to more expensive factory-made equipment when reconditioned items are available.

Clearly, one cannot recondition equipment indefinitely. At some point local blacksmiths will have to learn how to manufacture traction equipment from scratch at lower costs than the factories, or

[14] See, for example, Diagana et al. (1990), Kelly (1986), and Goetz (1993).

[15] Income figures are based on average 1988 and 1989 income data for households in the Peanut Basin (Kelly et al. 1993).

there will have to be some "new blood" pumped into the system from factory production to maintain the flow of reconditioned equipment.

Apparently, the relative lack of concern for equipment in the 1980s has not continued into the 1990s. Recent farm surveys suggest that the importance of the equipment constraint is rising. Gaye (1992b) presents evidence that the average number of functioning seeders and hoes per hectare has declined from 1986 through 1991 for a sample of 250 farms surveyed annually during that period. Gaye (1994) reports on a survey of a subset of the IFPRI/ISRA farmers who were asked to rank their production constraints: animal traction equipment now ranks second in importance—right after peanut seed and is tied with fertilizer. A failure to resolve the equipment problem in the next five to ten years could profoundly alter agricultural production in the Peanut Basin. After half a century of animal traction, it is difficult to envision farmers returning to hoe cultivation without serious decreases in production.

Fertilizer.[16] In the early 1980s, rules concerning farmers' access to fertilizer credit were tightened to counteract the high rate of credit defaults. The government also initiated a policy of restricting fertilizer distribution to those farmers in the higher rainfall areas. Fertilizer use dropped from 74 to 44 thousand metric tons between 1980/81 and 1981/82. Precipitous drops continued to occur throughout the 1980s. A reduction in the fertilizer subsidy almost doubled the farm-gate fertilizer price between 1982 and 1983, further exacerbating the problem. Use fell from 41,000 to 27,000 tons between 1984 and 1985, when the government imposed a *retenue* system, taxing farmers when they marketed peanuts to pay for fertilizer that would be delivered for the following season.[17] Credit continued to be a constraint during the 1980s, but the principal cause of the subsequent drops was a reduction in fertilizer subsidies, which led to sharp price increases (Kelly 1988).

USAID/Senegal funded a three-year declining fertilizer subsidy for <u>cash</u> sales of fertilizer by <u>private sector operators</u> from 1986 through 1989. The program had dual objectives: (1) to facilitate farmers' access to fertilizer, and, more importantly, (2) to encourage the transfer of fertilizer marketing functions to the private sector. The amount of the subsidy (24, 16, and 8 percent of the factory-gate price in 1986, 1987, and 1988, respectively) was considerably smaller than the 40 to 60 percent subsidies that farmers had known during the *Programme Agricole*. Moreover, world market prices for fertilizer were rising. Furthermore, Senegalese farmers were accustomed to purchasing fertilizer on credit, and had little experience with mobilizing the substantial amounts of money required for cash purchases. As a result, the subsidy provided little incentive for increased fertilizer use. Because so little fertilizer was bought on a cash basis, the subsidy applied to less than a quarter of the total fertilizer sales during the entire three-year

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[16] This discussion draws on fertilizer consumption, price, and subsidy information from USAID (1991) which has been partially reproduced in Appendix 1. These data are more accurate than the corresponding data in FAO documents, as they have been corrected to distinguish between the (1) quantities available (import and manufacturing data), and (2) quantities purchased by farmers (distribution records from the Senegalese Direction of Agriculture).

[17] Crawford and Kelly (1984) present a detailed discussion of the *retenue* program.

program. During 1986, its first year of operation, which coincided with the introduction of a new binary fertilizer that failed to gain farmers' confidence, fertilizer consumption hit its lowest level since independence—19,000 tons. By 1989, when the subsidy was phased out, the income from one kilogram of peanuts purchased only .79 kilograms of fertilizer; this was in sharp contrast to farmers' perceptions of what the peanut/fertilizer price ratio should be (based on *Programme Agricole* ratios ranging from 1.6 to 2.6). Price and fertilizer consumption data reported in Appendix 1 illustrate that the demand for fertilizer from 1960 to the present has been sensitive to large changes in the peanut/fertilizer price ratio.

The USAID program also failed to stimulate private-sector fertilizer marketing in the Peanut Basin. Most traders felt that the farmers' demand for fertilizer would be extremely low in the absence of liberal credit and subsidy policies (Gaye 1992a). Furthermore, the fertilizer market was only partially liberalized—import restrictions remained in force to protect the monopolistic position of Senegal's fertilizer manufacturing industry and wholesale prices continued to be largely determined by agreements between the government and the local fertilizer company.[18] Given the high fixed costs of the fertilizer manufacturer, the sharp decline in demand, and the government's inability to finance fertilizer subsidies, there was little leverage for lower prices.

By the end of the 1980s, privatization of fertilizer distribution appeared to be working in the Senegal River Basin (an irrigated rice zone) and for the irrigated horticultural sector, but not in the rainfed peanut/millet areas (Kelly and Ouédraogo 1992).[19] There is strong evidence that the failure of a private sector distribution system to materialize in the Peanut Basin is due more to demand constraints than to problems on the supply side. Numerous surveys throughout the Peanut Basin have shown that, given the cost/return ratios in the 1980s and 1990s, farmers prefer purchasing additional peanut seed rather than fertilizer, and pursuing extensive rather than intensive cultivation practices (Kelly 1988; Gaye 1992a). An economic analysis of returns to intensification with fertilizer versus extensification with peanut seed shows that it was more profitable to purchase peanut seed than fertilizer (Kelly 1988, using 1987 prices).

Although fertilizer use has risen slightly since its 1986 low, total national use remains at approximately 30,000 tons—substantially lower than the 50 to 70,000 tons consumed annually during the 1970s. Furthermore, there has been a dramatic shift in use patterns; peanut and millet production now account for less than 25 percent of the fertilizer used, with the rest going to cotton, irrigated rice, and horticultural production (i.e., to subsidized and/or lower risk situations). The latter two crops are ones where water, and therefore fertilizer productivity, can be controlled; cotton is grown under contract with inputs provided on credit. An encouraging

[18] In 1987 import restrictions on urea were relaxed, but those on compound fertilizer remained in effect. Retail prices in the 1990s have not been fixed. The manufacturer recommends a price based on the Dakar wholesale price plus transportation costs (26 CFA francs/ton kilometer in 1990), plus a margin (6000 CFA francs/ton in 1990). Ouédraogo (1990) presents some evidence that in competitive markets of the Senegal River Valley, retailers have sold at lower than recommended prices.

[19] There is some question about the success of privatization in the Senegal River Basin, as producer rice prices were subsidized throughout the 1980s and may have artificially inflated the demand for fertilizer.

note for the rainfed areas is that farmers have become much more careful about collecting and applying manure now that the price of fertilizer is generally out of reach. Even with this greater effort, however, survey evidence presented in Chapter 5 suggests that the available manure falls far short of needs.

Given the extremely low levels of fertilizer use per hectare, even in the mid-1970s, one would not expect to find any positive, statistically significant impact of fertilizer on aggregate productivity. Those who have tried to establish some type of relationship using aggregate data are—as one might expect—unable to show any significant effect (USAID 1991, for example). To conclude from such analyses, however, that fertilizer has no positive role to play in increasing productivity is not justified. One of the most obvious problems with this type of aggregate analysis is that it does not control for other conditioning factors, such as rainfall. For example, many of the years with the highest levels of fertilizer use happened to also be years of extremely poor rains; this creates a situation where an analysis of aggregate data could show that increases in fertilizer use lead to a drop in productivity (because low yields due to drought are correlated with high fertilizer consumption).

Conclusions about the productivity of fertilizer must be drawn from data that controls for the influence of factors other than fertilizer. An analysis of production data for farmer-managed trials conducted from 1965-1982 in the southern Peanut Basin shows that using the recommended dose of 150 kilograms of fertilizer per hectare increased peanut yields by 400 kilograms per hectare, peanut hay yields by 700 kilograms, and sorghum yields by 600 kilograms on average over the 17-year period. Results were less favorable for the lower rainfall areas in the central Peanut Basin where peanut yields increased by 200, peanut hay by 300, and millet by 250 kilograms per hectare (Kelly 1988). If the positive impact on yields shown by these analyses is not translated into a positive impact on net incomes, however, farmers are unlikely to become fertilizer enthusiasts.

Value/cost ratios provide some insights about fertilizer profitability. In the southern Peanut Basin the average value/cost ratio across years was 5 for peanuts and 11 for sorghum. These ratios were evaluated at the nominal prices prevailing from 1965 to 1982. A recalculation of these ratios using 1987 producer prices and unsubsidized fertilizer prices for the entire period resulted in ratios of 3 for peanuts and 6 for sorghum—well above the ratio of 2 that is used as a rule of thumb for judging farmers' interest in fertilizer (Kelly 1988). Although the average value/cost ratio over time was quite favorable, the study notes that the ratio is less than one 20 percent of the time and less than two in 40 percent of the years covered. In other words, the average returns are high, but the results in any given year are extremely variable, making fertilizer a highly risky investment.

The same study showed that the average value/cost ratios (using 1987 prices) were consistently below 2 for peanuts, but at the 3.5 level for millet in the drier, central part of the Peanut Basin. Furthermore, the probability of the ratio being less than 2 was quite high for peanuts (seven out of ten years), but reasonable for millet (two of ten years). The financial returns to fertilizer in these zones are problematic, particularly for peanuts. As these results are based on a long time series, they present a more realistic picture of the average farm-level results than research trial analyses that typically cover only a year or two of data.

These ratios have to be re-evaluated, however, in light of the recent monetary devaluation and changes in response that might have been brought about by declining soil quality and rainfall. It is unfortunate that most of Senegal's fertilizer trial data for the Peanut Basin were collected before 1980; as time passes, it becomes increasingly justifiable to question the relevance of the yield responses represented by these data sets. Nevertheless, the results do suggest that fertilizer has a positive contribution to make in zones with adequate rainfall, *if it is used regularly every year*. The key is to encourage regular use (through insurance or extended credit repayment programs, for example) so that farmers can survive the bad years and realize the overall positive gains.

The value/cost ratios cited above reveal another factor which complicates farm-level decisions about fertilizer use. Cereal crops are more responsive to fertilizer than are peanuts; however, less than 10 percent of the cereal output is sold (Kelly et al. 1993). This has been historically true and remains true today, despite significant progress since the mid-1980s in privatizing and liberalizing cereal marketing activities. As a result, most fertilizer used for cereal production must be paid for from peanut sales or nonfarm income. This creates serious constraints when those producing the cereals (usually the household heads) do not also produce a substantial amount of peanuts or have nonfarm income.

A further complication is evidence that using too much fertilizer on the fragile soils of the Peanut Basin can lead to a decline in soil nutrient content over time. Sarr (1981) did extensive soil tests on fields that had been continuously farmed for 17 years using different fertilizer application rates. He found that those soils which received the highest fertilizer doses (the doses that were recommended for use by the better farmers) generally had lower nitrogen and calcium content than those fields that received smaller fertilizer doses.[20] The conclusion was that fertilizer use is essential to maintain soil quality and improve productivity, but there are limits to the quantities that should be applied. Pieri (1989), drawing on Sarr's work in Senegal as well as work elsewhere in Africa, shows the dangers of using large quantities of fertilizer as a substitute for organic matter. The current trend in the agronomic literature is clearly toward a better balance between chemical fertilizer and organic matter. Such recommendations are, however, difficult to implement in the Sahel environment, where crop residues have multiple uses and the amount of available manure falls far short of what is needed.

Judging by the experience in agricultural productivity growth around the world, sustainable intensification of agricultural production without a greater use of fertilizer and manure is highly unlikely.[21] Nevertheless, there are serious constraints to overcome with respect to the cost of fertilizer and the availability of manure. Environmental concerns further complicate this issue. Some are worried that an increased use of fertilizer will be detrimental to the environment. On the other hand, continuation of the current low levels of productivity in the face of rapid

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[20] Soil analysis revealed that the nitrogen and calcium loss exceeded that estimated by mineral balance studies based on analyses of plant nutrient uptake.

[21] Byerlee (1993) presents a good discussion of the need for continued attention to the development and extension of seed-fertilizer technologies.

population growth may well put so much pressure on the land that the consequences would be worse than the consequences of substantially increasing fertilizer use.

Seed. Given the importance of peanut production to the Senegalese economy, peanut seed was the last input to have its government-run distribution system dismantled. To reduce the problems of credit defaults, the government introduced the *retenue* tax in 1981/82 whereby 10 percent of the proceeds from a farmer's peanut sales were withheld at marketing time and used by the government to pay for the seeds it distributed the following season. The amount withheld was increased from 1982/83 through 1985/86 to 20 percent of a farmer's sales. The program was not equitable because the amount of seed received continued to be based on the rule of 100 kilograms per taxable man and 50 kilograms per taxable woman regardless of the quantity of peanuts marketed by a household. Peanuts marketed through official channels dropped, and the government continued to have difficulties covering the costs of the seed distribution program.

By 1985 the government could no longer support the peanut seed program. SONAR was dissolved and the government made one last distribution for the 1985/86 season. Only those farmers who had marketed in official channels the prior year were eligible, and the quantities distributed were based on the quantities marketed. For the 1986/87 season, the government presented farmers with four options for obtaining peanut seed:

(1) save their own from the previous harvest;
(2) purchase seeds with cash;
(3) join a seed bank operated by Société National d'Approvissionnement en Graines (SONAGRAINES);
(4) purchase on credit.

None of these options was enthusiastically adopted by farmers. The most common practice was personal seed stocks. Farmers found it difficult to stock enough seed, however, because there was always the temptation to eat or sell it when emergencies arose. Protecting stocks against insects was also a problem.

Changes in peanut seed credit and distribution policies in the 1980s reduced the area planted in peanuts and triggered a chain of secondary effects that influenced intra-household income distribution, land use patterns (particularly fertility-enhancing millet/peanut rotations), and labor contracting practices.

The initial impact of the peanut seed constraint was to push many who would have normally grown peanuts as a cash crop to grow cereals instead. This affected women and unmarried men more than household heads. The latter found it easier to qualify for credit or purchase seed (Gaye 1992a). Because returns to both land and labor tend to be lower and more unstable for cereal than peanut production, the incomes of women and unmarried men were negatively affected by the change in peanut seed policy.

There are also signs that the change in seed policy may be having an indirect impact on soil fertility, and hence on land productivity. Since the introduction of peanut cultivation, rotating crop land between peanuts and millet has been an important component of farmers' soil management strategy. The peanuts add nitrogen to the soil, while millet extracts large quantities of nitrogen. By rotating land between millet and peanuts, farmers are able to restore some nitrogen to the soil without using manure or fertilizer. Before the seed policy changed, there was a fairly even division of crop land between the two crops; peanuts were seldom less than 48, nor more than 52, percent of the total cultivated area. In 1985, the peanut share hit a low of 27 percent and did not exceed 42 percent until the devaluation of the CFA franc in January 1994. Although we are unaware of any study regarding how this reduction in peanut production may be affecting the nitrogen content of the soils, one would expect it to be contributing to the decline in soil fertility perceived by farmers and documented by numerous surveys during the 1980s and 1990s (see discussion below and in Kelly 1988; or Gaye 1992a).

Peanut seeds are also linked to the procurement of contract laborers (*navétanes*) in Senegal. Goetz (1993) shows that in the southeastern Peanut Basin the peanut seed constraint can translate into a labor constraint that reduces both peanut and cereal production. Traditionally, contract laborers were provided food, lodging, a plot of land, and peanut seed during the cropping season in exchange for their working in household fields about 50 to 60 percent of the time. In most cases, the contract laborers helped out on the household's communal cereal fields and the peanut fields of the household head. Goetz shows that contract laborers can increase household cereal production beyond the household's marginal increase in demand for cereal resulting from the labor contract. He concluded that the new seed policy could indirectly decrease the amount of cereal produced if it forced a household to cut back on contract laborers.

New seed distribution policies have also made more difficult the task of maintaining the quality of national seed stocks. Overall seed quality can only be maintained in the long-term if farmers replace their own seed with purchases of higher-quality, certified seed every few years. Although between 25 and 33 percent of Senegal's peanut seed (25-33,000 tons) should be replaced annually to maintain seed quality, from 1987 through 1990 the amount of certified seed declined, plummeting to less than one-sixth of the total plantings. Difficult access to credit and the higher prices of certified seed were the principal constraints. The price of unshelled, certified seed sold by SONAGRAINES (the seed unit of SONACOS) increased, because a 20-franc differential was established between producer output prices and seed prices, which had previously been identical.

Qualifying for credit was difficult. At the beginning, credit was restricted to village cooperatives that had reimbursed all their prior-year loans. Furthermore, farmers had to make down-payments equal to 35 percent of their loans. This rate was substantially higher than the down-payments required for fertilizer (15 percent) and traction equipment (20 percent), because the government wanted to encourage farmers to conserve their own seed. Over time, rules restricting credit to cooperatives were relaxed and small groups of producers were able to borrow by forming private associations (*groupements d'intérêt économique*, known as GIE). Although reimbursement continues to be a problem, private associations have a better track record than cooperatives (Gaye 1992a). The better performance may be linked to the fact that these private associations are formed by freely- associating individuals, whereas village cooperatives have little leverage regarding who becomes a member. Even with this adjustment, numerous rural surveys (Kelly 1988; Gaye 1992a; USAID 1993; and Gaye and Sene 1994) confirm that farmers' peanut production is constrained by an inability to obtain the desired quantities of seed. Although farmers decried the seed "shortage," SONAGRAINES was obliged to sell a substantial amount of certified seed at a loss in both 1988 and 1989; it went to SONACOS for oil processing (Sene 1994).

In 1990, the *Projet Autonome Semencier* (PAS) was established to lower seed costs by promoting a private-sector seed production industry that would compete with SONAGRAINES. The PAS got off to a modest but good start, with virtually 100 percent of credit reimbursed and sales more than doubling from 1990 to 1991. The rules of the game quickly changed, however, because SONAGRAINES sold larger and larger quantities of seed on credit. The problem was further exacerbated following the parliamentary elections in February 1993. In an effort to reward the rural sector for their support at election time, the government authorized SONAGRAINES to sell all of its seed stocks on credit with no down payment. PAS operators were forced to do likewise. The results were disastrous, with less than half of the credit being reimbursed.[22]

Table 1 shows the quantities of certified seed sold for cash and credit by both SONAGRAINES and the PAS since 1986. It also presents information on the reimbursement rates and the quantities of unpurchased certified seed that were sold below cost for oil processing. The table reveals that without substantial amounts of credit, the farmers' demand for certified seed is well below the recommended replacement rates. One also notes that the *Projet Autonome Semencier* had a much better credit reimbursement record than SONAGRAINES, until election politics forced it to sell its entire stock on credit.

Another potential problem in the peanut seed sector is the growing evidence that the quality of the SONAGRAINES security stock, from which the certified seed comes, is declining. A 1993 report cited by Sene (1994) claims that the share of certified seed in the overall security stock went from 36 percent in 1990/91 to 64 percent in 1991/92 and then down to 34 percent in 1992/93. In addition, lower quality "N2" seeds have been reclassified into higher-quality "N1" seeds, and "N1" seeds have been reclassified into higher-quality base seeds, further contributing to the overall deterioration in seed quality.

In sharp contrast to peanut seed, the seed supply for cereals and cotton does not pose a serious problem because it represents a relatively small cost of production. Cotton seed is distributed free by the cotton parastatal to farmers entering into cotton production contracts.[23] Millet and sorghum seed are usually retained by farmers, who reserve the best seed from the prior harvest. As only 4 to 10 kilograms of millet/sorghum seed are needed per hectare, and the cost is low (65

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[22] The situation became even more complicated when SONACOS decided to cover the 1993/94 SONAGRAINES credit losses by withholding the 30 CFA francs/kilogram price increase owed to the farmers following the January 1994 devaluation. By July 1994, public opinion pressure forced SONACOS to abandon the policy, as it had been applied unilaterally to all farmers, including those who had already reimbursed their credit!

[23] It is difficult to be precise about who pays what in the cotton sector, because some inputs continued to be subsidized into the early 1990s (fertilizer, for example), and farmers did not receive the world market price for cotton.

to 100 CFA francs per kilogram), farmers do not face a cereal seed constraint. Maize seed is a bit more costly, but farmers who produce maize tend to be located in cotton production zones where they can obtain maize seed and fertilizer on credit through the cotton parastatal. The more important issues with respect to cereal seed are the need to (1) develop high-yield, drought-resistant varieties, and (2) encourage the use of certified seed. These are two approaches to cereal intensification that have not advanced very far in Senegal.

Table 1. Sales Activity for Certified Peanut Seed: 1987 to 1993

	87/88	88/89	89/90	90/91	91/92	92/93	93/94
PAS							
Cash Sales					1,200	2,800	
Credit Sales						700	4,321
Total Sales					1,200	3,500	4,321
Amount Processed							1,746
Percent of Credit Reimbursed					100	83.2	44.3
SONAGRAINES							
Cash Sales	31,723	21,572	13,397	12,356	9,816	3,905	
Credit Sales					12,578	16,770	35,865
Total Sales	31,723	21,572	13,397	12,356	22,394	20,675	35,865
Amount Processed		14,650	8,270		4,649	6,000	1,119
Percent of Credit Reimbursed					80.5	37.02	34.5
COMBINED SALES OF SONAGRAINES AND PAS	31,723	21,572	13,397	12,356	23,594	24,175	40,186

Source: Prepared from information presented in Sene (1994).
Note: Amounts are in metric tons.

One must conclude from the preceding discussion that despite significant changes in the peanut seed policy since 1985, problems remain unresolved with respect to both the quality and the quantity of seed. It would probably not be an exaggeration to say that in the rainfed production zones of Senegal, peanut seed is not just *the key seed* issue, but *the key agricultural* issue as well.

3.5.3. Research and Extension Programs

The agricultural policy focus during the 1980s and early 1990s was on input and output marketing reforms; nevertheless, these reforms had repercussions on research and extension programs.

Extension. In large part because extension activities had been carried out by the inefficient parastatals that fell into disfavor during the era of structural adjustment, farmers in the Peanut Basin have had little contact with extension services during the 1980s and early 1990s. Although SODEVA, the primary source of extension services in the Peanut Basin, still exists, its resources are extremely limited and devoted primarily to expanding maize production in the more humid parts of this traditional millet/sorghum area. Extension activities were tied to maize production contracts that offered participating farmers seed and fertilizer on a credit basis, as well as technical advice. Contracts stipulated that all production be sold back to SODEVA so that input costs could be deducted from the payments the farmers received. Unfortunately, SODEVA had difficulty recovering credit reimbursements because farmers were able to market the maize through parallel channels.

The confectionery peanut program expanded considerably during the 1980s, providing both inputs and technical advice to contract farmers. Although the responsibility for the program has been recently transferred to the private sector, it was in the hands of a parastatal during the 1980s and early 1990s. Debt recovery has been more successful for confectionery peanuts than for maize because there is no parallel market offering prices that compete with official prices. Despite the expansion in the program, few farmers in the Peanut Basin participate because the crop cannot be grown in drier zones.

In the early 1990s, the World Bank began funding a "Training and Visit" program. It is difficult to judge its impact at present because field activities did not get underway immediately. There are also numerous, private voluntary organizations working in selected areas of the Peanut Basin on projects that provide some technical and financial support to farmers. Several of these smaller projects are concentrating on research and extension of improved management practices rather than promotion of expensive, purchased inputs such as fertilizer and pesticides.

Research. The economic crisis that began in the late 1970s woke Senegal's agricultural research establishment to the fact that more attention needed to be given to socioeconomic and policy factors when designing research programs. It was also acknowledged that researchers needed to be more involved in on-farm trials and adaptive research.

In the early 1980s, ISRA created two new analysis units, one to deal with policy issues and another to deal with technology development and transfer. The policy unit worked on cereal marketing issues, assisting the CSA in their efforts to design a market information system, and identifying leverage points where changes in the rules and regulations concerning transportation and commercialization of cereals could reduce transactions costs. There was also a program to analyze input marketing policies (particularly the *retenue* tax). A farming systems research program was created to better address technology development and transfer issues. USAID provided support to these efforts and also funded graduate level training in the United States for about 25 Senegalese social and technical scientists.

Despite the efforts funded by USAID, investments in both research and extension have not kept up with needs in recent years. When structural adjustment cutbacks began, there was a general feeling that farmers in the Peanut Basin already knew how to grow peanuts, so research and extension efforts could be considerably reduced and redirected toward cereal production.[24] This conclusion is not supported by the empirical results presented in the next chapter, nor by much of the literature on the magnitude of extension efforts needed to encourage adoption of improved natural resource management practices. As noted in Chapter 1, the physical, social, economic, and policy environments in which agricultural production is carried out do not remain static over time. As a result, a constant flow of investment in both research and extension is required to ensure continuity in the development of new, adaptive technologies and management practices.

3.6. The Relationship Between Policy and Productivity

The fact that agricultural policy changes in Senegal have been numerous, and often implemented in tandem with broader policy measures, makes it difficult to establish links between specific policies and productivity outcomes. This is particularly true for the 1980s and 1990s because structural adjustment programs have simultaneously affected all sectors of the economy. In agriculture, the task is further complicated by the difficulty of separating the rainfall effect from the policy effects. Although it is not prudent to draw conclusions about the impact of particular policies on productivity, a look at the aggregate trends from 1960 to the present does suggest that Senegal has not yet hit on the appropriate combination of policies that are required for sustained growth in cropping productivity.

Table 2 summarizes peanut and millet/sorghum trends in terms of the area planted, production, and yields by decades, from 1960 through 1994. Average peanut yields during the 1980s surpassed those of the 1960s and 1970s by a small margin, but the area planted and total production were lower. Cereals exhibit a more consistent pattern, with small increases in the average values of most indicators from one decade to the next. For the 35-year period, however, productivity has been virtually stagnant. There has been a slight decline of about 1 percent per

[24] This attitude was expressed in the New Agricultural Policy as well as in other government and donor documents.

year in all three peanut measures, and an annual increase of about 1 percent for the cereal measures.

Looking at the physical measures of productivity presents only half the story—one must also look at the trends in the real value of agricultural production over time and what they imply about per capita growth in rural incomes.

Table 2. Productivity Trends in Senegal: 1960 to 1994

	Peanuts				Millet/ Sorghum			Rain	Population
Period Covered	Average Area Planted (1000 ha.)	Average Production (1000 tons)	Average Yield (kg/ha.) Oil	Confect.	Average Area Planted (1000 ha.)	Average Production (1000 tons)	Average Yield (kg/ha.)	Average for Entire Country (mm/year)	Millions of People at Beginning of Decade Shown
1960-69	1,066	932	877	---	974	487	499	762	3.187
1970-79	1,139	875	773	782	998	540	536	640	4.158
1980-89	917	778	883	802	1,064	644	598	587	5.538
1990-94	888	677	760	963	1,019	663	654	not available	7.404
Annual Change from 1960-93 (%)	-1	-1	0	1	0	1	1	-1	3

Source: Calculated from Ministry of Agriculture data reported in annual reports entitled "Resultats Definitifs de la Campagne Agricole"; data for 1960-1989 are available in USAID 1991; population data are from the World Bank time series available on CD ROM.

Figure 1 shows the trends in the real value per capita for Senegalese peanut and millet/sorghum production from 1960 through 1992.[25] In the absence of survey data on farm incomes for this period, the real value of crop production represents the best proxy for farm incomes that we can find.[26] The relatively stagnant trends in physical measures of productivity (Table 2, page 32) give way to strongly negative trends when the output is valued in inflation-adjusted income per capita (Figure 1). On average, the per capita, real gross value of peanut and cereal production declined about 3 percent annually; growth in population and inflation—combined with declining peanut output—overpowered the small gain in cereal productivity noted in Table 2.

There have been only five years since independence when the real, per capita gross value of peanut and cereal production exceeded that of 1960; three of those cases were in the early 1960s and the other two were in the mid-1970s. If we limit the comparison to only peanut production, we find just three years (1961, 1965, and 1975) when the real, per capita value of peanut production exceeded the 1960 level. Figure 1 also shows that there was substantial interannual volatility in crop income during the period, more so in the 1970s than in the 1960s or the 1980s.

Realizing that the real income from peanut production declined after 1965 adds to our understanding of the rise in credit defaults. The increase in the variability of real income also suggests a need for some type of crop insurance or income stabilization program. The absence of such programs, combined with a credit program that did not provide for renegotiating payment terms following a poor harvest, appears to have turned the credit program into a *de facto* insurance program. Had policy analysts paid more attention to trends in real farm income, rather than relying so heavily on such indicators as growth in aggregate production or purchases of modern inputs, the Government of Senegal may have been alerted early enough to the crisis of the late 1970s to have diminished its impact.

A review of government documents from 1960 to the mid-1980s suggests that the failure to monitor trends in real cropping income was symptomatic of a broader phenomenon that ignored economic trends and analysis in general. A few examples illustrate the point:[27]

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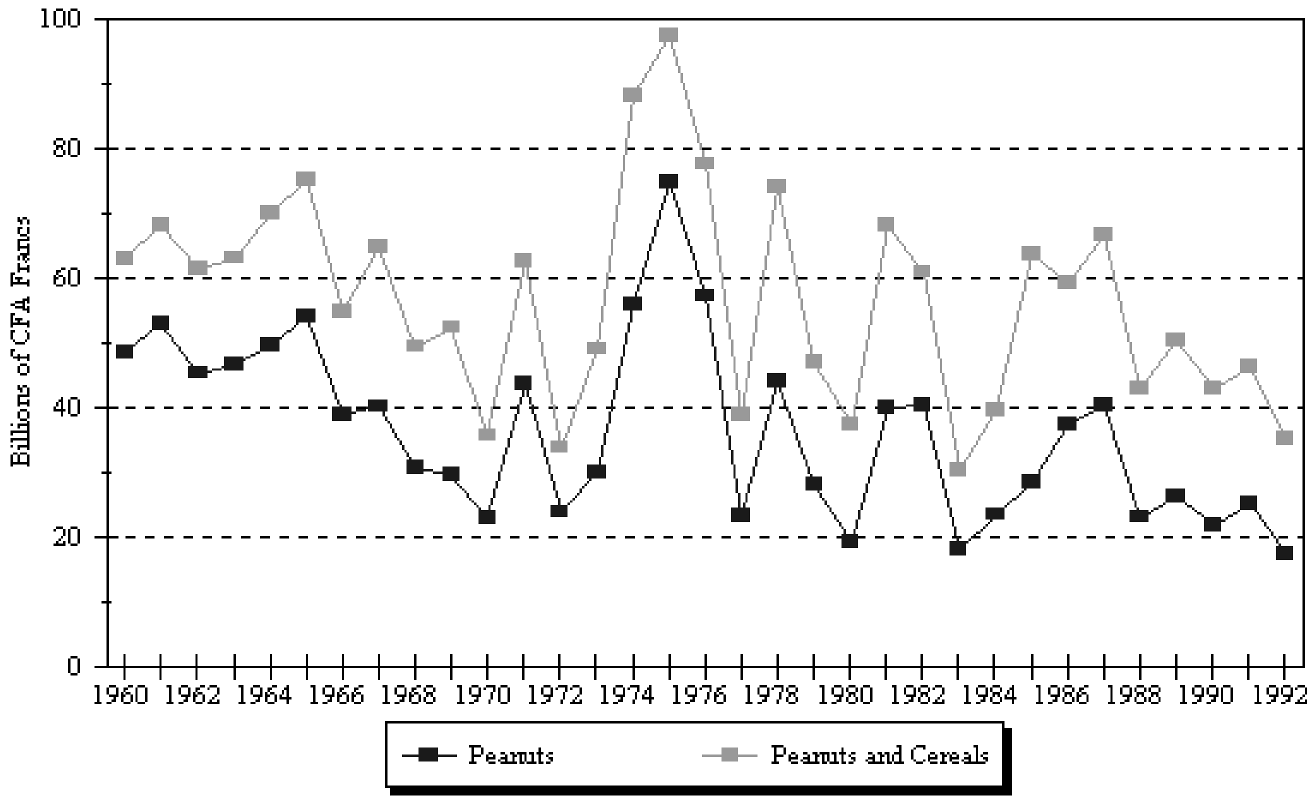
[25] Real values are obtained using a GDP deflator (base year = 1978). Population figures are our "guesstimate" of the Peanut Basin population as a share of the total Senegalese population reported in the World Bank's CD ROM data base. We assume that the Peanut Basin represented 60 percent of the total population in 1960, dropping to 44 percent in 1992. The analysis stops in 1992 to avoid the difficulty of drawing any conclusions about the impact of the January 1994 devaluation (which affected producer prices for the 1993 harvest).

[26] Using the value of gross output as a proxy for farm income is not ideal when there are changes in the relative prices of key inputs and outputs. As illustrated by the data in Appendix 1, there were some changes in the peanut/fertilizer price ratios during the 33 years covered, with the biggest changes occurring in the late 1980s. As inputs became relatively more expensive, the decline in real income was actually somewhat greater than that indicated in Figure 1.

[27] Comments about the lack of economic analysis are based on a thorough review of extension, research, and policy literature for Senegal that is presented in Kelly (1988).

Figure 1. Trends in the Real Value of Peanut and Millet Production: 1960-1992



(1) Researchers gave low priority to economic criteria when recommending fertilizer products;
(2) Extension services encouraged farmers to increase fertilizer and equipment orders with little analysis of their debt-carrying capacity and no thought to the relative returns of alternative investments on their farms;
(3) Input manufacturers forced ONCAD and farmers to indicate input needs for subsequent seasons prior to knowing the current year's harvest and before prices for the next year had been announced;
(4) The cooperatives, ONCAD, and the BNDS kept such poor records that rigorous financial or economic analysis was impossible, and fraud was encouraged; and
(5) Tax, subsidy, and price policies were so complex and intertwined that it was difficult to trace the profits and losses for different sectors, and for participants in each sector.

This lack of financial and economic analysis fostered a false sense of security during the 1960s and 1970s. Once the crisis was recognized in the late 1970s, there was still a tendency to focus on the institutional inadequacies of the parastatals; most analysts ignored the equally important issue of how the pursuit of the "technological imperative" associated with increased peanut production had affected farm incomes, and how it would likely affect them in the future. Since the mid-1980s, considerably more attention has been given to economic indicators, yet there is growing evidence that there has not been an adequate balance between the attention given to improving budgetary and fiscal indicators of macroeconomic performance and improving productivity and incomes in the agricultural sector. Recent research on economic growth multipliers in Africa confirms that there is considerable potential for stimulating demand-led economic growth by increasing agricultural incomes (Delgado et al. 1994), yet our analysis of productivity trends suggests that the current agricultural policies are not likely to tap this potential source of economic growth.

Although it is difficult to quantify the impact that selected policies have had on agricultural productivity *per se*, some links between policy changes and input use patterns can be established.[28] A combination of aggregate data on input use and surveys that document farmers' behavioral responses to particular policies permits us to draw a number of conclusions about the impact of the more dramatic policy changes—i.e., those implemented during the 1980s and 1990s.

Despite the abrupt halt in purchases of new animal traction equipment following the end of *Programme Agricole* credit in 1980, survey evidence shows that farmers are only now beginning to consider their traction equipment a constraint to improving their productivity. Apparently, changes in animal traction distribution and credit policies have not had much influence on productivity to date, but a continuation of current policies is likely to have a negative impact in the future.

[28] The underlying hypothesis of this discussion is that policies which discourage use of productivity-enhancing inputs also discourage increases in productivity.

The impact of declining fertilizer use is difficult to assess with aggregate data, given the low application rates prevailing prior to changes in fertilizer credit and price policies. Nevertheless, farmers' complaints about declining soil fertility and yields suggest that land productivity is declining—at least for those who can no longer maintain previous levels of fertilizer use.

Of all the input distribution and credit policy changes implemented during the structural adjustment era, the one with the most widespread and potentially negative impact on aggregate production in the Peanut Basin is the change in peanut seed policy. The 1986/87 production season, which marked the beginning of the new peanut seed policies, was a big disappointment for the peanut sector. The total area planted in peanuts was just under 600,000 hectares—the average area during the 1970s had been more than a million hectares. Fortunately, good weather provided average yields of almost 1000 kilograms per hectare, substantially more than the 750 kilograms per hectare averaged during the preceding 15 years. Nevertheless, the total harvest was only 590,000 tons, substantially lower than the average of 825,000 tons between 1970 and 1985. Fortunately, the substantial price increase introduced in 1985 (from 60 to 90 CFA francs/kilogram) provided farmers with an increase in gross peanut income despite the much lower aggregate production.

Although aggregate peanut production made a small comeback in the late 1980s, output and area cultivated up to the 1994 devaluation remained below levels prevailing in the 1960s and 1970s; hence, increased yields did not offset reductions in area planted. Unfortunately, the real gross value of peanut production, adjusted for inflation, fell in the late 1980s because declining world prices for peanut oil forced the government to reduce the producer price of peanuts in 1988.

While the 1980 changes in peanut seed policy have had a negative impact on peanut production, they appear to have had a positive net effect on aggregate cereal production. When the new peanut seed policy was implemented in 1985/86, the area planted in millet hit an all-time high—1.34 million hectares. Between 1960 and 1985, the hectares planted in millet exceeded 1 million hectares only 11 times; a level of 1.2 million had never been attained before. Since 1985/86, the area planted in millet fell below 1 million hectares only once, and the average yields remained above 600 kilograms per hectare through the end of the decade. The overall 35-year annual growth rate in millet/sorghum yields is mildly positive (1 percent). A comparison of the average yields over the last three decades shows small advances from 499 kilograms per hectare in the 1960s to 536 kilograms in the 1970s, and 598 kilograms in the 1980s. It is difficult to credit this small increase in yields during the 1980s to anything but good luck with weather and pests, since use of productivity-enhancing inputs (fertilizer, for example) remained fairly constant, at levels substantially below those prevailing in the 1970s.

The historical evidence reviewed in this chapter clearly supports the DPDA observation that: "The agricultural policies pursued to date ... have not produced the anticipated solutions for a sustainable renewal of agricultural production" (Government of Senegal, Ministry of Agriculture 1994, page 4). Although the objectives of structural adjustment reforms affecting the agricultural sector (reducing direct government involvement in agriculture and financial outlays for agricultural subsidies) make sense from a macroeconomic perspective, our historical review of Senegalese agricultural policy illustrates how very difficult it is to rapidly implement such radical changes, given the ingrained attitudes about "unproductive middlemen" and the lack of private sector businesses with extensive experience in the agricultural sector. Furthermore, the priority given to macroeconomic indicators made it difficult to develop policy measures that could simultaneously improve fiscal balances and maintain growth in real farm income. The poor access to agricultural credit and the lack of sustained growth in real farm income have made it difficult for farmers to mobilize the cash needed to invest in productivity-enhancing inputs. Our review of the aggregate data on crop production and the gross value of output shows that although some improvements have been realized, aggregate production and real cropping income have been virtually stagnant during the last 30 years.

Drawing broad conclusions about productivity trends from the aggregate numbers presented in this chapter is, however, fraught with problems. Growth rates are notoriously sensitive to the choice of beginning and ending years. Using the gross value of production as a proxy for farm income ignores the potential impact of changes in input prices and use patterns, as well as the fact that most farmers have both cropping and noncropping income. The real picture of what is happening to agricultural productivity in the Senegalese Peanut Basin lies behind the aggregate production and gross value numbers—it is found in a careful analysis of household data on current input use and net income patterns.

We turn from this discussion of input policy changes and their impact on aggregate production trends to a more in-depth picture of exactly what farmers are doing to survive, and the impact of this behavior on input use patterns, net cropping income, and selected measures of household crop productivity.

4. EMPIRICAL ANALYSIS OF INPUT/OUTPUT RELATIONSHIPS AND ECONOMIC EFFICIENCY

In this chapter we use IFPRI/ISRA farm survey data to describe typical crop production patterns that have emerged during the structural adjustment period. We use production functions to examine the agronomic (input/output) and economic (cost/returns) relationships between the levels of inputs used and the output obtained. In the next chapter we look at how factors such as household characteristics, access to credit, and nonfarm income influence access to inputs and productivity.

Using household data for the 1989/90 cropping season, this chapter:

(1) Describes the geographic area covered and the data used;
(2) Describes input use patterns and measures of both physical and financial productivity for the principal crops;
(3) Reports the results of production function estimation, including marginal products calculated from the models;
(4) Evaluates the relationship between marginal value products and input prices to identify input constraints;
(5) Discusses the implications for growth in productivity of input constraints and differences in economic returns between crops and across zones.

The analysis permits us to go beneath the surface of the aggregate trends data presented in the last chapter, thus gaining a better understanding of why productivity is not increasing more rapidly.

4.1. Geographic Coverage, Sample Selection, and Survey Methods

4.1.1. Location and Characteristics of Agroclimatic Zones Covered

This empirical work concerns the Senegalese Peanut Basin, covering the administrative regions of Louga, Thies, Diourbel, Fatick, and Kaolack. The Peanut Basin is comprised of four agroclimatic zones: north, center, southwest, and southeast. The zones are differentiated by their amount of rainfall, the length of their rainy season, their average temperatures, and their soil quality.[29] In general, each of these factors increases from the northwest to the southeast (see Table 3). The north has a typically Sahelian climate, with 300 to 500 mm of rainfall during a season which lasts three to four months. The climate in the center, southwest, and southeast can be loosely classified as Sudanian, with rainfall measuring 500 to 1000 mm per year and a rainy season that lasts five to six months. The level of rainfall during the 1989/90 cropping season was typical for each zone, except Niakhar in the center-west where it exceeded zone norms. Rainfall distribution was

[29] The agroclimatic zones used in this study are based on work by Martin (1988).

Table 3. Agro-Ecological and Demographic Characteristics of Study Zones

Characteristic	North	Center-west	Center	Southwest	Southeast
Typical rainfall (mm/yr)	300 to 500	500 to 700	500 to 700	700 to 1000	700 to 1000
1988/89 rainfall (mm/yr)	449	644	625	669	810
1989/90 rainfall (mm/yr)	not avail.	802	556	717	736
Length of rainy season (months)	3-4	4-5	4-5	5	6
Soil characteristics	sandy, ferric, unleached	sandy, ferric, leached	sandy, ferric, leached	sandy, ferric, leached	rocky plateau, some clay
Vegetation	open steppes with occasional trees	sparsely wooded savanna	sparsely wooded savanna	wooded savanna	more densely wooded savanna
Population density (persons/sq. km.)					
rural only	26	52	52	59	31
rural and urban	32	67	67	85	32
Infrastructure: from poorest (1) to best (5)	2	3	4	5	1

Source: Diallo (1989) for typical rainfall, length of rainy season, soil, and vegetation; Kelly et al. (1994) for population densities; Diagne (1994) for 1988 and 1989 rainfall.
Note: The ranking for infrastructure is based on researchers' perceptions, taking into account roads, railroads, markets, water, and public services (education, health care).

favorable in all zones but the north, which experienced a long dry spell shortly after planting.[30] Given the combination of good levels and distribution of rainfall, the 1989/90 harvest represents somewhat better than average cropping outcomes, but followed a poor harvest in 1988.

Although the clay content of soils increases, and soils become more leached as one moves from the north to the south, soils throughout the Peanut Basin are considered good for peanut production.[31]

Population density and infrastructure vary across the zones. The densest settlements are in the western part of the central Peanut Basin and the southwestern basin, while the sparsest are in the southeastern and northern parts of the Peanut Basin. Households in all zones but the north claim that they face some land constraints, but the problem is most acute in the center-west and southwest (Diagana et al. 1990). Roads, railroads, and markets were built to service the peanut sector; therefore, infrastructure is most developed near where the peanut processing facilities were built (Dakar, Diourbel, and Kaolack).

Recent thinking about how to improve agricultural productivity in Africa—particularly in zones considered to have lower potential due to fragile soils and low, unreliable rainfall—emphasizes the importance of developing location-specific technologies and policies. Location-specific knowledge is particularly important when developing and extending natural resource management practices that often have to be carefully designed to fit into already complex cropping systems (Byerlee [1993]; or Hazell [1995], for example). Recognizing that much of the Senegalese Peanut Basin falls into the category of lower potential, fragile agricultural environments, we consistently report all results for both the overall sample and for each agroclimatic zone. Although the zone-level detail may be tedious at times, we believe the quality of future research and policy design depends on our ability to identify and respond to cross-zone similarities and differences. To the extent possible, we keep the zone-level detail in the tables, discussing only the most important cross-zone findings in the text.

4.1.2. Sample Selection

The results described in Chapters 5 - 7 are based on data collected from a sample of 142 households located in the four agroclimatic zones described above.[32] The data were collected during a two-year survey, conducted collaboratively by the International Food Policy Research

[30] The timing of the rain can be as important as the level. The best crop response is usually obtained when there is an effective rain at least every ten days. This was generally the case during the 1989/90 season.

[31] Soil information and climatic classifications are based on Diallo (1989).

[32] Due to problems of missing data for certain variables, some of the analyses are based on fewer than 142 households; in such cases, the actual number of observations is reported.

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Institute (IFPRI) and the *Institut Sénégalais de Recherches Agricoles* (ISRA).[33] When appropriate, we supplemented these results with information from other recent socioeconomic and agronomic studies conducted in the Peanut Basin.

Households for the IFPRI/ISRA survey were selected randomly after a purposive selection of study zones and villages.[34] The sample included one study zone for each of the agroclimatic zones in the Peanut Basin but the central Peanut Basin, which was represented by two study zones because of its size, ethnic diversity, and differences in population density. The original sample in each study zone included 36 households spread equally across three villages (12 households per village). Due to attrition and missing data, most analyses for the present study are based on about 30 households per study zone.

As the sample size for each study zone was not proportional to the population living in the zone, all descriptive statistics for the overall sample were adjusted using appropriate weights. The within-zone sampling procedure was also nonproportional, since one-third of the households in each zone were purposively selected from market villages. This permits analysis of the impact that market infrastructure has on household production and consumption behavior. Because only 10 to 20 percent of the rural population actually live in market villages, all zone-level results were adjusted using appropriate weights. The map in Figure 2 delineates the four agroclimatic zones and their respective study zones. On the map, study zones are referred to using the name of the market village selected for each zone.

Table 4 summarizes information on the sample size and its relationship to the population represented. The IFPRI/ISRA survey zones used for these analyses represent approximately two million people, or 47 percent of Senegal's rural population. The center zone represents almost half of these two million people, thus its weight in calculating the overall sample averages is considerably larger than that of the other survey zones.

The overall sample size of 142 households is small, given the diversity of the household characteristics and crop production patterns exhibited in the data. Because the amount of data presented in the summary tables is already substantial, we do not report standard deviations or coefficients of variation for the descriptive statistics.[35] As is normal for this type of data, these measures of dispersion are large. This is true for the average values calculated at the zone-level, as well as for the overall sample averages. In the tables, we report results of the various tests used to identify statistically significant differences across the zones. In many cases, the reader will

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Figure 2. Agroclimatic and Study Zones Covered by Analyses

Note: Sagatta represents the north, Niakhar the center-west, Colobane the center, Passy the southwest, and Dyoli the southeast.

Table 4. Population and Sample Sizes for Study Zones

Characteristic	Overall Sample		North		Center-west		Center		Southwest		Southeast	
	PN	M/S	PN	M/S	PN	M/S	PN	M/S	PN	M/S	PN	M/S
Number of households	140	142	26	26	23	25	32	31	25	26	34	34
Percent of sample households in market villages			19	23	26	28	31	29	28	27	32	32
Rural population represented by sample	2,150,972		275,335		373,312		958,819		399,277		144,229	
Percent of population in market villages			14		21		17		14		15	

Source: Calculated from IFPRI/ISRA data for 1989/90 and Senegalese census data.
Notes: PN = peanut sample; M/S = millet/sorghum sample: As a few households did not grow both cereals and peanuts, the sample size differs for the crop by crop analyses presented later in the report. The number of households producing each crop are shown on the "number of households" and the "percent of households in market villages" lines.

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and the fact that the within-zone variability is often as great, or greater than, the across-zone variability. This is not an uncommon problem in African surveys where the costs of surveying dispersed populations in areas with poor transportation and communication infrastructures tend to limit sample size (see Kelly et al. 1995).

4.1.3. Survey Methods

The crop production analysis uses plot-level input/output data for the 1989/90 season, plus demographic, income, food consumption, and asset data collected for the same households between October 1988 and December 1990.[36] Input quantities for seed, labor, and chemicals are based on repeated farmer recall over consecutive two-week periods. Project personnel measured the area of each cultivated field using compasses and hand-held calculators. The data used do not include information on the quality of such inputs as soil and labor.

Output is based on farmers' reports of the number of standard units harvested (usually sacks for peanuts and bundles for cereals). The threshed grain from a sample of three cereal bundles was weighed for each crop/household combination. The total household production was obtained by multiplying the number of reported harvest units by the household's average unit weight.

Peanuts, a cash crop, tend to be marketed in relatively standard sacks. For each village, the average weight of a sack was determined by weighing ten sacks selected at random from the peanut marketing point used by the village.[37]

Cost data were obtained for all purchased inputs and imputed from survey price data for other inputs (seed stocked from the previous harvest, for example). Output was valued at the average, annual producer price obtained from transactions made by sample households.

The income data were aggregated by harvest year (HY88 and HY89). HY88 income includes cropping income (the total value of production minus the variable costs) from the 1988 harvest, plus all noncropping income earned from the beginning of the harvest (1 October 1988) through the end of the next cropping season (30 September 1989). As most noncropping income is earned during the dry season (November through April), HY88 income is considered to be an exogenous, predetermined variable at planting time (May/June 1989). Agricultural activities for 1989 continued through the millet harvest in early October and the peanut harvest in December. The official marketing campaign for peanuts continued through March 1990.

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[36] Although some crop production data are available for the 1990/91 season, the IFPRI/ISRA survey did not collect field measurement data for the second year of the survey, making it impractical to do "productivity" analyses for both years.

[37] Cereal bundles produced from 5 to 20 kilograms of threshed grain. Interviewers carried small scales that could weigh up to 25 kilograms. The larger size of the peanut sacks (50-60 kilograms) made it impractical for interviewers to weigh them, hence the decision to weigh a random selection of sacks at the peanut marketing points where large-capacity scales were available.

4.2. Characteristics of Sample Households

Table 5 presents the average values for variables reflecting farm and family size, household assets, level of food security, and general economic well-being for the overall sample and each survey zone. The weighted average family size for the entire sample is 8 adult equivalents. The average area cultivated is 8.5 hectares, approximately 1 hectare per adult equivalent.

Although households own a wide range of animal traction equipment (primarily horses, seeders, and hoes), the number of seeders per hectare provides a simple measure of animal traction capacity. The sample average is 1 seeder for every 5 hectares cultivated. This is within the recommended norms, and is also considerably higher than elsewhere in West Africa.

The value of livestock holdings may be thought of as the rural households' savings account—a place to park extra cash so that it appreciates in value without severely compromising the family's liquidity. The estimated value of the livestock holdings per household was close to 300,000 CFA francs at the beginning of the 1989/90 cropping season—this is approximately one year's income for the average household.[38]

A common measure of food security in rural areas is the share of cereal needs produced on the farm. The sample households produced about 50 percent of their cereal needs in HY88 (a fairly bad harvest year due to drought and locust attacks).

Rural household well-being and their financial capacity to invest in crop production depends on the household's total income from cropping and noncropping activities, as well as on their access to agricultural credit. Noncropping income accounted for 45 percent of total household income in HY88. This share was somewhat higher than what would be found in a typical year, as cropping income was unusually low, particularly for zones located in the north and the center-west. During the 1989/90 cropping season, about 25 percent of the sampled households had access to agricultural credit. Spread across the entire sample, the average amount received per household was only 4,500 CFA francs per hectare—about enough credit to purchase peanut seed for one-quarter of a hectare.

Although there are differences in the average values of these variables across zones, there are only three variables that exhibit statistically significant differences: hectares cultivated per adult equivalent, cereal sufficiency ratios for 1988/89, and the share of a household's total income earned from noncropping activities.[39] The center and southeast cultivate more land per adult equivalent than the other zones. The north, which received the brunt of the 1988 locust attack,

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[38] The average HY88 income per adult equivalent was about 37,000 CFA francs; the average household size was 8 adult equivalents; 37,000 * 8 = 296,000 CFA francs average annual household income. Because the 1988 harvest was poor, many households sold animals to purchase food before the livestock census was conducted. This suggests that following a better harvest season, the value of their "bank accounts" would be higher.

[39] Statistically significant differences were determined using analysis of variance and the relatively conservative Scheffe test at .05 probability.

Table 5. Household Characteristics: Average Values for Harvest Year 1988

Characteristic	Overall Sample	North	Center-west	Center	South-west	South-east	Differences
FARM/FAMILY SIZE							
Adult-equivalent (AE)	8.23	8.09	6.94	8.15	8.84	10.01	
Hectares (ha) cultivated	8.49	5.31	5.03	10.37	6.98	13.21	
ASSETS							
Number of seeders/ha.	.22	.23	.25	.23	.20	.14	
Livestock value (CFA francs)	319,000	370,000	469,000	234,000	296,000	419,000	
FOOD SECURITY							
Cereal sufficiency ratio for 1988/89	.50	.15	.51	.49	.62	.85	N ≠ all others SE ≠ all others
ECONOMIC VARIABLES							
Income per AE prior year (CFA francs)	37,440	41,140	27,450	32,780	47,980	51,970	
Percent of noncrop income prior year	45	74	45	40	43	30	N ≠ all others
Percent of households receiving credit	25	11	2	43	21	23	

Source: Calculated from IFPRI/ISRA data (1989/90) for 140 households.
Notes: Harvest year 1988 covers October 1, 1988, through September 30, 1989; hence these are average values prevailing when planting and input acquisition decisions were made in May/June 1989. Means for the overall sample are weighted averages of zone means; zone means are weighted to correct for oversampling of households in market villages. Zone differences were tested with a Scheffe test; when the "differences"column is empty, the Scheffe test was not significant at the .05 level of probability.

had the lowest cereal sufficiency ratio, while the southeast, with the highest 1988 rainfall in the survey, had the highest. The drought-prone north had a much higher share of noncropping income than all other zones (see Table 5, page 46, for details).

4.3. Input/Output Relationships and Efficiency

We separately examine each of the two principal crops grown in the Peanut Basin—peanuts and millet/sorghum—looking at the average levels of input use, productivity indicators, and measures of economic efficiency. In each case, we present weighted averages for the overall sample and each zone.

4.3.1. Peanuts

The average levels of inputs and outputs were calculated using household-level observations. In other words, all inputs used by the household for a particular crop were summed across the plots they farm and the total was divided by the total hectares planted for that crop.[40]

Input use patterns for peanuts. Table 6 summarizes the input use patterns for peanuts. The average area cultivated in peanuts per household is four hectares. The recommended peanut seeding density is 60 kilograms per hectare for the longer-cycle varieties used in the two southern zones, and 100 for the shorter-cycle varieties used in the north and center. The average seeding density across all zones is 110 kilograms per hectare. None of the zone-level average seeding rates is lower than 70 kilograms per hectare, even in the southern zones, where a rate of 60 kilograms is recommended. The average density of 150 kilograms per hectare in the center is substantially higher than the recommended levels, and is significantly higher than the densities for the other zones.

An application of fungicide to peanut seed before planting is highly recommended to conserve seed quality. The center-west and southwest use no fungicide on their peanut seed, while the others spend about 250 CFA francs per hectare on the product. This application rate is below the recommended levels, which would cost about 3000 CFA francs per hectare.[41]

As noted in Chapter 4, farmers in the Peanut Basin used substantial amounts of fertilizer on both peanuts and millet prior to changes in price and distribution policies in the early 1980s. Despite high rates of adoption in the past, not a single farmer in the sample used fertilizer on industrial

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[40] A Scheffe test (.05 level of significance) was used to determine whether or not differences between the zones were statistically significant.

[41] The recommended expenditure of 3000 CFA francs comes from Martin (1988). A high average expenditure on purchased inputs in the north results from two households that participated in a special nematocide eradication program, with one-time applications of expensive chemical treatments. The more typical fungicide expenditure for the north is similar to that found in the other zones.

Table 6. Input Use Patterns for Peanut Production by Zone

Inputs	Overall Sample	North	Center-west	Center	South-west	South-east	Differences
Land							
Average number of peanut hectares	4.01	1.98	1.93	5.67	2.39	5.89	
Average peanut hectares per AE	.49	.24	.29	.70	.27	.59	
Seed							
Kilograms of peanuts per hectare	110	72	82	150	99	75	C≠N,SE
Fungicide for seeds							
Cost/hectare (CFA francs)	275	1,177	none	249	none	223	
Soil ammendments							
Total number of fields manured	2	0	0	2	0	0	
Total number of fields fertilized	0	0	0	0	0	0	
Labor							
Household labor (hours/hectare)	359	344	458	274	390	531	SE≠N,C
Hired labor (hours/hectare)	10	4	0	19	2	14	
Invitation labor (hours/hectare)	7	6	1	1	1	59	SE≠OTHERS
Animal traction							
Household equipment (hours/hectare)	81	85	78	74	106	66	

Source: Calculated from IFPRI/ISRA data (1989/90).
Notes: Means for the overall sample are weighted averages of zone means; zone means are weighted to correct for oversampling of households in market villages. Zone differences were tested with a Scheffe test; when the "differences" number column is empty, the Scheffe test was not significant at the .05 level of probability.

peanuts produced for oil processing during the 1989/90 cropping season.[42] Manure is not traditionally used on peanuts because it increases pest problems; nevertheless, two farms did use some manure on their peanuts in an attempt to improve soil quality.

The amount of household labor used for peanut production averages 360 hours per hectare. The amount of labor used in the southeast is significantly higher than that used in the north and center. The heavier soils found in the southeast, and a somewhat lower ratio of animal traction equipment to hectares cultivated, are the most likely factors raising the amount of labor used in that zone.

Although most of the labor inputs are supplied by household members, there is a small amount of hired and "invitation" labor used. Invitation labor consists of friends coming to help out for a particular task and receiving in-kind payments, such as a meal, cigarettes, cola nuts, or tea. On average, only ten hours of hired labor are used per hectare—less than 3 percent of the total labor.[43] Inter-zone differences are not significant. Invitation labor (inter-household exchanges) is most popular in the southeast, where it accounts for 10 percent of the total labor inputs, versus less than 1 percent in the other zones.

The most important aspects of these input use patterns for understanding current agricultural productivity are:

(1) absence of fertilizer;
(2) absence of fungicide in two zones;
(3) peanut seeding densities that are higher than recommended rates;
(4) statistically significant inter-zone differences in peanut seeding densities and amount of labor (both household and invitational) used per hectare; and
(5) no statistically significant inter-zone differences in the area planted in peanuts, quantities of fertilizer and manure used, or hours of animal traction used.

As noted earlier, the lack of statistically significant cross-zone differences in the levels of some inputs occurs because the variation among households within each zone is as great, or greater than, the variation across zones. This suggests that household-specific factors that constrain access to inputs (household labor supply or financial liquidity, for example) may be more important determinants of input use patterns than the agroclimatic factors that differentiate the zones.

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[42] There were seven plots planted in confectionery peanuts in the southwestern Peanut Basin during the 1989/90 season. As confectionery peanuts are grown under contract, producers receive fertilizer on credit. The results reported here concern only those peanuts grown for oil.

[43] Note that there continues to be some use of contract labor ("navétane") in the Peanut Basin. Because these laborers are remunerated in the same manner as household members (food and lodging, a plot of land, and peanut seed credit), they are treated as household rather than hired labor. As noted in Chapter 3, difficult access to peanut seed has substantially reduced the amount of contract labor used.

Productivity Indicators for Peanuts. Table 7 presents the average values of the following productivity indicators: peanut yield per hectare, average physical product of peanut seed, and the net income per unit of land, household labor, animal traction, seed, and fungicide. Net financial returns were calculated as the gross value of production minus the actual and imputed costs of all the variable inputs except household labor. We comment on the most important results concerning the overall sample averages and the cross-zone differences.

The average yield for the overall sample is 1102 kilograms—this amounts to 76,300 CFA francs in gross revenue and 54,700 CFA francs in net income per hectare. Viewed from a purchasing power perspective, the net income from a hectare of peanuts could have bought about 780 kilograms of threshed, unprocessed millet at the prices that prevailed in 1990.[44]

A kilogram of shelled peanut seed produces an average of 10 kilograms of unshelled output. As the weight of shelled seed is about 70 percent of the unshelled weight, this represents a seed reproduction rate of only 7 kilograms of output per kilogram of seed. The expected norm for peanut seed reproduction rates is in the 10- to 20-kilogram range.

The average net returns to household labor are about 1500 CFA francs per day; this is three times the 500 to 600 CFA francs/day rate that is commonly cited as a rough approximation of the agricultural wage rate, and slightly more than the Senegalese legal minimum wage for unskilled labor (1472 CFA francs/day).[45] Unfortunately, household members do not earn this much money every day of the year. This result highlights a dilemma: Peanut production provides a good average return to labor during the cropping season, but fails to provide an adequate standard of living for the entire year.

The overall averages mask substantial differences in the value of average productivity indicators across all the zones. The most important distinction is that between the low- productivity zones (north and center-west), which realized average yields of about 800 kilograms, and the higher-productivity zones (center, southwest, and southeast), which realize yields above 1000 kilograms. Given the differences in rainfall and soil quality across zones, it is surprising that the yield differences are not statistically significant. The lack of statistical significance is due, in part, to the small sample size and the large within-zone yield variability.[46] Another contributing factor may be, however, the use of shorter-cycle peanut varieties that are well adapted to the shorter growing

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[44] Average, per hectare millet yields for this period were only about 500 kilograms, suggesting that a farmer would be better off growing peanuts and purchasing millet (see Section 4.3.2.).

[45] Due to very thin data on agricultural wages in the IFPRI/ISRA survey, and high variability in the rates, it was difficult to estimate a credible "average wage." The lowest rates for a full day of labor were about 500 CFA francs; rates for assisted labor (man and boy plus animal traction team) ranged from 1,000 to 2,000 CFA francs per day. Other sources use 500 to 600 CFA francs per day as a rule of thumb for agricultural wages (Martin [1988], or Sedes [1989], for example).

[46] The coefficient of variation ranged from 39 to 122 percent across zones; it was 77 percent for the overall sample.

seasons typical of the north and center. If this is true, it highlights the importance of developing seed varieties that are adapted to different agro-ecological environments.

Table 7. Mean Values of Productivity Indicators for Peanuts

Indicator	Overall Sample	North	Center-west	Center	South-west	South-east	Differences
Yield per hectare (kilograms of unshelled peanuts)	1,102	816	801	1,269	1,274	1,118	
APP of seed (kilograms of unshelled output per kilogram of shelled seed)	10.4	11.5	9.5	8.5	12.8	15	SE≠N,CW; C≠SW,SE
Net returns per hectare of peanuts cultivated (CFA francs)	54,666	40,501	34,841	60,847	70,915	59,737	
Net returns per household labor day (CFA francs)	1,496	983	710	2,142	1,643	992	C≠N,CW, SE; SW≠CW
Net returns per kilogram of shelled seed (CFA francs)	516	568	405	414	709	798	SW≠CW,C; SE≠CW,C
Net returns per hour of animal traction (CFA francs)	794	492	632	890	860	1,211	
Net returns per CFA franc of fungicide	150	129	no use	136	no use	288	SE≠N,C

Source: IFPRI/ISRA crop production data (1989/90).
Notes: APP is the average physical product. Means for the overall sample are weighted averages of zone means; zone means are weighted to correct for oversampling of households in market villages. Zone differences were tested with a Scheffe test; when the "differences" number column is empty, the Scheffe test was not significant at the .05 level of probability.

Although yield differences across zones are not statistically significant, there are important differences in other productivity indicators. The two zones with the lowest yields (north and center-west) consistently rank last or second-to-last for most of the other productivity indicators. There are no statistically significant differences between the north and the center-west, despite the fact that they are not located in the same agroclimatic region. Although the center-west belongs to the same agroclimatic region as the center (i.e., the central Peanut Basin), its peanut productivity is more similar to that found in the northern Peanut Basin.

Productivity patterns are not as homogeneous across the three zones with higher yields as they are in the two lower-yield zones. The center stands out in sharp contrast to the other zones, due to its much lower returns to seed and higher returns to labor. These differences are directly linked to differences in input use patterns (Table 6, page 48). Although the yields in the center are similar to those in the southwest and the southeast, farmers in the center use significantly more peanut seed and significantly less labor per hectare. This decreases the average returns to seed and increases the average returns per unit of labor relative to the other zones. Average returns to labor in the center are more than twice those in the southeast and 30 percent higher than those in the southwest.[47] Average returns to seed in the center are slightly less than half those for the other two zones.

These results suggest that simply dividing agricultural zones into high- and low-potential areas based on agroclimatic criteria may not be an adequate basis for developing technologies, identifying constraints, and designing policies to improve productivity. The analysis of economic efficiency which follows confirms that the principal constraints differ substantially across the zones.

Economic Efficiency in Peanut Production. An analysis of economic efficiency examines whether producers are allocating their inputs in a manner that maximizes their profits. We use production functions to examine economic efficiency and identify constraints to better productivity. Production functions permit us to compare marginal value products with input prices. A farm is operating most efficiently when the marginal value product of a particular input is exactly equal to the input cost (marginal factor cost). If the farm is operating with the marginal value product (MVP) of a particular input above the input price, that means there is a constraint in the use of, or access to, that input, and using more of that input (all else remaining equal) would increase the farmer's income; if the farm operates with the MVP less than the input price, the cost of the last unit of the input used is greater than the additional income earned by it.

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[47] Although we report only returns to household labor, we also calculated returns to total labor (household, hired, and invitational); the same pattern held, with Colobane realizing significantly higher returns to total labor than the other zones.

Using 616 plot-level observations, we estimate the following peanut production function with a quadratic functional form:[48]

$$Y = LAB + LAB^2 + SEED + SEED^2 + PUR + PUR^2 + LABSEED + LABPUR + SEEDPUR + ZCW + ZC + ZSW + ZSE$$

where

Y	= peanut yield per hectare (unshelled kilograms)
LAB	= hours of household labor per hectare
SEED	= kilograms of shelled seed per hectare
PUR	= CFA francs of expenditure for purchased inputs (fungicide and labor) per hectare
LABSEED	= LAB * SEED
LABPUR	= LAB * PUR
SEEDPUR	= SEED * PUR
ZCW	= dummy equal to 1 for center-west
ZC	= dummy equal to 1 for center
ZSW	= dummy equal to 1 for southwest
ZSE	= dummy equal to 1 for southeast

The labor and seed variables are straightforward, but the "purchases" variable requires explanation. This variable represents the total household expenditure on non-household labor and fungicide. The variable is constructed this way because (1) most households have zero levels of non-household labor, (2) many households have zero levels of fungicide use, (3) zero levels of fungicide use are 100 percent correlated with zone dummies for two zones, and (4) much of the hired and invitation labor is recorded in terms of cost, rather than time worked, making it difficult to combine with household labor hours. All of these factors make it problematic to create separate variables for fungicide and non-household labor. Combining the two different inputs into a cost variable is not ideal because it is difficult to interpret the coefficient. On the other hand, by incorporating this information into the model, we reduce the risk of introducing missing variable bias.

The production function does not include any capital or costs for fixed inputs, of which animal traction equipment is the most obvious. Because most traction equipment is more than 20 years old and considered fully depreciated (the average life is typically estimated at 10 to 15 years), we have not included the annual costs of depreciation.

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[48] We tried three functional forms—linear, quadratic, and Cobb Douglas. The linear model gave the best fit; this is not surprising with survey data, as one expects most farmers to be in the relatively linear second stage of the production function. Because (1) linear functions force marginal products of one input to be constant regardless of the levels used for the other inputs, and (2) they do not permit one to identify profit-maximizing levels of inputs, we preferred to use a nonlinear model. We chose the quadratic functional form because it provided a much better fit than the Cobb Douglas when evaluated in terms of adjusted R squares, scatter plots of residuals, and significance levels on *t*-tests for coefficients.

The statistical properties of the estimated model are generally acceptable—the adjusted R square is .56, and most significant coefficients have the anticipated sign. The surprising results are (1) insignificant coefficients for both the linear and quadratic labor terms, and (2) significant, negative coefficients for the purchased input variable. Both the linear and quadratic coefficients for seed inputs are highly significant and positive. The model suggests that there is a significant positive interaction between seed and the purchased inputs variable. As the purchased inputs are primarily fungicide, this is not surprising. Coefficients on the zone dummies reflect anticipated agroclimatic effects—the north, center-west, and center have small coefficients (i.e., low levels of output per unit of input), while the southwest and southeast have significantly higher coefficients.

Marginal physical products, marginal value products, and the ratio of the marginal value product to the input cost per unit are estimated from the production function results. The estimated marginal products are statistically significant (i.e., different from zero) and positive.[49] A comparison of the marginal products with the average products reported in Table 7 (see page 51) suggests that farmers are in the economically profitable stage of the production function where the average products exceed the marginal products.

The only input with a marginal value product exceeding the marginal input cost is seed. In other words, labor and purchased inputs are already being used in quantities above the economically optimal levels, so the optimum way farmers could earn more would be by increasing seeding density. An additional kilogram of peanut seed per hectare would increase peanut income by 2.84 times the cost of the additional seed. Since average seeding densities are generally at or above the recommended levels, these results are a cause for concern rather than a simple opportunity to increase productivity. The results suggest that extension recommendations are not in harmony with the current farm-level realities. This is not surprising, given the drastic cuts in the funding for extension activities since the early 1980s (see Chapter 3). Perhaps more important for future productivity growth, however, is the possibility that this result is linked to declining soil and seed quality.

Follow-up interviews by ISRA researchers were used to investigate the farmers' reasons for using seeding densities that exceed recommended rates. The interviews revealed that the practice is pursued primarily to compensate for declining soil fertility and land constraints. The typical explanation heard by researchers is paraphrased in the following paragraph:

> It is critical that the peanut plants cover the ground quickly after seeding, as this reduces weeding labor and helps maintain soil moisture. Now that fertilizer is rarely used, the soil quality has declined and it takes more seed per hectare (both closer rows and more seed per pocket) to ensure rapid ground cover.

Those who plant more closely to compensate for land constraints explained that denser planting helps them maintain previous peanut production levels, while freeing up more land for cereals.

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[49] The positive effect of the interaction between seed and purchased inputs overwhelmed the negative effect of the linear and quadratic coefficients, resulting in a positive marginal value product for purchased inputs.

They pointed out that declining soil quality forces them to plant cereal less densely than had been the pattern when fertilizer was available.

Poor seed quality was mentioned occasionally in the follow-up interviews, but much less frequently than land and soil quality. Farmers' failure to stress problems of seed quality in light of the concern expressed by the national seed service and SONAGRAINES (Chapter 3) raises an important question for future study. Are farmers erroneously placing more blame on decreasing soil quality than warranted, or are the seed services exaggerating the importance of certified seed to preserve their "raison d'être"?

The IFPRI/ISRA survey is not the only source of information suggesting that the traditional links between seeding densities and yields are changing. Cattan and Schilling (1990, page 194) provide agronomic evidence from the 1986 and 1987 cropping seasons that seed reproduction rates were about half of what they should have been; yet, they do not identify the cause.

Because the model described above does not include zone-input interaction terms, the marginal products are identical across all the zones. The inter-zone differences in input use patterns and average products described earlier suggest, however, that the marginal products and production constraints might differ across zones. To test this hypothesis we estimate a second model using the same variables and functional form as the production function just described, but adding interaction terms for each zone-input combination.

This second zone-input interaction model has approximately the same adjusted R square (.59), and the coefficients for the key input variables (linear, quadratic, and input-interaction terms) generally exhibit the same signs and levels of significance as those for the original model. However, seven of the twelve interaction terms are statistically significant, confirming that the slopes of the production function (and therefore the marginal products) differ across the zones. Table 8 compares the marginal value products for the overall sample with those estimated for each zone using the zone-input interaction model. Ratios of marginal value products to unit costs of each input are also presented.

The most important difference between the original model and the interaction model concerns the marginal value product of labor. The interaction model confirms that the marginal value products in the north and the center are not significantly different from zero, but it shows that those for the other zones are small and positive. The highest marginal value product of labor (593 CFA francs per labor day or 1 kilogram of output per labor hour) is in the southeast—the zone having the highest labor inputs per hectare. This is the only zone where the marginal value product of labor is larger than the estimated wage rate, suggesting that more labor could be used efficiently.

Although the low overall marginal products for labor suggest that more labor than necessary is, on average, being applied during the entire cropping season, the analysis does not address issues of seasonal bottlenecks. It is possible that the marginal value product of labor during a peak

Table 8. Marginal Analysis of Peanuts by Input and Zone

Marginal products/costs	Overall Sample	North	Center-west	Center	Southwest	Southeast
Household Labor						
MVP in CFA francs	229	-2	350	-26	270	593
MVP/MFC	**0.46**	**-0.00**	**0.70**	**-0.05**	**0.54**	**1.19**
Purchased Inputs						
MVP in CFA francs/CFA franc spent	0.91	2.31	-7.91	6.65	-2.24	0.56
MVP/MFC	**0.91**	**2.31**	**-7.91**	**6.65**	**-2.24**	**0.56**
Seed						
MVP in CFA francs	477	536	420	504	531	277
MVP/MFC	**2.84**	**2.75**	**1.56**	**3.21**	**2.90**	**1.52**

Source: Estimated using IFPRI/ISRA crop production data (1989/90).
Note: MVP is the marginal value product; MFC is the marginal factor cost (the unit price of an input). Results for the overall sample are estimated from the "base" model coefficients, while those for the individual zones use the "interaction" model coefficients (see text for fuller explanation). The producer price of peanuts used in analysis is the official price of 70 CFA francs/kilo. Seed prices used to calculate MVP/MFC are transaction-derived prices from the IFPRI/ISRA data. The opportunity cost of 500 CFA francs per day for household labor is based on information from a variety of sources.

period (weeding or harvesting, for example) might currently be equal to, or greater than, the wage rate.[50] If this were true, the development of labor-saving technologies to alleviate the bottleneck would be appropriate. If population densities in the Peanut Basin continue to increase and off-farm employment opportunities do not keep pace with this population expansion, people with no alternative sources of income will continue to farm, driving down even further the marginal products of labor—including those for peak periods.

The interaction model confirms the importance of the peanut seed constraint. The marginal product of seed is between 6 and 7.5 kilograms for all zones but the southeast, where it is

[50] Preliminary results of a linear programming model using some of the IFPRI/ISRA data suggest that there is an important labor constraint during the first weeding period, but substantial amounts of slack labor throughout the rest of the cropping season (Diagana and Kelly 1994).

significantly lower at 4 kilograms. Even the lowest marginal value product of seed exceeds the unit cost of seed, implying that more seed could be used efficiently. Higher marginal value products imply greater constraints on access to that particular input.

The marginal product of purchased inputs (hired labor and fungicide) is statistically significant and positive in the north (which has the second highest expenditures per hectare) and in the center (which has the second lowest expenditures). Increasing expenditures on fungicide and hired/invitation labor in the north by 1000 CFA francs (about double the current average) would increase output by 30 kilograms and gross income by 2100 CFA francs. Doubling the current outlay for these inputs in the center from 250 to 500 CFA francs would increase production by 25 kilograms and gross income by 1750 CFA francs, thus providing a good return on expenditures. In the southwest, the marginal value product is negative and significant (-.03 kilograms per franc of purchased inputs). As the purchased input variable in this zone consists primarily of invitation and hired labor, these results, combined with the household labor results, suggest that households would be operating more efficiently if they could increase household labor and decrease hired and invitation labor (or at least their costs).

Although the addition of the interaction terms does not substantially improve the overall predictive ability of the production function, it does provide policy analysts with a better grasp of what is happening and where. In both models, the overall importance of the seed constraint is confirmed, signaling also a potential problem with deteriorating seed and soil quality. While the original model leads us to believe that household labor is universally overused, the interaction model shows that household labor is somewhat constraining in the southeast, but that expenditures on hired and invitation labor are not economically efficient.[51] As noted above, the composite nature of the purchased input variable makes it difficult to interpret, but the results of the interaction model suggest that increasing the use of purchased inputs—given current levels of other inputs—could have a significant and positive impact on overall production in the north and center.

Summary of Main Points Concerning Peanut Productivity. The most important insights gained from this analysis of peanut productivity are:

(1) Average returns to household labor used for peanut production are better than alternative sources of income that pay at or below the minimum wage;

(2) Marginal returns to labor suggest that households are generally using more labor in peanut fields than what is economically justified, given the current levels of other inputs and assumptions about the opportunity cost of household labor;

(3) Although seeding densities are already higher than the recommended rates, increasing the amount of seed per hectare—given the current levels of other inputs—could significantly increase yields per hectare and returns to labor;

[51] An alternative interpretation of the labor results is that commonly used estimates of the agricultural wage rate are incorrect.

(4) The higher-than-recommended seeding densities now being used suggest that the quality of both seed and soil may be declining;

(5) The gap between the recommended and actual seeding densities suggests a need to review the recommendations and funding of those programs that facilitate interaction between researchers, extension services, and farmers;

(6) There are important cross-zone differences in input use patterns and returns to factors of production that suggest a need to target research, extension, and policy design at a level that is more disaggregated than the agroclimatic regions which have been typically used in the past.

4.3.2. Millet and Sorghum

Millet is the principal cereal grown in all zones but the southeast, where millet <u>and</u> sorghum are grown. Although there are some technical differences between millet and sorghum production (the quantity of seed per hectare is greater for sorghum and the growing season is longer), we combine the two crops for this analysis. All other aspects of the analysis are similar to the methods used for peanuts.

Input Use Patterns for Cereals. Table 9 summarizes the input use patterns for cereals. The average area cultivated in millet/sorghum is 4 hectares per household or .6 hectares per adult equivalent—approximately the same as for peanuts. Household labor is the most important single input; it averages about 300 hours per hectare, or about 85 percent of the amount used for peanut production. The overall sample average for use of hired and invitation labor is 2 and 6 hours, respectively; somewhat less than the amount of non-household labor used for peanuts.

In terms of quantity and costs, cereal seed is a relatively inconsequential input compared to peanut seed. Millet/sorghum seed per hectare averages about 4 kilograms, representing a cost of less than 300 CFA francs. Seed quantities reported include initial seedings plus any reseeding required due to poor germination or irregular rain at the beginning of the rainy season. Most cereal seed comes from home stocks; little is purchased and there are very few cases of farmers using certified seed.

Chemical fertilizer use on cereals is rare. The average area fertilized for the overall sample is only .04 hectares per household. Manure is commonly used on cereals in all zones, but the quantities are insignificant compared to needs. For the overall sample, an average of .4 hectares per household receives manure. At this rate of application, it would take a household about 20 years to apply manure to all the plots in a typical 8-hectare farm.

Households use animal traction equipment an average of 58 hours per hectare. Animal traction hours for cereals is about 75 percent that used for peanuts, primarily because the cereal harvest is done manually while the peanut harvest is done partially with animal traction.

Table 9. Input Use Patterns for Millet and Sorghum Production by Zone

Inputs	Overall Sample	North	Center-west	Center	South-west	South-east	Differences
Land							
Average number of m/s hectares	4.02	2.7	3.1	4.5	4.1	6.8	SE≠ all others
Average m/s hectares per ae	.55	.37	.52	.61	.55	.73	SE≠N
Seed							
Kilograms per hectare of m/s	4.4	4.9	3.4	4.6	4.4	4.1	
Soil ammendments							
Average hectares manured per household	.41	0	.47	.42	.65	.26	
Average hectares fertilized per household	.04	0	0	0	.07	.01	
Labor							
Household labor (hours/hectare)	304	295	442	188	402	328	CW≠C
Hired labor (hours/hectare)	1.82	3.4	0	3	.25	1.2	
Invitation labor (hours/hectare)	6	6	6.2	0	14.9	14.5	
Animal traction							
Household equipment (hours/hectare)	58	72	72	42	68	49	

Source: Calculated from IFPRI/ISRA crop production data (1989/90).
Notes: Means for the overall sample are weighted averages of zone means; zone means have been weighted to correct for oversampling of households in market villages. Zone differences were tested with a Scheffe test; when the "differences" number column is empty, the Scheffe test was not significant at the .05 level of probability.

Input use patterns for cereal production are more homogeneous across zones than is the case for peanuts. The only two statistically significant differences are that the southeast plants more land in cereals than the other zones, and the center uses substantially less household labor than the other zones. The difference in labor use is most pronounced between the center-west and the center—two study zones which are in the same agroclimatic region. One other cross-zone difference of note is that fertilizer is used only in the southwest and southeast. These zones have better rainfall, making fertilizer use less risky, but—equally important—they are located near the Gambian border and have easy access to subsidized Gambian fertilizers.[52]

In sum, the most important aspects of cereal input use patterns are:

(1) Extremely low use of fertilizer and manure;
(2) Extremely low use of certified seed;
(3) Few statistically significant differences in input use patterns across zones.

The lack of statistical significance in input use levels across zones has the same implications for cereal production as for peanuts—household-specific factors that constrain access to inputs (household labor supply or financial liquidity, for example) are probably more important determinants of input use patterns than the agroclimatic factors that differentiate the zones.

Productivity Indicators for Cereals. Table 10 presents the average values of the following productivity indicators: millet/sorghum yields per hectare, the average physical product of millet/sorghum seed, and the net income per unit of land, household labor, and animal traction. We discuss the most important findings concerning the overall sample averages and cross-zone differences in cereal productivity.

The average yield for the overall sample is about 500 kilograms of threshed grain per hectare; this is enough cereal to feed about 2.6 persons for a year.[53] Recall that the net income from a hectare of peanuts could purchase about 780 kilograms of cereal using 1990 prices (Section 4.3.1.).

The average net returns per household labor day are about 1000 CFA francs; this is 500 CFA francs less than the net returns to labor in peanut production, but still larger than the standard estimates of the rural wage, which are in the 500 to 600 CFA franc range.

Although input use patterns across zones are seldom statistically different, we find substantial differences in the productivity indicators. We classify zones into low and high productivity categories, using average yields. The drought-prone north and the high rainfall southeast both fall into the low productivity category, with yields below 500 kilograms. This is a surprising result for the southeast—generally considered a high potential zone—and it underscores the fact that agroclimatic zone alone is not necessarily a reliable indicator of productivity.[54]

[52] The January 1994 devaluation eliminated this advantage because Gambian fertilizers became more expensive to farmers who purchased with CFA francs.

[53] We use 190 kilograms of cereal per person per year in the calculations. This is roughly the amount that the Senegalese government uses in their food balance analysis.

[54] Since the rainfall during the survey year was within the normal limits (Table 3), low yields appear to have resulted from crop diseases and insect attacks.

Table 10. Mean Values of Productivity Indicators for Millet and Sorghum

Indicator	Overall Sample	North	Center-west	Center	South-west	South-east	Differences
Yield (kilograms of grain/hectare)	503	240	568	502	649	426	N≠SW
APP of seed (kilograms of threshed grain per kilogram of seed)	133	62	182	122	162	115	N≠CW,SW
Net returns per hectare of millet/sorghum cultivated (CFA francs)	33,472	14,730	43,356	34,827	37,800	22,945	N≠CW,SW
Net returns per household labor day (CFA francs)	1,086	514	817	1,506	1,042	634	N≠C,SW; C≠CW,SE
Net returns per hour of animal traction (CFA francs)	808	307	823	956	907	626	N≠C,SW

Source: IFPRI/ISRA crop production data (1989/90).
Notes: APP is the average physical product. Means for the overall sample are weighted averages of zone means; zone means are weighted to correct for oversampling of households in market villages. Zone differences are tested with a Scheffe test; when the "differences" number column is empty, the Scheffe test is not significant at the .05 level of probability.

The north ranks last and the southeast second to last with respect to every productivity indictor reported in Table 10. The absolute value of each indicator for the southeast is, however, almost twice the size of the comparable indicator for the north. These differences suggest that the two zones should not be placed in the same category when targeting research programs, extension activities, or agricultural policies.

Of the three remaining zones, the southwest and center-west have the best performance with respect to yield, average physical product of seed, and net income per hectare of cereal. Although the yields in the southwest are higher than those in the center-west, the average producer price of millet is higher in the center-west, giving households in the latter zone a higher average net return per hectare.

The center has lower yields than the other two high-yield zones, but exhibits the best returns to household labor and animal traction. For both peanut and cereal production, the center exhibits a consistent pattern of low labor inputs and high returns to labor.

Economic Efficiency of Cereals. We turn now to questions of economic efficiency in cereal production to examine the extent to which farmers could increase their profits by changing input allocation patterns. The production functions follow the same pattern as those for peanuts. We estimate a "base" and an "interaction" model with a full set of zone-input interaction terms. The only difference between the peanut and millet models is that the purchased input variable for cereals represents primarily hired labor inputs and an occasional fertilizer application. The only exception to this is in the southeast where some fungicide used on cereal seed is also included. The cereal analyses are based on 559 plot-level observations.

The adjusted R square for the base millet model is somewhat lower than that for peanuts (.45 versus .56). Both the linear and quadratic terms for seed and labor inputs are significant and have the anticipated signs. Not surprisingly, given the low level of use and frequency of non-use, the coefficients for the purchased inputs variables are not significant. Of the three input interaction terms, only the labor/seed coefficient is significant; it has a positive sign.

Coefficients for zone dummies in the "base" model conform to expectations based on yields presented in Table 10 (see page 61). Producers in the north and southeast obtain less output per unit of input than producers in the other zones. The low coefficient on the zone dummy for the southeast reflects the fact that the zone's yields were lower and its input intensity greater than elsewhere. The southeast had the highest average seeding rate (due partially to the fact that this is the only zone growing sorghum, and a hectare of sorghum uses more seed than a hectare of millet). Labor used is also marginally higher than in the north and substantially higher than in the center (which produced about 75 kilograms more per hectare).

Marginal products estimated for the overall sample are statistically significant (i.e., not equal to zero), and positive for seed and labor but not for purchased inputs. The marginal physical product of one kilogram of cereal seed is 53 kilograms of threshed grain, that for a day of labor about 6 kilograms. Seed is again the only input with a marginal value product larger than the input price, which suggests that farmers could improve their efficiency by increasing the amount of seed used per hectare. Unlike the case of peanuts—where reseeding is not used and more seed means denser planting—the millet result probably reflects the fact that farmers who were diligent about reseeding obtained better outcomes.

Adding the interaction terms increased the adjusted R square only slightly (.47 versus .45). Only four of the twelve interaction terms were statistically significant: labor in the higher potential southwest and southeast, seed in the southwest, and purchased inputs in the center where these expenditures were quite low.

Table 11 presents the marginal physical products and the ratio of the marginal value product to the unit cost of each input used in cereal production for the overall sample and each zone. The

Table 11. Marginal Analysis of Millet/Sorghum by Input and Zone

Marginal products	Overall Sample	North	Center-west	Center	Southwest	Southeast
Household Labor						
MVP in CFA francs	401	552	739	700	246	153
MVP/MFC	**0.80**	**1.11**	**1.48**	**1.40**	**0.49**	**0.31**
Purchased Inputs						
MVP in CFA francs/franc spent	0.82	2.60	2.31	23.10	0.30	0.57
MVP/MFC	**0.82**	**2.60**	**2.31**	**23.10**	**0.30**	**0.57**
Seed						
MVP in CFA francs	3570	864	516	3514	792	2616
MVP/MFC	**35.70**	**8.23**	**5.74**	**28.11**	**7.92**	**26.16**

Source: Estimated using IFPRI/ISRA crop production data (1989/90).
Note: MVP is the marginal value product; MFC is the marginal factor cost (the unit price of a given input). Results for the overall sample are estimated from the "base" model coefficients, while those for the individual zones use the "interaction" model coefficients (see text for fuller explanation). Prices used in the calculations are a composite of the IFPRI/ISRA transaction-derived prices and market price data from the Commissariat de Sécurite Alimentaire.

marginal products of labor are positive and significant for all zones, ranging from 3 to almost 10 kilograms per labor day. The marginal products for seed are highest (45 to 50 kilograms) in the center and southeast. These results are significantly different from those for the north, center-west, and southwest, which are not statistically different from zero. Given the insignificance of the purchased input variable in the base model, it is interesting to note that the marginal products for purchased inputs in the north and the center are positive and significant; they are .03 and .33 kilograms of output for 1 franc of expenditure on purchased inputs. These are the same zones which have significant and positive marginal products for purchased inputs used in peanut production.

A comparison of the marginal value products with the input prices reveals that the center-west and the center could increase their economic efficiency by using more household labor on cereals (MVP/input prices are 1.4 to 1.5). These are zones where more than an optimal amount of labor is being used on peanut fields; therefore, a reallocation of labor within the household could improve economic efficiency (see 4.3.3. on page 64) for an explanation of why this allocation would be unlikely to occur). All zones could increase income by increasing the amount of seed used per hectare. The MVP/input price ratio is extremely large in the center and southeast, zones that already have the highest seeding rates. Purchased inputs—mostly hired labor—could be used more in the north, center-west, and center. All of these are zones where household labor should also be increased.

The addition of the interaction terms does not substantially improve the overall predictive ability of the production function, and the cereal model has even fewer significant zone-input interaction terms than the peanut model. Nevertheless, the cereal interaction model does provide policy analysts with a better grasp of what is happening and where. The base model confirms the importance of increasing the amount of seed per hectare in all zones, but the "interaction" model shows that the center and the southeast have the most to gain. While the base model leads us to believe that labor is being universally overused (MVP<input price), the interaction model shows that using more household and hired labor in the north, center-west, and center could improve economic efficiency.

The most important insights gained from this analysis of cereal production patterns are:

(1) The average returns to household labor used in cereal production are higher than the prevailing agricultural wage rates (1000 versus 500 CFA francs per day) but somewhat lower than the Senegalese minimum wage and returns to peanut labor (both about 1400 CFA francs/day);

(2) Marginal returns to labor results suggest that households in the north, center-west, and center should be using more labor on cereals than they currently use, given assumptions about the opportunity cost of household labor during the cropping season;

(3) The ratio of the MVP to the input price for cereal seed suggests that increasing the amount of seed used per hectare in all zones, particularly the center and southeast, would increase economic efficiency; this reflects the fact that farmers who are more diligent about reseeding get better yields.

4.3.3. Comparing Peanut and Cereal Productivity

Although it is important to understand the input and productivity patterns for each of the principal crops grown in the Peanut Basin, it is the relative costs and returns of the two crops that influence farmers' resource allocation decisions. Table 12 compares the net returns to land and labor for peanut and millet production, showing that the returns to land planted in peanuts are 1.63 times greater, and returns to peanut labor are 1.38 times greater than returns to the same factors used for cereal production. This finding illustrates the fact that Senegalese farmers would be better off financially if they increased their production of peanuts. The two principal factors limiting peanut production are (1) access to peanut seed, and (2) limited access to chemical fertilizers, which obligates farmers to rotate their land between millet and peanut crops. The relatively better returns to peanuts provides evidence that farmers' interests are not complementary to the Government's stated objective of attaining 80 percent cereal self-sufficiency by the year 2000.

Interestingly, this pattern of peanuts being more profitable is consistent across all the zones but the center-west, where millet is more profitable. Although we are unable to pinpoint the reasons why millet is more profitable in the center-west, this distinction certainly has important implications for the design of research and extension programs for that zone.

Despite the overwhelming evidence that peanut production is more profitable than cereal production, marginal analysis suggests that—given the current land allocation decisions—allocative efficiency could be improved by moving some household labor from peanut to cereal fields. Table 13 compares the ratio of marginal value products to the unit input costs for both peanut and cereal production. Households in the north, center-west, and center could improve their allocative efficiency by transferring labor from peanut to cereal production (MVP/input cost ratios are greater than one for cereals and less than one for peanuts).

Table 12. Comparison of Net Returns to Peanuts and Millet/Sorghum

Crop and input	Overall Sample	North	Center-west	Center	Southwest	Southeast
Net returns to one hectare of land			(CFA francs)			
Peanuts	54,666	40,501	34,841	60,847	70,915	59,737
Millet and sorghum	33,472	14,730	43,356	34,827	37,800	22,945
Ratio of peanuts/cereals	**1.63**	**2.75**	**0.80**	**1.75**	**1.88**	**2.60**
Net returns to one day of household labor						
Peanuts	1,496	983	710	2,142	1,643	992
Millet and sorghum	1,086	514	817	1,506	1,042	634
Ratio of peanuts/cereals	**1.38**	**1.91**	**0.87**	**1.42**	**1.58**	**1.56**

Source: Estimated using IFPRI/ISRA crop production data (1989/90).
Note: Means for the overall sample are weighted averages of zone means; zone means are weighted to correct for oversampling of households in market villages.

Table 13. Cross-Crop Comparisons of Marginal Value Products and Costs

Marginal products	Overall Sample	North	Center-west	Center	Southwest	Southeast
Household Labor						
Peanuts: MVP/MFC	**0.46**	**-0.00**	**0.70**	**-0.05**	**0.54**	**1.19**
Cereals: MVP/MFC	**0.80**	**1.11**	**1.48**	**1.40**	**0.49**	**0.31**
Purchased Inputs						
Peanuts: MVP/MFC	**0.91**	**2.31**	**-7.91**	**6.65**	**-2.24**	**0.56**
Cereals: MVP/MFC	**0.82**	**2.60**	**2.31**	**23.10**	**0.30**	**0.57**
Seed						
Peanuts: MVP/MFC	**2.84**	**2.75**	**1.56**	**3.21**	**2.90**	**1.52**
Cereals: MVP/MFC	**35.70**	**8.23**	**5.74**	**28.11**	**7.92**	**26.16**

Source: Estimated using IFPRI/ISRA crop production data (1989/90).
Note: MVP is marginal value product; MFC is the marginal factor cost (the unit price of a given input). Results for the overall sample are estimated from the "base" model coefficients (see text for fuller explanation) while those for the individual zones use the "interaction" model coefficients. Prices are a composite of IFPRI/ISRA transaction-derived prices and market price data from the Commissariat de Sécurite Alimentaire.

Unfortunately, there may be sociocultural reasons for households not transferring labor from peanuts to cereals. Most cereal fields are cultivated collectively under the supervision of the household head, who is responsible for covering the costs of purchased cereals if household production is less than what is needed. Household members and contract laborers usually work in the collective cereal fields in the mornings and in their own peanut fields in the afternoons. The income from peanut fields, however, is personal income, which belongs exclusively to the person responsible for a particular field. Thus, the tradition of allocating morning and afternoon labor to different types of fields, as well as the current incentive structure, make it unlikely that households will shift labor out of peanuts and into cereals.

Poorly functioning markets for agricultural labor also make it difficult for households to hire labor for their cereal fields at peak periods. Agricultural labor markets appear to be hampered by a combination of poor household liquidity that limits the cash available to hire labor, and a limited labor supply, because most households prefer to work their own fields at peak periods.

5. WHAT DIFFERENTIATES HIGH-PRODUCTIVITY FARMERS FROM OTHERS?

The objectives of this section are to (1) test the hypothesis that household characteristics and input use patterns of "high-productivity farms" differ from "other farms"; and (2) quantify the relationship between selected household characteristics and production performance. Yields per hectare are used throughout most of this section to identify the high-productivity farms. We begin with a brief section on the methods used and the justification for using yields as the productivity indicator. Results of the analyses comparing high-yield farms with other farms are then presented, and are followed by a brief section on farms that have high returns to labor. A discussion follows regarding regression results that quantify the relationship between household characteristics and yields.

5.1. Data and Analytical Issues

In this section we use yield (output per hectare) as the primary variable for identifying high-productivity farms. Results presented in earlier sections suggest that labor is not presently the major constraint to improved productivity. There is, however, growing concern about the availability of land, particularly in the center-west and southwest where the population density is high. Concern about deteriorating soil quality throughout the Peanut Basin also increases interest in using yields as the primary indicator of productivity. We rely on yield, using physical rather than economic units, to identify high-productivity farms; however, we also present supplementary information on the relationship between high yields and net economic returns. Section 5.4. presents complementary information concerning labor productivity and key factors that differentiate those farms that exhibit high returns to labor.

Household-level observations, obtained by summing inputs and outputs across individual household plots, are used in the analyses. "High" peanut productivity farms are those that fall into the top 25 percent with respect to peanut yields; high cereal productivity farms fall into the same percent category with respect to cereals. In the case of each crop, the entire sample is ranked without regard to zone, thus permitting us to examine the influence of agro-ecological location on average productivity. *T*-tests are used to identify significant differences in productivity indicators (.10 level unless otherwise noted), and the mean values of the other variables examined. To quantify the relationship between household characteristics and yields, we use a simultaneous estimation (SUR) of peanut and millet yields on a set of variables representing the physical inputs and household characteristics.

5.2. Descriptive Analysis of Factors that Differentiate High-Yield Farms from Others

5.2.1. Overall Productivity Performance of High-Yield Farms

After classifying the farms according to their yield, we examine a variety of other productivity indicators to see if the high-yield farms perform consistently better across all the indicators, or only with respect to the indicator used for classification purposes (Tables 14 and 15). For example, do farms in the top quartile for peanut yields also obtain better returns to labor in peanuts?

Farms in the high productivity group for peanuts have yields and net returns per hectare that are two times those of the other farms. High-yield farms also obtain statistically better net returns to household labor and to seed. These results show that whatever the additional input costs the better producers incur, they are able to recover them with the income derived from the higher yields produced.

Farms with high cereal yields have average yields and net returns which are 3.5 times those of the other farms. Returns to labor and to seed for these farms are double the levels observed in the lower productivity group.[55]

5.2.2. Location

The location variables examined are agroclimatic zone and access to market infrastructure. Our hypothesis concerning agroclimatic zones was that high-yield farms would be more common in the southern zones, which have better soils and are less subject to drought. Our other hypothesis was that households in market villages would have easier access to inputs at lower prices, and therefore be more likely to realize better yields and higher economic returns. The null hypothesis tested was that the share of high-yield farms in a location is proportional to the share of sample farms from that location. The results of our tests for these hypotheses are summarized in Appendix 2, Table 5.1.

Our hypotheses are only partially confirmed. The statistically significant findings about location are that (1) farms in a southern zone are more likely to realize high yields for at least one crop, (2) farms in the southwest are more likely to have high cereal yields, (3) farms in the southeast are more likely to realize high peanut yields AND low cereal yields, (4) farms in the north rarely fall into the high-yield group for <u>any</u> crop, and (5) farms in market villages are NOT more likely to realize higher yields. The agroclimatic effects are generally as anticipated, with the exception of low cereal productivity found in the southeast. The market effect is surprising. It is possible that location in a market village stimulates productivity for nonfarm activities more than for cropping activities.[56] The finding concerning location near a market village should not be interpreted as evidence that easy access to markets does not foster better agricultural productivity, as there is

[55] There is also some correlation in productivity performance levels across all the crops. The farms with top cereal yields have significantly better peanut yields and returns to peanut labor. Reversing the analysis, we find that those farms with top returns to peanut yields have higher average millet yields; however, the difference is only weakly significant at .15. This suggests that good cereal productivity might be an indicator of good overall productivity, whereas good peanut productivity is not necessarily a reliable indicator of top cereal performance.

[56] Kelly et al. (1993) reports that households in market villages tend to have a higher share of income from nonfarm activities.

Table 14. Mean Values of Productivity Indicators for Farms with High Peanut Yields Compared to Other Farms

Indicator	Mean Values for High-Yield Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
<u>Average Physical Products (APP)</u>			
APP of land (kgs. of unshelled peanuts per ha.)	1,648	845	.000
APP of a household labor day	32	24	.02
APP of seed (kgs. of unshelled peanuts per kg. of shelled seed)	15	10	.000
APP of an hour of animal traction	22	17	no signif. dif.
<u>Net Financial Returns</u>			
Net returns per hectare of peanuts cultivated	114,304	58,548	.001
Net returns per household labor day	1,888	1,064	.006
Net returns per kilogram of shelled seed	835	490	.000
Net returns per hour of animal traction	1,219	799	no signif. dif.

Source: IFPRI/ISRA crop production data (1989/90).

ample evidence from other research that it has a very positive role to play on both the input and output marketing side (see von Thunen 1966, for example). It is also possible that the very low level of purchased inputs currently used in Senegal limits the potentially positive effect that living in a market village might have on input purchases and productivity. An alternative hypothesis is that the market density (infrastructure access) in the Peanut Basin is adequate, permitting all farmers to regularly attend a weekly market, and therefore no advantage is realized by those actually living in a market village. We believe it is a combination of these two factors that renders the market variable insignificant. The implication of this result is that increasing market density in Senegal's Peanut Basin is unlikely to have any impact on increasing productivity, given the country's current input use patterns.

Table 15. Mean Values of Productivity Indicators for Farms with High Millet/Sorghum Yields Compared to Other Farms

Indicator	Mean Values for High-Yield Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Average Physical Products (APP)			
APP of land (kilograms of grain per ha.)	1,028	306	.00
APP of a household labor day	21.6	11.2	.00
APP of seed (kgs. of unshelled peanuts per kg. of shelled seed)	204	98	.00
APP of an hour of animal traction	18	9.4	.00
Net Financial Returns			
Net returns per hectare of millet/sorghum cultivated	66,442	18,777	.00
Net returns per household labor day	1,416	712	.00
Net returns per kilogram of seed	13,441	6,117	.00
Net returns per hour of animal traction	1,115	580	.00

Source: IFPRI/ISRA crop production data (1989/90).

5.2.3. Farm Size

It is often supposed that economies of size exist in agriculture, although there has been evidence that smaller farms are more productive in some parts of Africa and other developing regions (Clay et al. 1995; Ellis 1993). In Senegal, we found that high-yield peanut farms have more cultivated land (11.4 versus 7.6 hectares), but that high-yield millet farms have less cultivated land (6.8 versus 8.8 hectares) than other farms.[57] The combined peanut and millet results suggest that there may be economies of size in peanut production but not in cereal production. An alternative explanation is that farms with top cereal yields may be land constrained, and may therefore be putting more effort into improving cereal yields to meet household consumption needs and free portions of their land holdings for peanut production.

[57] The difference for millet farmers is not significant at the .10 level, but is at the .14 level.

5.2.4. Assets and Sources of Cash

We tested the null hypothesis that there is no difference between high-yield farms and others in the amounts of assets and sources of cash. The variables examined were:

(1) total household income per adult equivalent during harvest year 1988;
(2) share of off-farm income in a household's total income for harvest year 1988;
(3) cereal sufficiency ratio for harvest year 1988;[58]
(4) kilos of peanuts produced during the 1988/89 cropping season;
(5) total amount of agricultural credit received by the household for the 1989/90 cropping season;
(6) amount of agricultural credit received per hectare for the 1989/90 cropping season;
(7) average daily caloric intake per adult equivalent during harvest year 1988;
(8) value of the household's livestock holdings; and
(9) number of seeders owned per hectare.

Our hypothesis is that the higher productivity farms have more fixed assets and more cash at planting time, thus permitting them to mobilize resources in a timely fashion and thereby obtain higher yields. The number of seeders represents capital investments in animal traction equipment, which permits timely planting and weeding. Our hypothesis for caloric intake is that higher levels foster better quality labor inputs. Livestock is an asset and it can also provide manure, thereby improving cropping productivity.

Because we do not have data on cash holdings at different points in time, some variables represent potential sources of cash, or assets that would reduce the need for cash at planting time. Livestock, for example, can be easily sold and can provide cash for purchased inputs and hired labor. A high cereal sufficiency ratio, for example, implies that households are less inclined to need cash for cereal purchases. Although the total household income for the entire year is important, it does not reflect the seasonality of different sources of income that might make some types of income better sources of cash for cropping inputs. A large share of noncropping income, for example, is earned during the dry season. This timing suggests that it may provide more cash at planting time than income from the previous (1988) peanut harvest. On the other hand, a good peanut harvest increases the probability of maintaining large stocks of peanut seed, thereby reducing the need to make cash purchases. Although the bivariate analyses comparing high-yield farms with others cannot sort out the intricacies of these complex relationships, they do help us identify which variables have significantly different average values for the two groups.

High-yield peanut producers had more total income, owned more livestock, and produced more peanuts during the previous year than did the other producers (see Appendix 2, Table 5.2). These farms also obtain more agricultural credit than the others, but do not obtain more credit per hectare planted. The larger values for all of these variables suggest that the high-yield peanut

[58] The cereal sufficiency ratio was the quantity of cereal produced during the 1988/89 season, divided by the estimated household coarse grain needs for the period October 1988 through September 1989.

farms have access to more cash (or less need for it due to larger seed stocks) than the other farms, which rely only on farm income sources.

High-yield millet farms own more livestock and more seeders per hectare cultivated (Appendix 2, Table 5.2). Since farmers use manure primarily on cereal fields, we believe the livestock link is due more to manure than to increased liquidity associated with livestock sales. More seeders per hectare result from the smaller farm size (characteristic of high-yield millet farms) and the indivisibility of seeders.[59] It is not surprising that high-yield cereal farms do not have statistically larger cash reserves, as cereal production is much less cost-intensive than peanuts.

5.2.5. Input Use

Farms with top yields for peanuts devote a larger share of cultivated area to this crop and use more household labor per hectare than peanut farms with lower yields (Appendix 2, Table 5.3). They also have higher peanut seeding densities and pay less per kilo of peanut seed than the other farms. There are no statistically significant differences in the amounts of hired or invitation labor, nor in the hours of animal traction used or expenditures on fungicide.

Farms with top cereal yields devote <u>less</u> land to cereals, and use more seed and animal traction per hectare. Their higher seeding rate is due to more reseeding after poor germination rather than higher seeding densities. There are no statistically significant differences between farms with top cereal yields and others in terms of hired or invitation labor, manure applications, or use of chemical inputs.

5.3. Quantifying the Relationship Between Household Characteristics and Yields

In this section we drop the binary distinction between high and low productivity farms, and instead use household-level observations to estimate cereal and peanut yields as a function of technical inputs (seed, labor, and purchased inputs per hectare) and selected farm characteristics. Although the use of some of the household characteristic variables raises questions of simultaneity bias due to the endogeneity of the explanatory variables, the estimation of primal (as opposed to dual) production functions is subject to this critique even when only physical inputs are used. The amount of labor applied to a plot, for example, is not a predetermined variable, but is subject to revision as the cropping season progresses. We use the results more to develop hypotheses about how household characteristics might influence yields than to present definitive statements about the direct influence of these variables on yields.[60]

[59] Extension services recommend one seeder for every five to seven hectares of land; the average size for high-yield cereal farms is slightly larger than that which can be cultivated by one seeder, but not large enough to justify two seeders.

[60] We assume the error terms are correlated and therefore estimate the model simultaneously using SUR. An alternative formulation would be to use a two-stage procedure, estimating the inputs as a function of the household

Given the desire in Senegal and elsewhere to understand the effect of noncropping income on crop productivity, we pay particular attention to this variable (represented by the share of noncropping income in total income). The hypotheses are that noncropping income can influence yield by (1) improving one's ability to purchase inputs, (2) decreasing household labor availability due to competing demands for noncropping labor, and (3) positively influencing farm management through increased flexibility obtained from better cash reserves, or negatively influencing farm management through decreased management time allocated to farm supervision. The net effect on yields is not apparent *a priori*.

A wide range of household characteristics are included to avoid biasing the coefficients of the noncropping income variable. Farm size is used to capture economies of size. Household size and composition (represented by the household population in adult-equivalents, the age of the household head, and the share of adult females in the household) are thought to influence the household's labor availability and management practices. The number of seeders owned per hectare (a proxy for equipment stocks in general) can increase the timeliness of seeding, and be a positive influence on yields or encourage extensive farming, which tends to decrease yields. Dummy variables are used to differentiate agroclimatic zones.

The functional form is quadratic in the technical inputs and age. The model contains a full set of input interaction terms, plus interaction terms between the noncropping income variable and each input. We also include a farm size/noncropping income interaction term to control for within-zone interactions between these two variables.[61] The millet model also includes zone/input interaction terms for purchased inputs and labor inputs in the southeast, because input use levels for this zone are much larger than those in the other zones, suggesting that the marginal products might also be different.

The R squares are .69 for the millet model and .85 for peanuts. These are both higher than the R squares obtained for the strictly technical production functions described in Chapter 4. The coefficients for seed and labor inputs are of the anticipated signs, and are usually significant at the .10 level. The purchased input variable (fungicide, nonhousehold labor, and fertilizer) is not significant. Statistically significant coefficients for most of the zone dummies confirm the agroclimatic effect on yields. Of the household characteristic variables, the number of seeders is the only significant variable in both the peanut and millet models, exhibiting a positive effect on cereal yields and a negative effect on peanut yields. Farm size is also negative in the peanut model. More seeders, combined with more land, seem to encourage extensive, rather than intensive, cultivation of peanuts, thus resulting in lower yields.

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characteristics in the first stage, and then using the predicted values and household characteristics in the second stage; this cannot be done because instrumenting three inputs with the same set of household characteristics creates problems of multicollinearity that prevent estimation of the second stage.

[61] We created a dummy variable equal to 1 for households in the top quartile of their zone with respect to total area being cultivated. The dummy was then multiplied by the share of noncropping income in total income.

Regression coefficients are used to estimate the marginal value products of technical inputs and the influence of noncropping income on yields (Appendix 2, Table 5.4).

The same general story regarding economic efficiency emerges from this analysis as that obtained with the strictly technical production functions. Seed is the constraining input for both peanuts and cereals. The marginal value products of labor for both crops are somewhat larger than those obtained in the previous estimates, but still below the estimated wage rate of 500 FCFA/day.

The impact of an increase in the share of noncropping income on cereal yields is negative and highly significant (.000) for small farms; it is negative and significant at the .06 level for large farms. The results imply that a one unit increase in the share of noncropping income will decrease cereal yield by almost 390 kilos for the smallest 75 percent of farms in each zone and by 250 for the largest 25 percent of farms (this result is based on the assumption that input use levels are computed at the sample average). The relationship is similar for peanut production: An increase in the share of nonfarm income is associated with a 470-kilogram decrease in peanut yields for small farms and a decrease of 247 kilograms for large farms.[62]

Because we do not have a strong theoretical basis for knowing which way the yield/ noncropping income chain of causality goes, interpreting these results is difficult. As noted in Chapter 2, there is clearly some two-way interaction between cropping and noncropping productivity. The higher level of statistical significance for the small farm results suggests that small farms with large shares of noncropping income realize lower yields. This result leads to another hypothesis: Perhaps small farms with large shares of noncrop income have lower yields because they were the last to settle in their villages and, therefore, obtained only small amounts of land with marginal or poor quality soils; i.e., it is the lack of access to good land and adequate farm sizes that drives them into noncropping activities, rather than the noncropping activities reducing labor and management applied to cropping activities.

We were able to do some follow-up survey work, and asked the farmers about this hypothesis (Diagana 1994). Farmers with small farms, low yields, and high shares of nonfarm income considered their land to be the same quality as that of their neighbors—i.e., poor quality land was not pushing them into noncropping activities. Farmers also thought it would be possible to expand their farm size, but they had not chosen to do so. Most claimed, however, that "push" factors were responsible for their entry into noncropping activities—cropping incomes simply were not adequate enough to meet their needs. Respondents further stated that they did not see much labor competition between the off- and on-farm activities, as they occur mainly in different seasons.

As these farmers have ruled out land quality as a cause of low yields, and claim that noncropping activities do not conflict with labor for cropping, one possible conclusion is that they were simply not very good farmers from the start (i.e., poor managers or poor knowledge of the technical aspects of farming), and have moved into noncropping activities where their skills are better used.

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[62] The latter case was significant at only the .15 level.

These are the types of behavioral influences on cropping productivity that are extremely difficult to capture, but need to be recognized when evaluating the determinants of productivity and designing agricultural policies. In general, this group of farmers claimed to be content with their current mix of cropping and noncropping activities, and has no desire to specialize completely in one or the other—a logical diversification strategy for the risky Sahelian environment.

A great deal more theoretical and empirical work needs to be done if we are to improve our ability to quantify the relationships between cropping and noncropping incomes using econometric techniques. During the interim period, improving the qualitative information collected in conjunction with largely quantitative farm surveys will help us interpret the results of less than perfect econometric models, and lay the foundations for improving them.

5.4. Descriptive Analysis of Factors that Differentiate Farms with High Returns to Labor

Farms with high returns to labor are those whose net returns to household labor place them in the top quartile of the sample. Net returns to household labor are calculated as the gross value of production, minus the actual or imputed cost of all inputs but household labor, divided by the number of household labor days used.[63]

We found that those farms with high returns to labor also exhibit high physical and economic returns to other inputs (Tables 16 and 17). Among the household characteristics examined, we found that location, credit, and livestock assets are associated with higher returns to labor. The center and southwest have a larger than expected number of high-returns-to-labor farms, with the three remaining zones having lower than anticipated numbers (Appendix 2, Table 5.5). Farm size does not differentiate high-returns-to-labor farms from others. Farmers with high returns to labor in peanuts use more credit and have fewer livestock assets than other farmers (Appendix 2, Table 5.6). For both the peanut and millet analyses, higher levels of caloric intake per adult equivalent are associated with higher returns to labor.

Input patterns also differ between the two groups of farms (Appendix 2, Table 5.7). High-returns-to-labor in peanuts are associated with less use of household labor and use of more seed per hectare than others. Differences in nonhousehold labor are not statistically significant, suggesting that high-return farms are not using outside labor as a substitute for household labor. The correlation between high seeding densities and higher returns to labor provides supporting

[63] For the rest of this discussion, the term "labor" will refer to household labor (exclusive of hired and invitational labor), unless otherwise noted.

Table 16: Mean Values of Productivity Indicators for Farms with High Returns to Peanut Labor Compared to Other Farms

Indicator	Mean Values for High-Return Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Average Physical Products (APP)			
APP of land (kgs. of unshelled peanuts per ha.)	1,451	895	.02
APP of a household labor day	50	18	.10
APP of seed (kgs. of unshelled peanuts per kg. of shelled seed)	12	11	.10
APP of an hour of animal traction	34	13	.09
Net Financial Returns			
Net returns per hectare of peanuts cultivated	75,936	43,865	.01
Net returns per household labor day	2,592	832	.00
Net returns per kilogram of shelled seed	659	543	.04
Net returns per hour of animal traction	1,738	625	.06

Source: IFPRI/ISRA crop production data (1989/90).

evidence for the farmers' claim that higher seeding densities increase their peanut yields and reduce weeding time (Appendix 2, Table 5.7).[64]

In the millet analysis there are no statistically significant differences in the input use levels between farms with high returns to labor and others (Appendix 2, Table 5.7). This provides further support for the hypothesis that it is the quality of the labor inputs (due perhaps to better caloric intake or skill), rather than the quantity of the labor used, that are responsible for the higher returns.

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[64] A recent document by Gaye and Sene (1994) reports the results of a follow-up survey of farmers in the IFPRI/ISRA sample who use high seeding densities. The objective of the survey was to better understand why farmers were using higher densities. The document also includes a review of recent agronomic literature on the relationship between peanut seeding densities and yields. Both the survey results and the agronomic research confirm that higher density improves yields and reduces weeding time. The agronomic literature, however, cautions that increased density, without the use of fertilizer, leads to a more rapid deterioration of soil quality.

Table 17. Mean Values of Productivity Indicators for Farms with High Returns to Millet/Sorghum Labor Compared to Other Farms

Indicator	Mean Values for High-Return Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Average Physical Products (APP)			
APP of land (kilograms of grain per hectare)	843	364	.00
APP of a household labor day	3.4	1.2	.00
APP of seed (kgs. of unshelled peanuts per kg. of shelled seed)	194	101	.00
APP of an hour of animal traction	20.9	8.3	.00
Net Financial Returns			
Net returns per m/s hectare cultivated	55,222	22,106	.00
Net returns per household labor day	1,816	568	.00
Net returns per kilogram of seed	12,932	6,283	.00
Net returns per hour of animal traction	1,357	504	.00

Source: IFPRI/ISRA crop production data (1989/90).

5.5. Summary

The data presented in the tables, and the discussion in this chapter, illustrate that there are substantial differences in productivity among sample farmers, even among farmers located in the same agroclimatic zone. Using variables available from the IFPRI/ISRA data set, we have identified some of the factors that differentiate higher-productivity farms from others in an effort to obtain insights about the types of policies that might improve agricultural productivity throughout the entire Peanut Basin.

Results suggest that research and extension need to pay more attention to recommendations for peanut seeding densities and the long-term impact of current practices. Evidence that better caloric intake is associated with higher returns to labor has implications for the design and use of food aid and food for work programs. The correlations between productivity performance and access to cash reserves (credit and livestock assets, in particular) suggest that policies and programs to improve cash liquidity will have beneficial effects on peanut—but not millet—productivity.

Although there is evidence that noncropping income is reinvested in cropping activities, we are unable to establish a clear link between high shares of noncropping income and better cropping productivity. Many farmers with large shares of noncropping income (particularly those with small farms) appear to have been "pushed" into their noncropping activities by poor agricultural productivity and low cropping incomes. More research is needed to determine the extent to which improving farmers' access to noncropping income will increase agricultural productivity.

6. FACTORS INFLUENCING ACQUISITION OF CONSTRAINED INPUTS

Results presented in earlier sections showed that the farmers' inability to obtain desired quantities of peanut seed is a major constraint to increasing aggregate production and productivity of key inputs such as land and labor. In this chapter we describe the three principal modes of acquisition used by farmers, and examine the factors that influence the quantities of seed obtained via each mode. We use regression analysis to quantify the relative importance of factors influencing access to peanut seed, and evaluate the extent to which policy interventions can act on these factors to reduce constraints. The analysis is restricted to the four zones in the central, southwestern, and southeastern Peanut Basin, where most households continue to rely on crop production for more than half their income.[65]

6.1. Modes of Peanut Seed Acquisition

Three principal options for acquiring peanut seed are open to farmers: credit, cash purchase, and use of household stocks from the previous harvest.

6.1.1. Credit

The Formal Sector. Formal-sector credit is offered by the rural credit bank (CNCAS), which has branches in the regional capitals but not in the smaller towns or villages. Formal-sector credit is not given to individual farmers, but is instead given to village cooperatives (*sections villageoises*) or private producer associations (*groupement d'intérêt économique* or GIE) that have been given the legal status required to apply for formal-sector credit. The process of establishing a GIE is time consuming and not easily accomplished (see Gaye 1991; and Ouédraogo and Faye 1990). A GIE is, however, a group of freely associating individuals, whereas the village cooperative is open to all inhabitants of the member villages—regardless of credit-worthiness!

Farmers have access to formal-sector credit if (1) they belong to one of these two organizations, and (2) that organization has reimbursed most of the credit received during the previous year.[66] In other words, if a farmer reimbursed his previous loan, but other members of his group did not, he might be ineligible for formal-sector credit. If a farmer's group is eligible, the farmer obtains credit by paying 35 percent of the total seed purchase cost up front, with the balance being paid

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[65] We included the northern Peanut Basin in some preliminary analyses. The significance and signs of a number of variables changed substantially when the northern zone was removed. We believe this is because households in the north are following an unequivocal strategy of moving toward specialization in noncropping activities (see Kelly et al. 1993). This results in a different relationship between the nonfarm income variable and peanut seed than that found in the other zones. Given the limited number of observations, it was not practical to include zone interaction terms for all of the explanatory variables. Since we were primarily looking for policy-relevant results that would provide guidance on how to improve farmers' access to inputs in zones where cropping continues to be viable, we decided to model only the four zones that earn most of their income from cropping.

[66] Minimum reimbursement rates have varied, but they have usually been over 85 percent.

after the peanut harvest. Orders are placed with the cooperative or GIE, which deals directly with the CNCAS. Orders must be in 50 kilogram increments, and are placed at a specified time of the year (usually well in advance of the planting season). It is important to note that it is not necessary to post collateral, such as land or assets, to obtain formal-sector credit. In theory, if not in fact, reimbursement is guaranteed by the social cohesion (and pressure) of the other members of the group.

When all the paperwork is complete, the cooperative or GIE receives a chit for the authorized amount of seed, and arranges to have it transported from the nearest SONACOS sales point to the cooperative's or GIE's home village. Members must then collect their seed from this delivery point. All seed obtained through formal-sector credit comes from SONACOS-certified seed stocks. The SONACOS sales points are located at the collection points where farmers sell their peanuts. Some of these collection points are in highly frequented market villages, but many of them are not.

The Informal Sector. Informal-sector seed credit is scarce and the procedures for obtaining it are varied (see Gaye 1986 and 1992a). In some cases, it is simply a husband lending his wife the seed from his stocks, and being reimbursed in-kind, without interest, after the harvest. In other cases, wealthy producers stock more seed than they need and provide it on credit to less well-to-do farmers at planting time. Interest rates are extremely variable, ranging from 0 to more than 100 percent on an annualized basis. Rates are often not fixed at the time the seed changes hands. If the ensuing harvest is a good one, the rates are high; if it is a poor one, the rates are low.[67] Transactions tend to take place in homes and villages, rather than in market situations. Repayment is usually in-kind, but is sometimes in cash. Small amounts of informal credit are obtained in market villages from local shopkeepers or peanut traders, but this is rare (see Gaye 1992a). In contrast to formal-sector credit, there are no restrictions on the minimum quantities bought or the timing of the purchases. Collateral is seldom required. For most transactions, the borrowers tend to be well-known by the lenders, and it is the social relationship that cements the transaction rather than a more formal sales agreement.

Credit is the least-employed mode of peanut seed acquisition. It is used by 31 percent of the households in the four zones covered here, and accounts for only 12 percent of the seed used. In the center-west only 4 percent of the households use credit, while in the center 57 percent use it. It is difficult to draw conclusions from the data about the reasons for this skewed distribution. The center-west appears to do better with millet than with peanut production (returns to both land and labor); this may discourage the farmers from heavily investing in peanut seed. It is also possible that high rates of credit defaults during the previous season made many village cooperatives ineligible for credit in 1989. Another hypothesis is that the Serer ethnic group predominating in this zone is less inclined to use credit than their Wolof neighbors. The large share of households using credit in the center is explained by strong ties with Touba, the capital of

[67] This information was obtained by the principal author through discussions with farmers in zones where informal credit was the most common. The informal-sector example of variable rates determined by the quality of the harvest appears to be worthy of further investigation. It is possible that this procedure, which can be thought of as a combination of credit and insurance, might improve reimbursement rates in the formal sector.

the Mouride Islamic Brotherhood. The Mourides are avid peanut cultivators, and have political clout that facilitates access to credit and inputs (see, for example, Cruise O'Brien 1971; or Jammeh 1989).

6.1.2. Cash Purchases

Cash purchases can be made at local markets, at SONACOS seed depots (only during the two-month period preceding the planting season, in minimum quantities of 50 kilograms), or from friends and neighbors. Most cash transactions are made in market villages. Cash purchases are more common than credit (64 percent of the surveyed households), and represent 25 percent of the seed used.

The distribution of cash purchases differs across the zones. Virtually all households purchase some seed for cash in the central zone—the zone with the largest share of credit purchases. Only 30 percent of the households in the southwest make cash purchases, and about 50 percent in the center-west and southeast. The relatively large share of households making cash purchases in the center-west supports the hypothesis that farmers in the zone want to grow peanuts, but prefer not to incur debt to do so.

6.1.3. Stock Drawdowns

Seeds are usually stored in sacks under beds or in the corner of a bedroom, since granaries are used primarily for cereals. Given that many households stock several hundred kilograms of seed, a lot of living space must be turned over to peanut seed storage; yet, attempts to popularize village-level storage have not been very successful. Occasionally, household heads will store their seed with trustworthy traders or friends in nearby villages, thus reducing the temptation to eat or sell the seed before planting. During the January-to-March period, most seed is shelled and sorted; some is treated to protect it against insect attacks, but not as much as the extension service recommends.

Using seed stocked from the previous year is the most common mode of acquisition. Eighty-four percent of the households store seed, and stocks account for 63 percent of the total seed planted. Households in the center are more likely (23 percent) than others (0 to 17 percent) to have no seed stocks—this explains why they are more likely to purchase seed on a cash or credit basis. The quantity of stocked seed is a function of household resource allocation decisions, as well as how good the previous cereal and peanut harvests were. The poorer the harvest, the lower the stocks will be, since the households must sell peanuts to pay their taxes and purchase necessities. The 1988/89 season, the year preceding the one for which we are modeling peanut seed acquisition, was poor in the center-west due to locust attacks; the production of cereals suffered more than peanuts. Harvests in the center and southwest were mediocre in 1988/89, and those in the southeast were average. Forty-three percent of the sample obtains peanut seed from only one source—usually stocks—but occasionally cash or credit purchases. Forty-four percent of the households use two modes of seed acquisition (usually stocks plus credit or cash purchases), and twenty-two percent use all three modes of seed acquisition.

6.2. The Model

Two important objectives for Senegal's peanut sector are (1) to maintain peanut production at a level that keeps the processing industry running at or near capacity, and (2) to increase farmers' incomes. Farmers' inability to obtain the desired quantities of peanut seed is a major roadblock on the road to attaining both of these objectives. Although some aspects of the seed marketing and distribution systems could be improved, farmers' inadequate cash reserves and poor access to credit remain the principal bottlenecks to obtaining the quantity and quality of seed desired.

The goal of this section is to inform decision makers regarding the types of nonprice policies and programs that would most likely improve farmers' access to peanut seed. We accomplish this by modeling the value of seed acquired via the three principal modes of acquisition (stocks, credit, cash purchase) as a function of variables that reflect both household needs and capacity. Needs are represented by such variables as farm and family size, while capacity is represented by such variables as cash earned from noncropping sources, prior-year peanut harvest, and cereal stocks.

The results of these models provide guidance, for example, on whether increasing a household's financial capacity by raising nonfarm income would result in more seed purchases, which would therefore have positive spillover effects on agricultural production. Going a step further, clarifying the relative impact of nonfarm income on different modes of seed acquisition provides information for fine-tuning policy interventions, so that programs which promote nonfarm income can be coupled with those that would increase seed supplies in the channels most likely to be affected.

6.2.1. The Variables

Our hypothesis is that household and farm characteristics determine the quantity of seed needed, as well as the household's capacity for obtaining it from different sources. We assume that household characteristics that affect need (farm and family size, soil quality, and seeding density patterns) and capacity (assets, prior harvests, and income) are predetermined at planting time.

The dependent variables examined are the (1) value of the seed obtained using both formal- and informal-sector credit (CREDIT), (2) value of the seed purchased for cash (CASH), (3) value of the seed planted from stocks (STOCKS), and (4) total value of the peanut seed planted (ALLSEED).[68] The ALLSEED model allows us to evaluate the analytical contribution made by

[68] All values for CFA franc variables are in thousands of CFA francs. Household-level values for all dependent variables were obtained by summing across plot-level data using the actual cost of the seeds purchased for cash or on credit, and the imputed value of home-produced seed. Imputed values are based on zone-specific prices estimated from seed purchases enumerated during the survey period.

disaggregating seed acquisition into different sources, noting the extent to which the determinants of the total seed quantity used differ from the determinants of seed quantities obtained from different sources. We use the value of peanut seed, rather than the quantity of seed, because of our interest in liquidity constraints.[69]

Table 18 shows the mean values of the dependent variables. The total value of the seed used is highest in the center, even though the total farm size is larger in the southeast. This is linked to a generally higher seeding density in the center, and a tendency to plant a larger share of cultivated area in peanuts. The center also exhibits the highest value of seeds purchased on credit and for cash; this is coupled with the lowest value of stocked seeds. The shares of total seed obtained from each source are easily calculated from the data in the table. Stocks provide 82 percent of seed in the southeast and 74 percent in the center-west, but only 45-52 percent in the center and southwest. Table 18 also shows the ratio of the amount of peanut seed stocked to the amount of

Table 18. Mean Values of Peanut Seed Acquired for 1989/90 Season, by Mode of Acquisition

Variable	Overall Sample	Center-west	Center	South-west	South-east
Total Peanut Seed ('000 CFA francs)	65.6	38.8	99.5	35.5	76.1
Credit Purchases ('000 CFA francs)	7.9	.3	19.2	2.5	7.0
Cash Purchases ('000 CFA francs)	16.5	9.7	34.4	14.7	6.8
Stocks ('000 CFA francs)	41.2	28.8	45.9	18.3	62.4
Ratio of Seed Stocked to Quantity Harvested in 1988*	.16	.37	.12	.09	.11

Source: ISRA/IFPRI survey data (1989/90).
* The ratio is calculated by dividing the kilograms of shelled seed by the kilograms of unshelled seed.

69 An alternative would be to use prices as explanatory variables. This was not done because: (1) prices calculated for each zone would be correlated with the zone dummies, causing perfect multicollinearity; if we eliminated the zone dummy, the price variable would be picking up both zone and price effects, thus providing biased results; (2) prices for different modes of acquisition would have to be considered, necessitating a large number of additional variables; and (3) price data were very thin for some zone/mode combinations, making it difficult to create a complete set of price variables.

peanuts harvested the previous year. The center-west is quite different from the other zones in this respect, with a ratio of .37 versus .09 to .12 for the other zones. This illustrates that the choice to store seed, rather than to purchase it, is not necessarily correlated with the size of the prior-year harvest or the agroclimatic potential of the zone.

The same set of explanatory variables is used for all four regressions.

Liquidity variables:

LIVESTOCK	Income from livestock sales in thousands of CFA francs
NONFARM	Income from nonfarm activities (noncropping, nonlivestock) in thousands of CFA francs

Farm and household characteristics:

FARMSIZE	Farm size in cultivated hectares
AE	Household composition in adult equivalents
EDHHH	Binary variable = 1 if the household head has some formal schooling in the French school system
EDKIDS	Binary variable = 1 if any children in the household attend French school
MARKET	Binary variable = 1 if the household is located in a market village
NAVETANE	Number of contract laborers living in the household during the survey period
ZCW	Binary variable = 1 if the household is located in the center-west
ZC	Binary variable = 1 if the household is located in the center
ZSW	Binary variable = 1 if the household is located in the southwest
ZSE	Binary variable = 1 if the household is located in the southeast
	Note that all four zone dummies are used, and the intercept is omitted to avoid perfect multicollinearity.
CONTACT	Binary variable = 1 if the household had any contact with extension or other agricultural service programs during the survey period
HISEED	Binary variable = 1 if the household exhibits a pattern of seeding more densely than others (i.e., is in the top quartile)

Stock and asset variables:

CSR88	Cereal sufficiency ratio showing the adequacy of the previous year's cereal harvest
PN88	Kilograms of peanuts harvested in previous year
NUMSEED	Number of seeders owned by the household

Tables 19 (farm and household characteristics) and 20 (income patterns) contain the mean values of the explanatory variables for the overall sample, and by zone. Table 20 also includes information on total household income and the share of noncropping income in total income—variables that are not used in the regression model but that help us interpret the results.

Many of the variables in these tables have been discussed in Chapter 4. Those not previously mentioned are education, contact with agricultural services, use of contract laborers, cereal sufficiency ratios, and prior-year peanut harvests.

Table 19. Mean Values of Farm and Household Characteristics for the Sample Used in Seed Acquisition Models

Variable	Overall Sample	Center-west	Center	South-west	South-east
Farm Size (hectares)	9.14	5.2	10	7	12.6
Family Size (adult equivalents)	8.6	7	8.2	9.3	9.6
Education of Household Head (percent with formal schooling)	.04	0	.07	.08	0
Education of Children (percent of households with children in school)	.38	.65	.27	.8	0
Market Location (percent of households located in a market village)	.3	.26	.33	.28	.32
Contact with Agricultural Services (percent of households with contact)	.29	0	.13	.48	.47
Navétane (average number of contract laborers/household during survey)	.12	0	.13	0	.27
Number of Seeders per Household	1.5	1	1.9	1.3	1.6
Cereal Sufficiency Ratio from 1988/89 harvest	.6	.5	.4	.6	.8
Peanut Harvest 1988 (kilograms)	2081	700	1770	1929	3404
Peanut Seeding Density Patterns (share in top quartile for seed per hectare)	.29	.09	.5	.12	.38

Source: Calculated from IFPRI/ISRA data (1989/90).

Table 20. Income Patterns of Households in Seed Acquisition Models

Variable	Overall Sample	Center-west	Center	South-west	South-east
Total Household Income, 1988/89 ('000 CFA francs)	353.9	183.8	278.0	439.5	473.2
Livestock Income ('000 CFA francs)	40.5	12.9	60.4	16.9	59.2
Nonfarm Income ('000 CFA francs)	111.5	77.0	66.5	234.5	84.1
Share of Noncropping Income in Total Income	.43	.49	.46	.57	.30

Source: Calculated from IFPRI/ISRA data (1989/90).

One notes a low rate of literacy among household heads (0 to 8 percent, depending on the zone). Households with children in school are much more common (30 to 80 percent of the households, depending on the zone), except in the conservative southeast (no children in public schools), where Koranic school is preferred to the formal French system.[70]

Contact with agricultural services varies, being more common in the higher-potential southern zones, where there are more crops grown under contract (cotton in the southeast and confectionery peanuts in the southwest).[71]

Contract laborers (*navétane*s) were not used in the center-west or southwest during the survey period. There is approximately one contract laborer for every ten households in the center, and almost three for every ten households in the southeast. These numbers show that those zones with the larger farms are more likely to use contract laborers.

Cereal sufficiency ratios based on the prior-year's harvest range from .4 to .8, with better results in the southern zones. Peanut production from the previous year follows a similar pattern, with larger harvests per household in the southern zones.

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[70] USAID (1993) reports that 80 percent of rural households have at least one person with some formal schooling. Their numbers are higher than ours because they include Koranic training and we do not.

[71] These crops are grown by only a few sample households; the number of fields for each crop was only seven for the entire sample.

6.2.2. Hypotheses Concerning the Variables

Liquidity is represented by two variables that reflect income sources that can provide cash shortly before planting time: livestock sales (LIVESTOCK) and nonfarm income (NONFARM). Our hypothesis is that all three modes of acquisition should be enhanced by larger cash reserves. Cash purchases require the most liquidity, as the cash is rendered at the time of purchase, usually May or June. Credit purchases made in the formal sector (about 85 percent of all enumerated credit purchases) require a 35 percent down payment, so the need for liquidity is smaller but still important. Credit purchases in the informal sector generally do not involve a down payment. Although households do not need cash to mobilize their seed stocks at harvest time, a poor cash situation between harvest and planting can result in diminished stocks—seeds are often eaten or sold when cash is short.

The household characteristics control for inherent differences among households. We expect larger farm size (FARMSIZE) and larger household size (AE) to be positively correlated with overall seed use (ALLSEED).[72] It is more difficult to hypothesize about the relationship for the different modes of acquisition. It seems probable that larger farms and larger households would have both a greater demand for peanut seed and be more likely to have a larger supply from stocks.

Having a literate person in the household could help with the administrative paperwork required to obtain credit through formal channels (particularly that related to creating legally recognized private associations), and could improve the management of the household's cash assets. A more realistic hypothesis is, however, that the education variables differentiate those households that have taken the initiative to improve their lot from those that are doing little to adapt to the changing economic, social, and political environments. In other words, instead of being a proxy for literacy, the education variables could be a proxy for initiative.

Location in a market village (MARKET=1) should stimulate access to both cash and credit purchases. Although weekly markets do not always have official SONACOS sales points, peanut seeds are sold by private traders and individual producers in most markets. Proximity to markets is expected to have a depressing effect on household seed stocks, as it would make peanut sales easier once the official marketing season closes in February or March.

The signs and significance of the zone dummies will vary, depending on the relative importance of a particular mode of acquisition in a zone. The virtual absence of credit in the center-west suggests that the coefficient for ZCW in the credit model should be negative and significant. The large share of cash and credit purchases in the center implies that the ZC coefficient will be positive and significant in the cash and credit models.

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[72] It is possible, though, that large households (more AE) with an unusually large share of dependent children and a small share of active farmers would have a lower demand for peanut seed; although such cases exist, we would expect the opposite effect to prevail.

Even though the use of contract laborers (NAVETANE) has declined in recent years (see discussion in Chapter 3), 12 percent of the households in the analysis still use some. By tradition, contract laborers are provided a plot of land and peanut seed as part of their payment; hence, we expect households that use contract laborers to stock more seed in anticipation of the in-kind wages that will be required at the beginning of the planting season.

Although extension and other rural services (food bank or seed bank programs, for example) have been sharply curtailed during the last decade, we include the CONTACT variable to test the hypothesis that households with such contacts stock more of their own seed—a behavior that the agricultural services have tried to encourage.

We consider peanut seeding density to be predetermined, as recent work by Gaye and Sene (1994) confirms that land quality is the most important determinant of seeding densities. We expect that households using higher seeding densities (HISEED=1) will obtain more seed from all sources.[73]

Of the three variables reflecting assets, two are based on the quantity harvested the previous year. Higher cereal sufficiency ratios (CSR88) should improve liquidity (thereby increasing purchases), as household food demands are less likely to compete with seed demands. The quantity of the previous peanut harvest (PN88) should have a positive effect on seed stocks and a negative impact on purchases (assuming that farmers prefer to store, rather than sell and repurchase).

Seeders (NUMSEED) represent an input that complements seed, since more seeders permit more rapid seeding—the key to higher peanut yields. For this reason, we expect overall seed use to be positively correlated with the number of seeders owned. Seeders can also serve as collateral for food credit during the cropping season. Once seeding has taken place, the seeders are not needed until the following year; hence, farmers are willing to turn the seeders over as loan collateral. Seeders have also been sold to pay off both seed and food loans following a poor harvest (Kelly 1986). Although using seeders for collateral appears to be less common, now that it is much more difficult to purchase replacements, we expect a positive relationship between the number of seeders and the amount of seed obtained on credit, because the option is there to sell the seeder when repayment time arrives.

6.2.3. Regression Estimation Methods and Results

The ALLSEED regression is estimated using ordinary least squares (OLS). Given the large number of zero observations for the dependent variable in the other models, we use a Tobit estimation (maximum likelihood) to correct for estimation problems associated with the censored distribution (Maddala 1983). The models do not contain an intercept, and instead used all four

[73] If, however, there are quality differences among the sources (stocked seeds being better quality than purchased ones, for example), then farms using more of the poorer quality seed might be planting more densely because of seed, rather than land, quality. Although we believe this latter scenario is occurring (see Chapter 3), the farmers interviewed by Gaye and Sene (1994) rarely mentioned seed quality as a reason for denser planting.

zone dummies. For the estimate of the total value of all peanut seeds (ALLSEED), the marginal effect is equal to the estimated coefficient. For the Tobit models, the marginal effect of changes in the explanatory variables with continuous data is calculated using the estimated coefficients and the estimated value of sigma, as described in McDonald and Moffitt (1980) and Green (1992). The coefficients on the binary variables represent the effect of moving from one group to another.

Statistical Properties of the Models. Table 21 summarizes the results for all four models, showing the regression coefficients and the marginal change in the dependent variable given a one unit change in the explanatory variable. The OLS model of total peanut seed planted explains a large share of the variability in the data (adjusted R square of .81). Seven of the seventeen explanatory variables are significant at the .10 level or better.

The sigmas estimated in all the Tobit models are highly significant, confirming that it is necessary to correct for the censored distribution. There is no easily estimated measure of how much variability in the data is explained by the Tobit model (comparable to the adjusted R squared used for OLS models, for example). Consequently, we use the adjusted R squared values obtained for the same models run in OLS to compare the relative strength of the explanatory power for each model. The explanatory variables used appear to explain more of the variability in stocks (adjusted R square of .74) than the variability in cash purchases (adjusted R square of .52) or credit purchases (adjusted R square of .29). In other words, the regressions do a relatively good job of explaining stocks, a fair job of explaining cash purchases, and a poor job of explaining factors that influence the use of credit.[74] As the share of observations with use levels greater than zero increases, the explanatory power of the model increases. In the discussion that follows, we mention variables that are significant, with probabilities as high as .20, because we believe the low significance levels are due to the small sample size.

The ALLSEED Model. Interestingly, the liquidity variables (livestock and nonfarm income) do not have a statistically significant impact on the total value of seed used. This suggests that liquidity serves more as a stimulus for replacing household seed with outside sources that might be of better quality than for increasing the total quantity of seed acquired. Among the household characteristic variables, farm and household size are significant. An additional hectare of cultivated land increases seed expenditures by 7300 CFA francs, while increasing the household size by one adult equivalent decreases expenditures by 1700 CFA francs. This may reflect a tendency of larger households to plant more land in cereals, for food security reasons, which also decreases the quantity of peanut seed demanded. The only other characteristic variables of significance are the zone dummies for the two southern zones, suggesting that households in these zones use less total seed (all else being equal) than households in other zones.

All three of the asset variables are significant at better than the .10 level. An extra kilogram of harvested peanuts increases the total seed used by only 9 CFA francs (about 1/20th of a

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[74] During the research program, a considerable amount of time was spent trying to model the factors influencing a household's access to credit (endogenous switching models similar to Carter [1989], for example). Unfortunately, none of the analyses produced results with acceptable statistical properties and interpretations that met the test of common sense.

Table 21. Impact of a Unit Increase in Selected Variables on Peanut Seed Expenditure, by Mode of Acquisition

Dependent Variable→	**All Seed (OLS)**	**Stocks (Tobit)**		**Cash (Tobit)**		**Credit (Tobit)**	
	Coefficient Equals Marginal Impact	Tobit Coefficient	Marginal Impact	Tobit Coefficient	Marginal Impact	Tobit Coefficien t	Marginal Impact
Adj. R squared for OLS runs	.81	.74		.52		.29	
Independent Variable↓							
LIQUIDITY							
LIVESTOCK	.04	-.007	-.003	.003	.001	.08+	.04
NONFARM	.002	-.08**	-.04	.05**	.03	-.09+	-.04
FARM AND HOUSEHOLD CHARACTERISTICS							
FARMSIZE	7.3**	7**	3.5	.4	.18	1.1	.54
AE	-1.7*	-.9	-.5	-.9+	-.44	-2.6*	-1.3
MARKET	-2	-9.7	-9.7	-6.8	-6.8	13.3+	13.3
EDHHH	23.5	2.4	2.4	24.4**	24.4	-20.9	-20.9
EDKIDS	14.5+	6.3	6.3	17.8**	17.8	8.6	8.6
ZCW	1.6	3.6	3.6	-5.1	-5.1	-48.6**	-48.6
ZC	5.3	-22.8*	-22.8	19.4**	19.4	-5.4	-5.4
ZSW	-29.1*	-24.5+	-24.5	-6.0	-6.0	-16.6	-16.6
ZSE	-28.4*	-26+	-26	3.1	3.1	-26.2+	-26.2
NAVETANE	-3.8	-8.1	-4.0	5.5	-2.8	9.8	4.9
CONTACT	-.02	5.3	5.3	.84	.84	8.5	8.5
HISEED	9.7	-14.8+	-14.8	36.1**	36.1	13.4+	13.4
ASSETS							
CSR88	-29**	-27.2*	-13.5	-16.8*	-8.2	-4.5	-2.3
PN88	.009**	.01**	.006	-.002+	-.001	-.004	-.002
NUMSEED	10.3*	2.6	1.3	2.5	1.25	8	4

Source: Estimated from IFPRI/ISRA survey data (1989/90).
Notes: * indicates significance at .10 or better

** indicates that regression coefficient was significant at .05 or better.
+ indicates significance at .20 or better

kilogram), while owning an additional seeder is associated with 10,300 CFA francs more seed.[75] A higher cereal sufficiency ratio is associated with less rather than more peanut seed. It is possible that the variable reflects a household's preference for millet (in the crop mix sense) over peanut production rather than a better liquidity position.

The EDKIDS variable is significant at the .20 level, suggesting that either literacy and/or initiative (as hypothesized in 6.2.2.) may influence the quantity of seed acquired.

The Credit Model. Only two variables are significant at the .10 level or better in the credit model: household size and the zone dummy for the center-west. An increase in household size by one adult equivalent decreases seed credit by 1,300 CFA francs, and living in the center-west means that seed credit could be as much as 48,600 CFA francs less per farm than credit in the other zones.

A number of variables that are significant at the .20 level warrant discussion. The two liquidity variables appear to operate in different directions: more livestock income increases seed credit, while more nonfarm income decreases the amount of seed credit obtained. This result, when combined with the positive relationship between nonfarm and cash purchases (see below) suggests that households with more nonfarm income are able to purchase seed for cash so they use less credit.[76]

As noted in Chapter 5, farms with larger shares of nonfarm income tend to be smaller and obtain lower yields. The combination of these two factors may make them poor candidates for informal-sector credit. These results also support the hypothesis that households sell livestock to obtain cash, and then use the credit option more than the cash option because it requires less up-front cash at planting time (i.e., less liquidation of livestock assets).

The market variable is positive (13.3) and significant at the .2 level, suggesting that location in a market village may facilitate access to credit. This may be because cooperatives/GIEs in the market villages have better reimbursement rates, so members remain eligible for credit; it may also reflect more opportunities for informal credit from traders.

High seeding density also has a positive coefficient (13.4), suggesting that households seeding more densely obtain more seeds on credit than other households. Given the evidence presented in this document and elsewhere that denser seeding is associated with better yields (Gaye and Sene 1994), farmers seeding more densely may have more confidence in their ability to reimburse the credit.

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[75] The relative sizes of these effects reflect to some extent the value of each explanatory variable (70 CFA francs per kilogram of peanuts and 30-50,000 CFA francs for a seeder). The seeder price is for "reconditioned" equipment rather than new, as the latter was seldom purchased during the 1980s (see Chapter 3).

[76] An unresolved question is whether farms with more nonfarm income prefer to use cash rather than credit (reducing transaction and interest expenses) or whether they are not eligible for credit due to poor personal reimbursement records or high defaults by their cooperative/GIE.

None of the asset or education variables is significant, even at the .20 level.

The Cash Purchases Model. The nonfarm income variable is highly significant in the cash purchases model. An increase of 1,000 CFA francs in nonfarm income generates a 30-CFA franc increase in the value of peanut seed purchased for cash (this represents about one-sixth of a kilogram). This finding supports the argument offered above that farms with more nonfarm income prefer to increase cash rather than credit purchases. The size of the effect is, however, small. Given that a hectare of peanuts requires about 16,800 CFA francs for seed expenditures, nonfarm income would have to increase by 560,000 CFA francs to provide seed for an extra hectare of peanuts. This is a big increase, given that the average level of nonfarm income per household during 1988 was 111,500 CFA francs. Diagana (1994), in a qualitative follow-up survey of an IFPRI/ISRA subsample, found that nonfarm income is "first" used to buy food, and then "second" to buy peanut seed and repair animal traction equipment. This corroborates our statistical findings.

Among the variables that represent household characteristics, education of the household head and living in the central Peanut Basin both have strong positive influences on the amount of expenditures for cash purchases of peanut seed. Farms with an educated household head spend 24,400 CFA francs more on cash purchases than farms with illiterate household heads. Again, we can only speculate that literacy improves a household's ability to earn and manage cash, or that education is a proxy for initiative. The zone coefficients show that farms in the center spend 19,400 CFA francs more on cash purchases than farms in the other zones.

As mentioned above, the lower amount of seed stocks held in the center provides some justification for the larger credit and cash purchases. The reason for the lower stocks is not clear, as the peanut harvest was not unusually poor the previous year. Household size in adult equivalents is significant at the .20 level, and suggests that adding one more adult equivalent will <u>decrease</u> cash purchases by 900 CFA francs; this is the same negative relationship we obtained in the model of overall seed use.

Among the remaining characteristic variables, seeding density patterns have the biggest effect. Being in the top quartile with respect to peanut seed planted per hectare means spending 36,100 CFA francs more on cash purchases than other households. Having children in school is also important, increasing cash purchases by 17,800 CFA francs. Both results are significant at the .05 level or better.

Among the asset variables, only the cereal sufficiency ratio is significant at the .10 level. Increasing the ratio one unit decreases purchased seed by 8,200 CFA francs. This is the same type of relationship we found in the overall seed use model, again suggesting that households with higher cereal sufficiency ratios may prefer to cultivate more cereals and less peanuts. In other words, the hypothesized liquidity effect of having better cereal supplies (i.e., food purchases do not compete as much with peanut seed purchases) is overwhelmed by the household's desire to produce more cereal than peanuts. This decreases the demand for peanut seed from all sources for households with high cereal sufficiency ratios. The effect is much stronger than that associated with the liquidity variables. For example, a one unit increase in the cereal sufficiency ratio would cancel out the positive effect of a 273,000-CFA franc increase in nonfarm income! The peanut harvest variable (PN88) is also negative and significant at the .20 level. This is what we expect—a larger harvest means less need to purchase because one can stock seed. The impact is small, however; a one kilogram increase in the amount of peanuts harvested results in only a 1 franc decrease in cash purchases. This result simply confirms that the seed constraint is so important that increased personal stocks do little to curb attempts to acquire seed from other sources; both nonfarm income and the cereal sufficiency ratio have a larger impact on cash purchases than seed stocks.

The Stock Drawdown Model. We find that a 1000-CFA franc increase in nonfarm income results in a 40-CFA franc decrease in seed stocks. The decrease in stocks is 10 CFA francs larger than the increase in cash purchases generated by the change in nonfarm income, suggesting that seed purchases do not fully compensate for the lower stocks. As expected, livestock income does not have a significant impact on stocks.

The characteristic variables of significance are the zone dummies and cultivated area (FARMSIZE). Increasing the total area cultivated by one hectare increases the value of peanut seed stocks by 3500 CFA francs. This provides enough seed for about one-fifth of a hectare.

The zone dummies simply confirm that more peanut seed (about 25 kilograms more per household) is stocked in the center-west (the zone using virtually no credit) than in the other three zones. This appears to be due more to the personal preferences of the Serer farmers living in the zone than to better harvests.

The last characteristic variable of interest in the stock drawdown equation is seeding density (HISEED). Being in the top quartile for peanut seeding density is associated with having 14,800 CFA francs less of an investment in peanut seed stocks. Given that the level of significance is .20, we cannot draw strong conclusions from this result. The combination of the negative sign for this variable in the stocks equation, and the positive signs in the purchase and credit equations, suggests that seed quality may be an issue.

The prior-year harvest, as expected, has a positive but small influence on the amount of seeds stocked. An additional kilogram of production results in 6 CFA francs of additional stocks. In other words, it would take about 28 kilograms of extra output to generate 1 kilogram of additional seed stock. This contrasts sharply with the large negative reduction in stocks (-13,500 CFA francs) associated with an increase in the cereal sufficiency ratio.

6.3. Policy Implications

The explanatory variables that can be manipulated by policy, or that permit seed suppliers to target particular groups, are those variables that have the most important policy implications. We review the key findings concerning these variables in the following paragraphs.

6.3.1. Noncropping Income Sources

A key hypothesis is that noncropping income from livestock production and nonfarm sources can alleviate liquidity constraints and improve access to seed; hence, policies to increase income from these sources would benefit peanut production. The empirical evidence is mixed. On the negative side we find that:

(1) Neither livestock nor nonfarm income has a significant impact on the total quantity of seed acquired; and
(2) Increased nonfarm income is associated with a sharp decrease in the amount of peanut seed stocked that completely overwhelms the very small, positive impact on cash purchases.

On the positive side we find that:

(1) Increased livestock income is associated with small increases in credit purchases and no significant decline in seed stocks; and
(2) As credit purchases tend to be certified seed, the implication is that more livestock income could indirectly contribute to improvements in seed quality.

Although the direct impact on credit purchases is still relatively small (40 FCFA more seed for each 1000 FCFA of income), the implication is that policies and programs to increase livestock income will have a more positive impact on the quantity and quality of peanut seed used than programs to encourage growth in nonfarm income. Not only does increased livestock production have a positive impact on the acquisition of certified peanut seed, but livestock production can also contribute to soil fertility. Another plus is the fact that credit programs for livestock fattening activities have generally had better reimbursement rates than those for crop production.

The gist of these findings is <u>not</u> that programs to encourage nonfarm income growth are unnecessary, as there has been ample evidence that nonfarm income reduces income variability and improves food security (Kelly et al. 1993). The point is that in the very narrow context of improving the quantity and quality of the peanut seed used by farmers, increasing livestock income will produce better results.

6.3.2. Education and Extension

The education variable is associated with higher levels of cash purchases. All else being equal, a household with some formal schooling will spend 24,000 FCFA more on cash purchases than one without schooling. Similarly, a household with children attending school will spend 18,000 FCFA more on cash purchases. As we cannot be sure that education *per se* is responsible for these differences (rather than some underlying characteristic such as personal initiative), it would not be prudent to suggest that increasing literacy could increase cash purchases of peanuts. The result does suggest, however, that traders specializing in cash sales should concentrate their efforts in the zones which have higher literacy and school attendance rates (the southwest or center-west, for example) rather than zones with very low school attendance (the southeast, for example).

We consider the absence of a statistically significant link between seed acquired and contact with farmer support and extension services a reflection of the quality of the services during the survey period, rather than a measure of extension's capacity to influence seed acquisition behavior in the future. Extension services, particularly for peanut production, were cut back dramatically during the 1980s. Although this was the time when farmers first began storing their own peanut seed, there was little guidance from extension services on ways to cut storage losses and maintain seed quality. It was also during this period that many farmers began increasing peanut seeding densities to compensate for declining soil quality, receiving no technical advice on the long-term consequences of these practices for the quality of both seed and soil.

It is true that farmers in the Peanut Basin are extremely knowledgeable about peanut production; this does not mean, however, that there is no need for continued research and extension on peanut technologies and management practices. The changing physical and economic environments in which peanut producers are operating demand changes in production practices. Research and extension programs have an important role to play in ensuring that the new practices adopted by farmers move the rural sector toward sustainable patterns of agricultural intensification in both the short- and long-term.

6.3.3. High Seeding Densities

Interestingly, farmers who fall into the high-density seeding category store about 15 kilograms less seed than other farmers, while they purchase 36 kilograms more seed for cash and 13 kilograms more on credit. The underlying motivation for this combination of behaviors cannot be established precisely from the available data. One hypothesis is that farmers who are planting more densely recognize that seed quality is declining and are therefore storing less of their own seed and purchasing larger amounts, so as to improve their average seed quality. This hypothesis is not supported, however, by follow-up interviews with farmers who seed more densely than others, since these farmers rarely mentioned seed quality as being a problem. Another hypothesis is that those farmers who plant more densely prefer to sell most of their harvest, invest the peanut income in other activities during the dry season, and then purchase seed at planting time. The positive relationship we found between nonfarm income and cash purchases provides some support for the latter hypothesis.

Given the potentially negative impact of high seeding densities on seed quality, it is reassuring to know that those farmers who use the highest seeding densities do not rely entirely on their own seed from year to year. Although the relationship between seeding densities, soil quality, and seed quality is a complex one that clearly requires more attention from research and extension services, it appears to be in the short-term interests of the government to foster programs that will encourage more purchases of certified peanut seed in the center and southeast, where higher seeding densities are the most common. Improving access to credit in these zones would also increase the use of certified seed.

6.3.4. Cereal Sufficiency Ratios

The fact that an increase in the cereal sufficiency ratio is consistently associated with lower quantities of purchased peanut seed, regardless of the mode of acquisition, suggests that the currently employed, low-input intensive technologies do not encourage simultaneous production increases in both principal crops. There is a conflict between increased cereal production and increased peanut production, such that households who give priority to cereal sufficiency do so at the expense of peanut production.

This finding suggests that the government goal of increasing cereal production to 80 percent of the nation's needs by the year 2000, while still producing enough peanuts to satisfy industrial processing needs, will not be accomplished without policies that foster agricultural intensification.

7. SUMMARY OF MAJOR FINDINGS AND POLICY IMPLICATIONS

7.1. Fostering Agricultural Productivity Growth: Lessons from History

Although Senegal has experienced a number of spurts in agricultural production and productivity growth since independence, trends from 1960 through 1993 have been either stagnant (in terms of aggregate production and yields), or negative (in terms of real value of production). Although short-lived, the periods characterized by growth spurts provide insights about policies that stimulate productivity. Similarly, the periods of productivity decline serve as guidance on policies to avoid. Key insights from a historical review are:

Agricultural intensification and productivity growth are driven by cash crops with reliable markets and predictable prices—peanuts serve this role in the Senegalese Peanut Basin;

Agricultural research has had a major impact on maintaining peanut productivity despite sharp, secular reductions in rainfall (e.g., development of the shorter-cycle peanut varieties);

Although market liberalization has improved the efficiency of cereal markets, it has not had a strong impact on aggregate cereal production because cash crops are still more profitable and still have more predictable markets;

Vertically integrated extension, input distribution, credit, and output marketing systems serve well the geographically dispersed smallholder producers characteristic of the Senegalese Peanut Basin (and much of Africa), encouraging investment in agricultural intensification more than the less integrated systems that have evolved in recent years;

Although vertically integrated systems can respond well to African smallholders' needs, they can also become costly and inefficient, particularly if managed by individuals or institutions that respond more to political pressure than to business logic;

A lack of attention to rural literacy, extension, and farm-level financial analysis has fostered the adoption of such technologies as animal traction and fertilizer that farmers now find difficult to sustain. Paying more attention to (1) transferring the knowledge and skills necessary to increase the profitability of these inputs, and (2) conducting financial analyses of farmers' debt-carrying capacity would have improved the farmers' ability to capture the full benefits of these technologies and sustain their use;

As farmers' responses to changes in production incentives are often delayed by a cropping season or two, using data only on the physical output or the quantities of inputs purchased to evaluate productivity can lead to unfounded complacency about aggregate trends and delay needed policy changes. Had Senegal given more attention to economic analyses of the agricultural sector during the 1960s and 1970s, the severity of the economic crisis that brought structural adjustment to the forefront in the 1980s might have been diminished. There is evidence that Senegal failed to adequately monitor:

(1) Trends in farmers' real income;
(2) Trends in input/output price ratios;
(3) The net financial impact of agricultural subsidies and taxes on different stakeholders (farmers, fertilizer manufacturers, government, cooperatives, etc.).

7.2. Agricultural Productivity in the 1990s

7.2.1. The Typical Peanut Basin Farm

An average of 11 people (8 adult equivalents) cultivate 8.5 hectares of land allocated fairly equally between peanuts and millet/sorghum. Virtually all farms own at least one set of animal traction equipment (horse, seeder, and hoe), with the average amount of equipment per cultivated hectare meeting the recommended norms. The value of livestock holdings is 300,000 CFA francs—equal to about one year of income for the average household. Cereal production from the prior harvest averages from 50 to 75 percent of a household's annual needs, depending on rainfall and pest attacks.

Input Use Patterns. Although use of animal traction is ubiquitous, current production in the Peanut Basin must be characterized as low external input farming. Use of productivity- enhancing inputs has declined substantially during the 1980s and 1990s: aging animal traction equipment is not being replaced, fertilizer use is virtually nonexistent, the quantities of organic matter being returned to the soil are far from adequate, and use of certified or hybrid seed is extremely rare, as is the use of chemical inputs to protect seed quality or fight pests. Family labor is under-utilized during slack periods, while wage laborers are rarely hired during peak periods.

The key strategies being used by farmers to increase yields and/or incomes cannot be sustained in the long-term:

(1) extensification on marginal lands,
(2) increasing peanut seeding density per hectare to compensate for declining soil quality, and
(3) increasing the quantity, but not necessarily the quality, of labor.

7.2.2. Input Constraints

Constraints on the use of purchased inputs vary:

(1) Fertilizer is not used because it is considered too expensive and too risky at its current prices (peanut/fertilizer price ratios have been less than 1 during most of the last ten years, while farmers consider ratios in the 1.5 to 2.5 range appropriate);
(2) Fungicides are not used to protect peanut seed at planting due to inadequate appreciation of the yield-enhancing potential;
(3) Insecticides are not used to protect seed during storage because their application precludes future sale or consumption should that become a necessity due to poor harvests;

(4) Hired labor is rarely used because labor markets function poorly, due to the absence of a "landless" class available for hire during the peak periods; it is also more difficult to secure contract laborers for the entire season because farmers are unable to provide the traditional in-kind payment of enough peanut seed to cultivate one hectare of land;
(5) Certified seed is not purchased because (a) many farmers do not associate the higher price with higher yields, and (b) it is not marketed in convenient quantities, at convenient locations and times;
(6) The use of organic matter is inadequate because (a) reduced pasture prevents animals from staying in production zones, and (b) multiple uses of crop residues compete with crop production needs; and
(7) The agricultural credit system's failure to support variable loan repayment schedules, allowing for high inter-annual variability in crop yields, limits the role that credit can play in increasing the use of purchased inputs.

7.2.3. Economic Efficiency of Input Use

Although the economic efficiency of current input use practices varies by farm type and agroclimatic zone, two findings apply in almost all situations.

(1) If farmers continue to cultivate without fertilizer, the primary means of increasing yields and profits will be to increase seeding rates beyond their current levels (which already exceed the rates recommended by extension services); and
(2) The marginal value product of household labor is less than the prevailing wage rate, suggesting that more labor than necessary is being used in crop production.

In the case of peanuts, increased seeding rates mean denser planting to compensate for the deteriorating quality of soil and seeds. The danger here is that the pursuit of peanut yield increases and short-term profits will further mine the soil and deteriorate seed stocks in the long term.

In the case of cereals, higher seeding rates mean more attention to reseeding when the first seeding does not germinate well.

Although African agriculture is generally characterized as labor constrained, there is substantial labor slack for all activities but the first weeding in all zones but the southeast. This result can be explained by some combination of inadequate opportunities for employment in noncropping activities and/or households placing a lower value on their time than the prevailing market wage. Programs to generate rural employment during the slack periods, and/or technologies that reduce the weeding bottleneck, are needed.

In the southeast, the marginal value product of labor is higher than the wage rate, suggesting that more labor can be profitably used. More labor is needed in this zone because animal traction equipment owned per hectare is lower than elsewhere, soils are heavier, and rainfall higher (encouraging weed growth).

7.2.4. Factors Contributing to Higher Productivity

Location, farm size, access to cash, nonfarm income, input use patterns, and adequacy of caloric intake are the principal factors that differentiate high productivity farms from others.

Location. Our analyses confirm that zones with better soils and more rain tend to have better yields; there were, however, notable exceptions in 1989/90:

(1) Cereal yields in the southeastern Peanut Basin were significantly lower than those in less favorable zones; and
(2) Peanut yields in the drier northern and central zones were not statistically different from those in the higher rainfall zones.

Failure to control crop disease appears to have caused the low cereal yields in the southeast. We attribute the second result to the successful development and use of shorter-cycle peanuts that are well-adapted to conditions in the drier zones. Had these varieties not been developed, more than half the Peanut Basin would no longer be producing peanuts.

Farms located in market villages were no more productive or likely to use purchased inputs than farms with more difficult market access. This finding results, in part, from the already dense market coverage throughout the Peanut Basin—an indirect benefit of the early introduction of cash crops. Although research in other countries has shown that improved market coverage can be a boon to input purchases and agricultural intensification, increasing the number of market villages in the Peanut Basin will not have a measurable impact on productivity given the current production patterns and price relationships.

Farm Size. There is no clear link between farm size and productivity in the Senegalese Peanut Basin. A large farm size is correlated with higher peanut yields, and a smaller farm size correlates with higher cereal yields. This suggests that there may be economies of size in peanut, but not millet, production. It is also possible that small farms have land constraints and are intensifying their cereal production to free up land for peanuts.

Access to Cash. Farms with the best peanut yields have better access to cash at planting time. This access comes from a combination of higher overall incomes, larger prior-year peanut harvests, more livestock which can be easily converted to cash, and better access to credit. Access to cash improves the timeliness of seed acquisition and planting. It also facilitates the repair of equipment and hiring of day laborers. Access to cash does not differentiate high-productivity millet producers from others. This is not surprising because the costs of purchased inputs for millet are extremely low when compared to peanuts.

Nonfarm Income. Although there is evidence that noncropping income improves food security and is reinvested in cropping activities, we are unable to establish a clear link between high shares of noncropping income and better cropping productivity. There is a tendency for productivity (measured in yields) to decline as the share of nonfarm income in total income rises, yet there is no evidence that the former is caused by the latter. To the contrary, farmers with large shares of noncropping income (particularly those with small farms) appear to have been "pushed" into their noncropping activities by poor agricultural productivity and low cropping incomes. Our inability to establish a positive link between nonfarm income and productivity may be because (1) there is no such link, or (2) currently available data and modeling techniques are not adequate. More research is needed to determine the extent to which improving farmers' access to noncropping income can increase their agricultural productivity as well as their total household income.

Input Use Patterns. Higher peanut yields are obtained by farmers who use higher seeding densities and employ more household labor per hectare. We also note that those who obtain higher yields also purchase peanut seed at lower prices than other farmers. Higher millet yields are obtained by farmers who are diligent about reseeding, and who use more animal traction per hectare (for both the additional seeding and weeding).

Adequacy of Caloric Intake. Productivity measured in terms of returns to labor is higher in households that have better levels of caloric intake. This suggests that food security and health are important "inputs" influencing the quality of labor used in agricultural production.

7.2.5. Factors Contributing to Peanut Seed Acquisition and Quality

Two important objectives for the peanut sector are to (1) maintain peanut production at a level which keeps the processing industry running at or near capacity, and (2) increase farmers' incomes. Farmers' inability to obtain the desired quantities of peanut seed is a major blockage on the road to attainment of both these objectives. Although diversification toward noncropping sources of income is common in the Peanut Basin, peanut production remains the most important single source of income. Without more peanut seed and improved productivity in the peanut sector, rural households are unlikely to realize significant increases in their income.

Although some aspects of the seed marketing and distribution systems could be improved, farmers' inadequate cash reserves and poor access to credit are the principal bottlenecks to obtaining more and better quality peanut seed—at present, there is probably more of a demand- than a supply-side problem.

Programs to increase livestock income have the potential to improve farmers' access to peanut seed and stimulate credit purchases of certified seed. Such programs serve the dual objectives of increasing access to seed and injecting better quality seed into the production process, while contributing to improved soil fertility by making more manure available.

Other factors that encourage renewal of seed stocks through replacement of home-produced with purchased seed are higher levels of education and increases in nonfarm income. In other words, increasing the level of education or nonfarm income will increase the amount of seed purchased (for cash or credit). This increase in purchases is accompanied by a decrease in personal stocks of seed. Households using higher seeding densities also purchase more and store less seed.

One important factor associated with lower quantities of peanut seed is a high cereal sufficiency ratio. It appears that current low input intensive technologies do not encourage simultaneous production increases in both principal crops. This finding suggests that the government goal of increasing cereal production to 80 percent of the nation's needs by the year 2000, while producing enough peanuts to satisfy industrial processing needs, will not be accomplished without policies that foster agricultural intensification.

7.3. Where Do We Go From Here?

Senegal needs to encourage farmers to move from the present pattern of increasing yields by mining the soil to an agriculture based on more intensive production technologies that conserve the natural resource base while increasing returns to land and labor. The recent devaluation of the CFA franc has improved the profitability of export crops such as peanuts, and increased the demand for local cereals, yet there is little evidence that farmers are moving toward the type of agricultural intensification needed to meet Senegal's long-term income and food security goals. As this type of intensification is not only in the long-term interests of farmers, but also in the long-term interests of the entire nation, farmers cannot be expected to carry the full financial burden of the transformation. The government has an important role to play in fostering those policies and public investments that will induce private farmers and other business people to invest in the production, marketing, and use of more intensive, yet sustainable, agricultural production technologies. In the absence of this "enabling" environment, there is little hope for improving agricultural productivity.

Our objective is not to examine specific program options in terms of their costs and benefits and make precise recommendations, but to identify the strengths and weaknesses of farmers' production practices, government policies, and agricultural support services currently found in the Peanut Basin. The primary utility of our findings will be to focus attention on the critical issue of access to productivity-enhancing inputs. We believe the most urgent issues to address are:

(1) the quality and quantity of the peanut seed available to farmers;
(2) restoring soil fertility;
(3) renewing animal traction stocks;
(4) land tenure legislation; and
(5) increasing rural cash income to improve food security and input access.

The following paragraphs offer some ideas about remedial actions which are suggested by our research. The next logical step is to evaluate the relative costs and benefits of these suggested options, with the view of developing policies and programs that are economically feasible and sustainable.

7.3.1. Peanut Seed

We have identified the availability and use of high-quality peanut seed as the most urgent problem in the Peanut Basin. There is a need to improve farmers' capacity to pay for seed, as this not only increases the quantities planted but also contributes to improved seed quality through replacement of household stocks. Among the options to consider are:

(1) making more credit available;
(2) making reimbursement terms more flexible and responsive to high inter-annual variability in cropping outcomes; and
(3) promoting alternative cash sources (livestock and nonfarm enterprises) that can help farmers buy seed.

There is also a need to improve the seed storage, supply, and marketing systems. Some options to consider are:

(1) promoting the sale of certified seed through marketing campaigns;
(2) increasing distribution points for certified seed (at all markets instead of just at "collection points");
(3) encouraging sales of smaller units of seed than the standard 50-kilogram sacks now used;
(4) making certified seed available through the dry season, rather than just in the two-month period before planting;
(5) increasing competition in the production and sale of certified seed; and
(6) fostering extension programs that promote the use of insecticides and fungicides that maintain seed quality.

7.3.2. Soil Fertility

A major thrust should be to improve farmers' access to fertilizer. Options to consider are:

(1) cutting the costs of production and distribution through infrastructure investments that reduce transportation costs, reduction of import duties and taxes, and programs that increase fertilizer demand to levels that would foster economies of scale in production and distribution;
(2) judicious use of fertilizer subsidies based on cost-benefit analyses that show a net benefit of the subsidy to society in general;
(3) updating agronomic research on fertilizer response, with particular attention paid to the use of locally produced phosphates and technologies that combine fertilizer with improved farm management practices (water harvesting, wind breaks, bunds, etc);
(4) conducting cost/benefit analyses of the subsidies that would be required to increase fertilizer use to a more reasonable level (taking into account the risk associated with fertilizer use to avoid overestimating the beneficial effects); and
(5) greater private-sector involvement (extension services, demonstration trials, etc.) in the promotion of fertilizer use.

An equally important thrust is the need to promote greater use of organic matter to improve soil fertility. The principal sources are manure, crop residues, and urban wastes. Some possibilities for encouraging greater use of organic matter are:

(1) programs that promote livestock fattening to increase manure availability;
(2) feasibility studies for converting urban waste to soil supplements;
(3) research and extension on agroforestry technologies that increase green manure or animal fodder;
(4) programs that link input use and improved natural resource management practices (tying fertilizer credit to practices such as composting, for example); and
(5) programs to find substitutes for crop residues now used for purposes other than soil enhancement (promoting living fences rather than using crop residues such as millet stalks, for example).

7.3.3. Animal Traction Equipment

Most existing animal traction equipment is fully depreciated. In the next five to ten years there will be a major need for manufacturing, sales, and credit programs to encourage recapitalization of the animal traction equipment stock. Among the measures to consider are:

(1) credit and technical support to local blacksmiths who have been the primary source of equipment since 1980;
(2) creating a financial analysis unit in the extension services that can help farmers evaluate their debt-carrying capacity, particularly for traction equipment; and
(3) studying ways to reduce the production costs for industrially manufactured equipment.

7.3.4. Land Tenure Legislation

Our research suggests a need for land tenure reform that permits (and legally protects) land transactions so as to ensure better land allocation (i.e., those who need it, get it). This will increase cropping specialization by funneling more land to more productive farmers.

At the same time, research suggests that titling land so that it can be used as loan collateral does not have strong farmer support (farmers fear they will lose their land).

7.3.5. Income Diversification

Survey results suggest that most farmers do not want to abandon farming, but do want to diversify their income sources so as to reduce their risk, improve their access to inputs, and increase their income and food security. Policy options that would help farmers diversify their income sources include:

(1) the promotion of microenterprise programs (credit, training, etc.) in rural areas, particularly in fragile zones;
(2) industrial planning that encourages employment generating activities in rural areas that have high levels of underemployed labor; and
(3) programs that encourage the development of rural enterprises that support agriculture through upstream (input provision, for example) and downstream (output processing, for example) linkages.

APPENDIX 1

Fertilizer Consumption and Price Data: 1965-1994

Appendix 1. Fertilizer Consumption and Price Data: 1965-1994

Year	National Fertilizer Consumption in Tons	Percent of Fertilizer for Peanuts and Coarse Grains	Fertilizer: Farm Price in CFA francs per kg.	Fertilizer: Percent of Farm Price Subsidized	Peanuts: Producer Price in CFA francs per kg.	Peanut/ Fertilizer Price Ratio
1965/66	30,791	100	12	46	21.5	1.79
1966	47,545	100	12	44	20.5	1.71
1967	60,310	100	13	40	18.0	1.38
1968	35,536	100	12	45	18.0	1.50
1969	21,190	100	11	32	18.5	1.68
1970	14,820	86	11	34	19.5	1.77
1971	29,830	77	12	45	23.1	1.93
1972	49,570	78	12	62	23.0	1.92
1973	35,800	73	16	55	29.5	1.84
1974	63,830	87	16	44	41.5	2.59
1975	77,860	84	20	70	41.5	2.08
1976	86,670	80	25	57	41.5	1.66
1977	68,910	74	25	53	41.5	1.66
1978	69,690	75	25	50	41.5	1.66
1979	50,470	74	25	54	45.5	1.82
1980	74,680	76	25	61	44.0	1.76
1981	44,560	75	25	70	60.0	2.40
1982	25,410	38	25	77	50.0	2.00
1983	35,120	45	50	50	50.0	1.00
1984	41,168	50	90	0	60.0	0.67
1985	27,082	47	105	16	90.0	0.86
1986	19,900	58	65.6	27	90.0	1.37
1987	22,400	40	78.5	20	90.0	1.15
1988	23,032	36	80	9	70.0	0.88
1989	26,345	23	88.8	0	70.0	0.79
1990	22,801	na	88.8	0	80.0	0.90
1991	32,000	na	88.8	0	80.0	0.90
1992	30,445	na	88.8	0	70.0	0.79
1993	47,019	na	90	0	100.0	1.11
1994	38,600	33	130	0	120.0	0.92

Sources: Data through 1989/90 from USAID (1991); more recent information obtained from a variety of GOS sources, rough estimates, and personal communications from Senegal.
Notes: The peanut/fertilizer price ratio represents the number of kilograms of fertilizer a farmer can purchase with the income from one kilogram of peanut production. "NA" means data not available.

APPENDIX 2

Supplementary Tables to Chapter 5

Table 5.1 Locational Characteristics of High-Yield Farms Compared to Other Farms

Part A. Farms with High Peanut Yields

Location	Number of Households from the Location Expected to be High-Yield Farms	Actual Count of High-Yield Farms	Probability that Distribution of Highly Productive Farms Is Proportional Across Locations (*t*-test)
Market village	9.2	8	>.10
Zone			.03 (overall)
North	6.1	3	fewer productive than expected
Center-west	5.4	3	fewer productive than expected
Center	7.5	8	as expected
Southwest	5.9	6	as expected
Southeast	8.0	14	more productive than expected

Part B. Farms with High Millet Yields

Location	Number of Households From the Location Expected to Be High-Yield Farms	Actual Count of High-Yield Farms	Probability that Distribution of Highly Productive Farms is Proportional Across Locations (*t*-test)
Market village	10	9	no signif. dif.
Zone			.00 (overall)
North	6.6	3	fewer productive than expected
Center-west	6.1	6	as expected
Center	7.6	8	as expected
Southwest	6.4	14	more productive than expected
Southeast	8.3	4	fewer productive than expected

Source: Calculated from IFPRI/ISRA data (1989/90).

Table 5.2 Mean Values of Selected Characteristics for High-Yield Farms Compared to Other Farms

Part A. Farms with High Peanut Yields

Variable	Mean Values for High-Yield Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Total household income per AE for prior year (CFA francs)	48,944	38,863	.04
Share of off-farm income in total income for prior year	.32	.53	.00
Cereal sufficiency ratio from prior-year harvest	.62	.47	no signif. dif.
Agricultural credit for current year (CFA francs/household)	12,490	6,256	.08
Agricultural credit per hectare	3,911	2,864	no signif. dif.
Caloric intake per adult equivalent (kcal/day)	2,231	2,283	no signif. dif.
Value of livestock holdings (CFA francs/household)	531,367	319,977	.05
Seeders owned per hectare cultivated	.22	.20	no signif. dif.

Part B. Farms with High Millet Yields

Variable	Mean Values for High-Yield Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Total household income per AE for prior year (CFA francs)	41,981	40,866	no signif. dif.
Share of off-farm income in total income for prior year	.45	.49	no signif. dif.
Cereal sufficiency ratio from prior-year harvest	.57	.49	no signif. dif.
Agricultural credit for current year (CFA francs/household)	6,117	8,422	no signif. dif.
Caloric intake per adult equivalent (kcal/day)	2,255	2,281	no signif. dif.
Value of livestock holdings (CFA francs/household)	510,328	331,027	.10
Seeders owned per hectare cultivated	.26	.20	.06

Source: IFPRI/ISRA crop production data (1989/90).

Table 5.3 Input Use Patterns of High-Yield Farms Compared to Other Farms

Part A. Farms with High Peanut Yields

Input	Unit	Mean Values for High-Yield Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Land in peanuts	share	.53	.37	.00
Labor				
Total household	hours/hectare	494	367	.03
Hired labor	hours/hectare	6.5	5	no signif. dif.
Invitation labor	hours/hectare	29	13	no signif. dif.
Animal traction	hours/hectare	81	81	no signif. dif.
Seed	kilograms/hectare	119	87	.04
	CFA francs/kilogram	180	192	.06
Chemical inputs (mostly fungicide)	CFA francs/hectare	544	364	no signif. dif.

Part B. Farms with High Millet Yields

Input	Unit	Mean Values for High-Yield Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Land in millet/sorghum	share	.50	.58	.01
Labor				
Total household	hours/hectare	493	289	.00
Hired labor	hours/hectare	1.9	1.3	no sign. dif.
Invitation labor	hours/hectare	5.3	9.8	no sign. dif.
Animal traction	hours/hectare	85	54	.06
Seed	kilograms/hectare	6.1	4.1	.02
Manure	share of fields	.09	.07	no sign. dif.
Chemical inputs (fertilizer and fungicide)	CFA francs/hectare	485	78	no sign. dif.

Source: IFPRI/ISRA crop production data (1989/90).

Table 5.4 Marginal Physical Products of Key Inputs and Noncropping Income Shares

	Millet/Sorghum		Peanuts
Zones	North, Center-west, Center, and Southwest	Southeast	All Zones
Marginal Physical Products (MPP) of Inputs			
MPP of household labor in kilograms per day	6.97 (.00)	.11 (.78)	.62 (.00)
MPP of purchased inputs in kilograms per CFA franc of purchase	.09 (.05)	.009 (.83)	-.01 (.25)
MPP of seed in kilograms of threshed cereal and unshelled peanuts	57.1 (.00)	57.1 (.00)	8.9 (.00)
Noncropping Income Impact			
Small farms: MPP in kilograms of output for each percentage point increase in share of noncrop income	-389 (.00)	-389 (.00)	-467 (.00)
Large farms: MPP in kilograms of output for each percentage point increase in share of noncrop income	-249 (.06)	-249 (.06)	-247 (.15)

Source: Estimated using IFPRI/ISRA crop production data (1989/90).
Note: Significance level of marginal products in parentheses.

Table 5.5 Locational Characteristics of Farms with High Returns to Labor Compared to Other Farms

Part A. Farms with High Returns to Peanut Labor

Location	Number of Households From the Location Expected to be High-Return Farms	Actual Count of High-Return Farms	Probability That Distribution of Highly Productive is Proportional Across Locations (*t*-test)
Market Village	25	26	no signif. dif.
Zone			.007 (overall)
North	6.5	4	fewer high-return than expected
Center-west	6.8	2	fewer high-return than expected
Center	8	17	more high-return than expected
Southwest	6.3	9	more high-return than expected
Southeast	8. 5	3	fewer high-return than expected

Part B. Farms with High Returns to Millet Labor

Location	Number of Households From the Location Expected to Be High-Return Farms	Actual Count of High-Return Farms	Probability That Distribution of Highly Productive is Proportional Across Locations (*t*-test)
Market village	10.3	9	no signif. dif.
Zone			.00 (overall)
North	6.8	4	fewer high-return than expected
Center-west	6.3	4	fewer high-return than expected
Center	7.8	16	more high-return than expected
Southwest	6.5	10	more high-return than expected
Southeast	8.6	2	fewer high-return than expected

Source: Calculated from IFPRI/ISRA data (1989/90).

Table 5.6 Mean Values of Selected Characteristics for Farms with High Returns to Labor Compared to Other Farms

Part A. Farms with High Returns to Peanut Labor

Variable	Mean Values for High-Return Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Total household income per AE for prior year (CFA francs)	43,642	40,439	no signif. dif.
Share of off-farm income in total income for prior year	.45	.49	no signif. dif.
Cereal sufficiency ratio from prior-year harvest	.47	.52	no signif. dif.
Agricultural credit for current year (CFA francs/household)	13,689	5,738	.01
Agricultural credit per hectare	7,792	1,551	.07
Caloric intake per adult equivalent (kcal/day)	2,413	2,219	.03
Value of livestock holdings (CFA francs/household)	225,303	418,998	.01
Seeders owned per hectare cultivated	.20	.21	no signif. dif.

Part B. Farms with High Returns to Millet Labor

Variable	Mean Values for High-Return Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Total household income per AE for prior year (CFA francs)	41,712	40,950	no signif. dif.
Share of off-farm income in total income for prior year	.42	.50	.14
Cereal sufficiency ratio from prior-year harvest	.54	.50	no signif. dif.
Agricultural credit for current year (CFA francs/household)	10,257	6,983	no signif. dif.
Agricultural credit per hectare	6,267	2,058	no signif. dif.
Caloric intake per adult equivalent (kcal/day)	2,392	2,232	.07
Value of livestock holdings (CFA francs/household)	541,196	320,840	.17
Seeders owned per hectare cultivated	.23	.20	no signif. dif.

Source: Calculated from IFPRI/ISRA data (1989/90).

Table 5.7 Input Use Patterns of Farms with High Returns to Labor Compared to Other Farms

Part A. Farms with High Returns to Peanut Labor

Input	Unit	Mean Values for High-Returns Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Land in peanuts	share	.44	.39	no signif. dif.
Labor				
Total household	hours/hectare	256	445	.000
Hired labor	hours/hectare	6	5	no signif. dif.
Invitation labor	hours/hectare	10	19	no signif. dif.
Animal traction	hours/hectare	70	85	no signif. dif.
Seed	kilograms/ha.	129	83	.08
	CFA francs/kg	184	190	no signif. dif.
Chemical inputs (mostly fungicide)	CFA francs/ha.	160	488	no signif. dif.

Part B. Farms with High Returns to Millet Labor

Input	Unit	Mean Values for High-Returns Farms	Mean Values for Other Farms	Significance Level of *t*-test for Equal Means
Land in millet/sorghum	share	.53	.57	no signif. dif.
Labor				
Total household	hours/hectare	260	366	.12
Hired labor	hours/hectare	2.3	1.1	no signif. dif.
Invitation labor	hours/hectare	5.7	9.7	no signif. dif.
Animal traction	hours/hectare	55	64	no signif. dif.
Seed	kilograms/ha.	4.5	4.6	no signif. dif.
Manure	share of fields	.11	.06	no signif. dif.
	ha./household	.44	.35	No signif. dif.
Chemical inputs (fertilizer and fungicide)	CFA francs/ha.	419	97	no signif. dif.

Source: Calculated from IFPRI/ISRA survey data (1989/90).

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