Farmers' Demand for Fertilizer in the Context of Senegal's New Agricultural Policy: A Study of Factors Influencing Farmers' Fertilizer Purchasing Decisions

by

Valerie Auserehl Kelly

Reprint No. 19 1988

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SPECIAL NOTE FOR ISRA-MSU REPRINTS

In 1982 the faculty and staff of the Department of Agricultural Economics at Michigan State University (MSU) began the first phase of a planned 10 to 15 year project to collaborate with the Senegal Agricultural Research Institute (ISRA, Institut Sénégalais de Recherches Agricoles) in the reorganization and reorientation of its research programs. The Senegal Agricultural Research and Planning Project (Contract 685-0223-C-00-1064-00), has been financed by the U.S. Agency for International Development, Dakar, Senegal.

As part of this project MSU managed the Master's degree programs for 21 ISRA scientists at 10 U.S. universities in 10 different fields, including agricultural economics, agricultural engineering, soil science, animal science, rural sociology, biometrics and computer science. Ten MSU researchers, on long-term assignment with ISRA's Department of Production Systems Research (PSR, Département de Recherches sur les Systémes de Production et le Transfert de Technologies en Milieu Rural) or with the Macro-Economic Analysis Bureau (BAME, Bureau d'Analyses Macro-Economiques) have undertaken research in collaboration with ISRA scientists on the distribution of agricultural inputs, cereals marketing, food security, farm-level production strategies and agricultural research and extension. MSU faculty have also advised junior ISRA scientists on research in the areas of animal traction, livestock systems and farmer groups.

Additional MSU faculty members from the Department of Agricultural Economics, Sociology, Animal Science and the College of Veterinary Medicine have served as short-term consultants and professional advisors to several ISRA research programs.

The project has organized several short-term, in-country training programs in farming systems research, agronomic research at the farm-level and field-level livestock research. Special training and assistance has also been provided to expand the use of micro-computers in agricultural research, to improve English language skills, and to establish a documentation and publications program for PSR Department and BAME researchers.

Research publications from this collaborative project have been available only in French. Consequently, their distribution has been limited principally to West Africa.

In order to make relevant information available to a broader international audience, MSU and ISRA agreed in 1986 to publish selected reports as joint ISRA-MSU International Development Paper Reprints. These reports provide data and insights on critical issues in agricultural development which are common throughout Africa and the Third World. Most of the reprints in this series have been professionally edited for clarity; maps, figures and tables have been redrawn according to a standard format. All reprints are available in both French and English. A list of available reprints is provided at the end of this report. Readers interested in topics covered in the reports are encouraged to submit comments directly to the respective authors, or to Dr. R. James Bingen, Associate Director, Senegal Agricultural Research and Planning Project, Department of Agricultural Economics, Michigan State University, East Lansing, MI 48824-1039.

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ABSTRACT

This is a preliminary report on a study of Senegalese farmers' decisions to purchase fertilizer for use in rainfed agriculture. The report presents findings on farmers' perceptions of fertilizer productivity, patterns of fertilizer acquisition and use, and decision-making processes. A hierarchical decision model is developed for the 1985/6 season; implications for policy and marketing programs are discussed. The findings show that the principal impediments to fertilizer purchases during 1981-85 were poor cereal harvests and lack of financial liquidity; should these constraints be alleviated, farmers' preferences for investments which they consider more important (seed) or "less risky" (livestock, petty commerce, and agricultural equipment) will become the major constraints on use of fertilizer. It is recommended that small quantities of fertilizer be placed on sale in weekly markets from at least one month before to one month after the first rains in order to encourage purchases.

FARMERS' DEMAND FOR FERTILIZER IN THE CONTEXT OF SENEGAL'S NEW AGRICULTURAL POLICY: A STUDY OF FACTORS INFLUENCING FARMERS' FERTILIZER PURCHASING DECISIONS

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1988

This reprint originally appeared as "Farmers' Demand for Fertilizer in the Context of Senegal's New Agricultural Policy: A Study of Factors Influencing Farmers' Fertilizer Purchasing Decisions." Bureau d 'Analyses Macroéconomiques Institut Sénégalais de Recherches Agricoles, 15 September 1986

This reprint is published by the Department of Agricultural Economics, Michigan State University, under the Senegal Agricultural Research and Planning Project Contract 685-0223-C-00-1064-00 at Michigan State University funded by the U.S. Agency for International Development, Dakar, Senegal.

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ISSN 0731-3438

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Published by the Department of Agricultural Economics, Michigan State University, East Lansing, Michigan 48824-1039 U.S.A.

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UNDERSTANDING FARMERS' DEMAND: A CRITICAL ELEMENT IN DEVELOPING EFFECTIVE FERTILIZER MARKETING AND DISTRIBUTION PROGRAMS

Since 1980 Senegal has moved rapidly from a fertilizer distribution policy based on subsidized prices and farmer credit to a policy based on full cost prices and limited credit. Parastatal agencies previously responsible for input distribution have lost their mandate; the government, encouraged by certain foreign aid agencies, wants the "private sector" to take over. Neither the Senegalese government nor the private sector has previous experience in marketing fertilizer under these new credit and price conditions; hence there is no way of predicting farmers' demand. It is difficult for distributors to know exactly what products to make available, where, and when.

In view of this situation, the Bureau d'Analyses Macroéconomiques (BAME) of the Institut Sénégalais de Recherches Agricoles (ISRA) designed a research program to provide policy makers and private sector distributors with better information on farmers' decision making with respect to acquisition and use of fertilizer. The objectives of the program were:

1) To understand how farmers' attitudes toward and knowledge of fertilization techniques inhibit purchases;

2) To identify factors that have influenced past fertilizer purchases;

3) To understand how farmers evaluate the costs and benefits of fertilizer purchases;

4) To develop hierarchical decision models of the fertilizer purchase decision-making process;

5) To identify the major constraints on fertilizer use and to suggest measures to overcome these constraints.

This is an interim report that provides preliminary findings on farmers' perceptions, past patterns of fertilizer acquisition and use, and decision-making processes.[1] A hierarchical decision model is developed for the 1985/6 season; the implications for policy and marketing programs are discussed. The findings suggest that the chief impediments to fertilizer purchases during 1981-85 were poor cereal harvests and a lack of financial liquidity at the farm level. Should these constraints be alleviated, inadequacies in the fertilizer distribution system and farmers' preferences for investments that they consider more important (seed) or less risky (livestock, petty commerce, and agricultural equipment) will become the major constraints on fertilizer investment.

BACKGROUND ON THE STUDY AND RESEARCH DESIGN

We chose a behavioral study of farmer decision making as a first step toward a better understanding of Senegalese fertilizer demand because:

1) A literature review revealed that earlier studies have assessed farmers' willingness to purchase fertilizer primarily by determining whether value/cost ratios calculated using yields from researcher supervised trials were acceptable relative to given norms. This method unfortunately makes no use of information from farmers.

2) Econometric techniques frequently used to estimate fertilizer demand are inappropriate given the lack of good time-series data and the significant price, policy, and climatic changes experienced in Senegal during the last five years.

3) Recent policy or project documents have relied on unconfirmed hypotheses about farmers' attitudes concerning fertilizer use. This study seeks to move us from the realm of unconfirmed hypotheses about farmer behavior to concrete descriptions of what producers have actually done and why.

Given the limited financial and logistic resources available for the research, the Departments of Gossas and Nioro were selected as study areas

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[1]More detailed information and in-depth analysis will be included in a forthcoming Ph.D. dissertation on this topic.

because they represented two relatively different agro-ecological zones[2] in the Sine Saloum, which is the major peanut and millet producing area of Senegal. Formal questionnaire interviews with 98 farmers were followed by 46 in-depth informal interviews. The formal questionnaires were administered by four interviewers who had previous experience with farm level interviewing and data collection. The in-depth interviews were conducted by the principal researcher and an economist colleague from the region.

The sample was drawn from a 1983/4 sample of 105 farmers surveyed in the Departments of Gossas and Nioro by the Société de Développement et de Vulgarisation Agricole (SODEVA). Use of this sample provided access to two to four years of detailed input/output data on the farmers chosen for our study. (See Appendix I for characteristics of the 98 farms and Appendix II for a map locating the villages in the sample. For more details about the SODEVA sampling methodology see Gazagnes and D'Hiver, 1978.)

FARMERS' BELIEFS AND KNOWLEDGE ABOUT FERTILIZER AND FERTILIZER SUBSTITUTES

Although fertilizer has been available to Senegalese farmers since the 1950s, there is little reliable information on farmers' perceptions of its performance. Brochier (1965) conducted a farm level survey in the early 1960s on farmers' attitudes toward modern inputs. Finding that farmers considered chemical fertilizer too expensive for general use but of particular value on very poor soils, he concluded that farmers had a poor understanding of the technology.

This chapter discusses farmers' perceptions of: (a) the importance of fertilizer problems relative to other agricultural production problems, (b) the effectiveness of fertilizer relative to other soil renewal techniques, (c) the additional production obtained from millet and peanut fertilizer, and (d) correct fertilizer application technique.

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[2]Gossas has lower rainfall, shorter growing seasons, and sandier soils than Nioro. In recent years, government policy has favored Nioro farmers by allocating a larger share of officially distributed seed and fertilizer to them. This was done because the government believed that scarce agricultural resources were being wasted in zones such as Gossas where the risk of drought was very high.

The Relative Importance of Fertilizer Problems

Not a single farmer considered a lack of fertilizer to be his main production constraint during the 1981-85 period. Poor rains and lack of peanut seeds were the most frequently cited constraints. On the other hand, 28 percent did rank fertilizer problems among their three major bottlenecks.

Farmers who note the absence of fertilizer as a constraint are more likely to have purchased the input during the last five years than those not mentioning a fertilizer problem. Surprisingly, however, those farmers with access to organic fertilizers and fallow land are as likely to mention fertilizer constraints as those without such access.

Perceptions of Alternative Soil Renewal Techniques

Senegalese farmers have three primary options for soil renewal:

1) Chemical fertilizers

2) Fumier: Spreading manure from animals kept near the family compound. This technique requires a great deal of labor for transporting and spreading the manure on selected fields.

3) Parcage: Application of manure by cattle "parked" on a field for an extended period of time. This method usually provides more manure per unit of area and is less labor-intensive than fumier.

Farmers' comments concerning these three techniques provide important insights about their criteria for evaluating alternative fertilization methods and those factors that inhibit greater use. The most frequently cited observations were:

1) Parcage increases cereal yields more than fumier and fertilizer; it also has a four to five year carry-over effect.

2) Chemical fertilizer increases peanut yields more than other techniques. Organic fertilizers tend to increase the yield of hay but not that of peanuts; they also increase pest problems.

3) Horse manure increases striga weeds in Gossas, hence farmers in that zone prefer fertilizer to fumier on millet. Nioro farmers are less concerned with striga and rank fumier higher than fertilizer.

4) Fertilizer "kills" striga.

5) Chemical and organic fertilizers are substitutes, but farmers disagree about the rate of substitutability. For example, about half of the farmers believe that 50 kilos of chemical fertilizer could correctly fertilizer more area than the manure produced annually by one horse, and about half believe the opposite.

6) Labor shortages, lack of transport, and insufficient fodder to keep animals in the compound year round restrict the use of fumier.[3]

7) Insufficient pasture near the fields needing manure and fear that animals grazing on distant fields are easy prey for thieves restrict the use of parcage.

8) Parcage causes the most crop damage if the rains are not good and is therefore considered the most dangerous technique to use.

Despite the greater risk associated with parcage farmers continue to use it. The high risk of crop loss if rains are poor is compensated for by the carry-over effect which promises a good crop in subsequent years. With chemical fertilizer, the initial crop loss may be less but there is no carry-over effect. Furthermore, where risk is involved farmers follow two different strategies. They are willing to employ fully inputs that have few alternative uses (organic fertilizers, family labor or animal traction) in the hope that Allah will bring the necessary rains. When a cash investment (e.g., fertilizer) is involved, however, farmers more cautiously consider the consequences of poor rains since cash can be used to purchase food if harvests are bad.

Research by Sarr (1984) confirms farmers' beliefs that manure increases cereal production but has little positive impact on peanuts. Preliminary results reported by Thiam (1986) suggest that adding chemical fertilizer to millet fields having received organic fertilizers does not significantly

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[3]Easy access to chemical fertilizers during the credit program could also be considered a constraint on the use of "fumier" as 35 percent of farmers admitted that they did not make full use of available manure when they could afford chemical fertilizers.

increase yields for three of four millet varieties tested, but the added product obtained by applying only organic fertilizer is substantial. Thiam's results (from trials in Nioro) imply that farmers have little to gain by adding chemical fertilizer to organically fertilized millet fields; many Gossas farmers, however, will not use fumier unless they also have enough chemical fertilizer to "kill" the striga.

Comparing farmers' perceptions and concerns to those discussed in recent reports of research on organic fertilizers helps us identify future directions for research and extension programs. It is clear that researchers and extension agents should give greater attention to manure related striga and pest problems, particularly in Gossas. Researchers also need to pay more attention to developing recommendations for soil renewal programs that make optimal use of both types of fertilizer. This requires taking into account labor, transport, and cash constraints as well as the limited availability of manure.

Farmers' Perceptions of Fertilizer Response

Farmers' perceptions of fertilizer yield response were elicited because (1) existing response data are available largely from researcher controlled trials and therefore of questionable use as a guide to what farmers can expect, and (2) the value/cost ratio used by researchers to assess the economic appeal of fertilizer assumes that farmers have some concept of yield response. Table 1 compares the median[4] value of fertilizer yield response reported by farmers who were able to quantify the response with results from various trials and farm surveys.

A quick glance at the table highlights one of the greatest dilemmas facing farmers as well as agricultural technicians, researchers, and policy makers--existing data (whether simple perceptions or based on controlled experiments and surveys) are extremely variable. Much of the variability in the data is due to the different ways that stochastic factors are treated in analysis of fertilizer yield response. Agronomists frequently exclude data

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[4]Median values were used because we wanted to reduce the influence of extreme perceptions, which we thought were due more to farmers' poor grasp of measures used (kilos and hectares) than to actual yield response.

TABLE 1

FARMERS' PERCEPTIONS OF FERTILIZER RESPONSE COMPARED WITH EXPERIMENTAL, EXTENSION, AND SURVEY RESULTS

	Without Fertilizer (kilos/ha)	Additional Kilos/Hectare With Fertilizer[a]	Additional Kilos/Kilo Nutrient[b]
Peanut			
Gossas			
Farmers' perceptions[c]	950	+300	5.5
Extension demonstrations[d]	1,104	+230	4.3
Pre-extension trials[e]	1,100	+210	3.9
IFDC[f]	1,209	+155 - 415	1.9 - 5.2
Nioro			
Farmers' perceptions	1,300	+600	11.1
Extension Demonstrations	1,600	+473	8.6
Pre-extension trials	1,540	+250	4.6
IFDC	1,708	+232 - 436	2.6 - 4.8
SODEVA survey data[g]	1,186	+228	4.6
Millet			
Gossas			
Farmers' perceptions[h]	400	+300	7.1
Pre-extension trials[i]	370	+320	7.6
Land improvement trials	383	+647	15.4
IFDC	752	+491 - 874	3.5 - 6.24
Nioro			
Farmers' perceptions	600	+400	9.5
IFDC	664	+364 - 1,003	2.7 - 7.7
SODEVA survey data[j]	640	+74	2
Experimental units data[k]	358	+449	7.1

Notes: See following page.

Sources: (1) Farmers' perceptions are based on 1985/6 survey data for 31 farmers who were able to quantify peanut response and 23 able to do so for millet. (2) Extension demonstration data is from trials conducted in the 1960s and 1970s by the Institut de Recherches pour l'Huile et les Oléagineux (IRHO) and the Institut de Recherches Agronomiques Tropicales (IRAT) and reported in International Fertilizer Development Center (IFDC), April 1977, tables 28 and 29. (3) Pre-extension trial data is for 1965-71; reported in ISRA (1972), Annex III-2 and III-3. (4) IFDC data reported in IFDC (1980); see note 6 (next page) for explanation of how we interpreted the data. (5) SODEVA survey data for 1981 analyzed by us and reported in Kelly and Gaye (1985). (6) Land improvement data is unpublished data from 1973-80 ISRA

TABLE 1 - Continued

trials in the Amelioration Foncier program at Boulel. (7) Experimental Units data from 1972 survey in Thyssé Kaymor; data analyzed and presented in Ramond and Tournu (1974).

[a]Quantities and formulas applied vary by source therefore simple comparisons of additional kilos/ha are only valid when formulas and quantities are identical. The response per kilo of nutrient, reported in the next column, is a more appropriate measure for comparisons.

[b]Response per kilo of nutrient was calculated using the formula and quantity reported by each source. If no formula was specified, we assumed use of the most commonly available fertilizer for the zone and years concerned.

[c]Use of 60-20-10 (36 kilos of nutrient/100 kilos of fertilizer) was assumed for Gossas and Nioro. Quantities used per hectare were 50-225 kilos; 150 kilos was the modal and 175 the mean response. The response per kilo was calculated for each farmer; an average of the results is reported.

[d]Demonstrations in both Gossas and Nioro used 150 kilos/ha of 6-20-10.

[e]Pre-extension trials used 150 kilos of 6-20-10 per hectare in Gossas and 150 kilos/ha of 8-18-27 in Nioro.

[f]The IFDC designed trials to test various levels of each nutrient while the remaining nutrients were held at near optimal levels. A quadratic function, which did not include nutrient interaction terms, was estimated separately for N, P, and K. Given this design, it is impossible to estimate a precise yield response to total NPK. Response ranges presented above reflect our interpretation of data reported in IFDC 1980. Minimum response is obtained by using the IFDC function for the most productive nutrient (usually phosphorous in Senegalese peanut and millet production) and calculating expected yield response for the recommended dose of that nutrient. Maximum response is obtained by subtracting without-fertilizer yields from total yield estimated with the same function. We used the following nutrient application rates in our calculations:

Peanuts: Gossas N(10 kg/ha)-P(30)-K(40); Nioro N(10)-P(40)-K(40)
Millet: Gossas N(60)-P(40)-K(40); Nioro N(60)-P(34)-K(40)

[g]Use of 6-20-10 was assumed; average dose/ha was 64 kilos.

[h]Use of 14-7-7 (28 kilos of nutrient per 100 kilos of fertilizer) assumed for both Gossas and Nioro; application rates ranged from 50-200 kilos/ha; 150 kilos was the modal and 135 the mean response. Response per kilo of nutrient calculated as for peanuts (see note c).

[i]Millet data was not available for Gossas so we show here data on use of 150 kilos/ha of 14-7-7 in Tip/Theneiba which is located in the same isohyet as northern Gossas and (on the next line) 150 kilos/ha of 14-7-7 in Boulel which is in the same isohyet as southern Gossas.

[j]Average application per hectare was 65 kilos; use of 14-7-7 assumed.

[k]Average dose per hectare was 119 kilos; we assumed use of 8-18-27.

from experiments that have "failed" due to disease, insects, or destruction by cattle yet these are real risks faced by farmers. Many farmers interviewed discussed the potential effects of these factors when asked to estimate fertilizer response in a year of average rainfall. Most, however, were unable to systematically analyze the impact of these factors due to imprecise recall of past experience and a reluctance to analyze agricultural outcomes in probabilistic terms (everything depends on Allah). Non-stochastic factors related to farming practices (planting and weeding dates, use of pesticides, soil preparation, etc.) are another source of variation. Agricultural trial data are obtained under cultural conditions that are much more favorable than those encountered on a typical Senegalese farm.[5]

There are few clear patterns discernable in the data presented in table 1. Farmers' perceptions of without-fertilizer peanut yields are consistently lower than without-fertilizer yields reported for research and extension activities, but higher than SODEVA survey results. Farmers' perceptions of peanut response to fertilizer are greater than all other sources reported but the higher range of IFDC results. Millet data do not exhibit similar patterns. Farmers' optimism about peanut response is surprising given that they use poorer crop management practices than researchers. We suspect that farmers' perceptions are somewhat inflated due to a tendency to report responses experienced in a particular year rather than what can be expected on average.

Farmers' perceptions suggest that economic returns will be greater if fertilizer is used on peanuts (peanut responds more to fertilizer than does millet, and peanut prices are higher). Informal discussions with respondents revealed, however, that they prefer to use fertilizer on millet. Farmers seem to base fertilizer use decisions on the relative differences between fertilized and unfertilized fields rather than the absolute increases. Gossas farmers perceive a 75 percent and Nioro farmers a 67 percent increase in millet yield compared to only 31 and 46 percent increases in peanut yields.

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[5]For example, IFDC treated 50 percent of millet trials with pesticides. As farmers rarely use pesticides this could explain why IFDC fertilizer response tends to be higher than farmers' perceptions.

Peanut and millet value/cost ratios calculated with farmers' perceptions (using 1986/7 subsidized fertilizer prices of 64 FCFA/kg) range from 2.6 to 5.6. In all cases the perceived value/cost ratio exceeded 2--the level of economic returns which researchers have consistently maintained is sufficient to incite farmers to invest in fertilizer.

The discussion of perceived yield response applies to only 50 percent of farmers able to quantify millet response and 67 percent able to quantify peanut response. Those who were unable to quantify yield response generally believed that it was positive. Whether the inability of these farmers to quantify response inhibits fertilizer investment remains an open question. The biggest and most regular fertilizer purchaser interviewed was unable to quantify response, suggesting that such knowledge is not a prerequisite to fertilizer investment.

Farmers' Perceptions of Appropriate Fertilizer Application Technique

It has been suggested that the low demand for fertilizer arises from farmers' failure to follow recommended practices. It is argued that farmers apply inappropriate amounts, at incorrect times, on the worst soils. The mediocre results thereby obtained lead farmers to discount the value of fertilizer and choose other investments instead. Since most farmers do not follow ISRA's recommendations (spreading fertilizer before soil preparation and incorporating it into the soil with a light plowing), it is important to understand how and why fertilizer is actually applied.

Over 50 percent of farmers prefer to spread peanut fertilizer after the first weeding and millet fertilizer after thinning--much later than the recommended dates. Actual application dates reported in SODEVA data for Nioro were even later than expressed preferences; only 20 percent of peanut fields received fertilizer before the first weeding and only 10 percent of millet fields were treated before thinning.

The timing of fertilizer application is influenced to some extent by labor and equipment constraints, but personal beliefs about agronomic relationships and risk avoidance strategies are also important factors which influence application practices. An example of the former is the commonly

held belief that fertilizer should not be applied before weeding and thinning because early application "wastes" fertilizer on weeds and millet plants which are later removed. With respect to risk avoidance strategies, we found that most farmers are unwilling to apply fertilizer before plant emergence due to the risk of losing the entire investment from bad germination.

Other agricultural practices may also be responsible for less than optimal returns to fertilizer investments. Farmers know that fertilizer formulas differ for peanuts and millet but consider the two more or less interchangeable and thereby may get less than maximum possible returns (e.g., by using too much nitrogen on peanuts or not enough on millet). During the last five years fertilizer has been used almost entirely on cereals (millet and corn), although yield data and farmers' perceptions suggest that it could be used more profitably on peanuts. Farmers offer several explanations for this. It is easier to apply small quantities of fertilizer around selected millet plants than around peanut plants. In addition, given the small difference between peanut and millet prices, the need to assure cereal crops is dominant. Finally, as noted earlier, farmers influenced by relative rather than absolute yield increases prefer to fertilize millet instead of peanuts.

Extent to Which Beliefs and Knowledge Constrain Fertilizer Investments

This chapter has described farmers' beliefs about and knowledge of various soil renewal techniques and analyzed the extent to which beliefs and knowledge inhibit investment. At present the greatest constraint on fertilizer investment is farmers' tendency to give low priority to fertility problems--only 28 percent rank it among their top three constraints. Farmers have clear (although frequently conflicting) ideas about the pros and cons of chemical and organic fertilizers. In general, reliance on only organic fertilizer is not considered adequate. In recent years, however, threat of drought has caused farmers to rely on organic fertilizer rather than assume the dual risk of crop loss and loss of cash investments associated with chemical fertilizers. It is difficult to conjecture about

the impact of farmers' perceptions of yield response on investment decisions. Even though farmers tend to use agricultural practices which do not encourage maximum fertilizer response, the median value of yield response perceived by respondents was as good or better than most experiment and survey results. It is our impression, however, that the dual risk associated with the use of chemical fertilizers and farmers' beliefs that no one can predict rains do significantly constrain fertilizer investment despite the relatively high value/cost ratios calculated using farmers' perceptions.

FACTORS INFLUENCING FARMERS' FERTILIZER PURCHASING BEHAVIOR

When Credit was Available

This chapter describes fertilizer acquisition patterns and identifies those factors which influenced the quantity and frequency of purchases during the 1958-81 period when fertilizer credit was available.[6] Table 2 summarizes data on the mode of acquisition, the frequency of purchases and quantities bought.

The most popular mode of acquisition was credit only, but 35 percent of farmers made some cash purchases, usually from cooperative members selling credit-acquired fertilizer because they needed quick cash. Seventy-one percent of farmers purchased fertilizer for more than half of the agricultural seasons that they actually farmed during the credit program; but only 43 percent ordered annually. Those ordering less than half the time either had access to organic fertilizers or believed that fertilizer was not a good investment for them (they had very fertile soil or thought fertilizer was too risky). Gossas and Nioro farmers tended to order different quantities. (This is probably related to inter-zonal differences in farm size and access to organic fertilizer.)

Farmers explained that they did not analyze potential returns when deciding on quantities of fertilizer to order during the credit program

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[6]Credit was available in Nioro through the 1981/2 season; it was available in Gossas through the 1980/81 season.

TABLE 2

CHARACTERISTICS OF FERTILIZER ACQUISITION DURING THE FERTILIZER CREDIT PROGRAM

Dept.	No. of Cases	Credit Only	Credit Plus Cash in Same Year	Credit or Cash But Never Both In Same Year	Purchased Only	No Fertilizer Acquired
A. Mode of Acquisition						
Gossas	(22)	55%	4%	23%	4%	14%
Nioro	(24)	42%	33%	17%	8%	0%
Total	(46)	48%	19%	19	7%	7%

Dept.	No. of Cases	Every Year	>50% of Time	<50% of Time	Never
B. Frequency of Purchases					
Gossas	(22)	32%	27%	27%	14%
Nioro	(24)	29%	50%	21%	0%
Total	(46)	43%	28%	22%	7%

Dept.	No. of Cases	<5 Sacks	5-10 Sacks	>10 Sacks	Zero
C. Usual Quantities Purchased					
Gossas	(20)	35%	15%	35%	15%
Nioro	(24)	29%	50%	21%	0%
Total	(44)	32%	34%	27%	7%

because rains were generally good, fertilizer was cheap, and one did not have to worry about covering costs. Table 3 lists the factors cited as influencing fertilizer investments during the credit program.

Peanuts--both available seed and revenues--determined the size of most fertilizer orders because peanuts were the primary if not only source of revenue for debt reimbursement. A common decision process was to estimate revenues given seed availability and deduct from them anticipated agricultural debts (seed and equipment), and personal cash needs (clothing, rice, tithe, medical expenses, etc.). Fertilizer orders were then placed for an amount equal to or less than the expected balance. Thirty-two percent of farmers were guided by the expected production in a good year and only 15 percent considered available collateral. These two facts provide some insight into why agricultural debt defaults were common.

Farmers claimed that during the credit program fertilizer price increases were so small that they did not strongly influence fertilizer acquisition. Table 4 reveals that increasing fertilizer prices were generally cushioned by increasing peanut prices. An examination of total amounts of peanut and millet fertilizer sold suggests no clear relationship between fertilizer price changes and fertilizer demand before the credit program ended in 1981.

When Credit is not Readily Available

This section presents the general characteristics of fertilizer transactions during the 1981-85 period. It describes farmers' purchasing behavior and discusses the factors determining purchases and the types of economic reasoning involved. Most acquisitions during this period were cash purchases, but Nioro farmers had access to fertilizer through confectionery peanut or maize contracts and Gossas farmers were offered cowpea contracts in 1985.

General Characteristics of Fertilizer Purchases

In any given year between 1981 and 1985, 70 percent of farmers made neither cash nor credit purchases. The remaining 30 percent were unequally

TABLE 3

FACTORS INFLUENCING FERTILIZER INVESTMENT DECISIONS DURING THE FERTILIZER CREDIT PROGRAM

Factor	Number of Farmers Acknowledging Influence of Factor (N=46)
Anticipated peanut revenues	19
Relative success of previous harvest	11
Amount of peanut seed available	10
Change in the price of fertilizer	10
Anticipated social obligation	9
Value of collateral available for debt repayment if crop were to fail	7
Size of areas to be cultivated	6
Access to organic fertilizers	6
Soil quality of available fields	5
Anticipated revenues from all crops	4
Anticipated non-agricultural revenues	0

TABLE 4

PRICE RELATIONSHIPS AND QUANTITIES OF PEANUT AND MILLET FERTILIZER SOLD IN SENEGAL 1965-86

Agricultural Season	Producer Price of Peanuts (FCFA/kg)	Fertilizer Price Paid By Farmers (FCFA/kg)	Pn/Fert Price Ratio	National Fertilizer Sales for Peanuts (metric tons)	and Millet (metric tons)
1965/6	21.5	12	1.79	26,106	4,685
1966/7	20.5	12	1.71	38,423	9,122
1967/8	18	13	1.38	48,214	12,096
1968/9	18	12	1.50	25,891	9,645
1969/0	18.5	11	1.68	12,790	8,400
1970/1	19.5	11	1.77	6,490	6,199
1971/2	23.1	12	1.93	12,598	10,485
1972/3	23.1	12	1.93	22,426	16,435
1973/4	29.5	16	1.84	16,610	10,776
1974/5	41.5	16	2.59	30,473	24,909
1975/6	41.5	20	2.08	36,892	28,201
1976/7	41.5	25	1.66	46,859	30,644
1977/8	41.5	25	1.66	34,247	19,328
1978/9	41.5	25	1.66	36,700	33,133
1979/0	45.5	25	1.82	22,915	13,841
1980/1	46[a]	25	2	23,595	26,640
1981/2	60[b]	25	2.4	16,250	19,540
1982/3	60[b]	25	2.4	1,500	8,100[c]
1983/4	50[d]	50	1	1,200	14,700
1984/5	60[e]	90[f]	.67	8,920	11,548
1985/6	90	105[f]	.86	5,075	8,582
1986/7	90	64	1.4	not av	not av

Sources: 1965-79 from United States Agency for International Development (USAID), 1983; 1980-present, personal communication from USAID/Dakar. Data are approximate as different sources frequently contain conflicting information.

[a]50 FCFA minus retenue of 6 FCFA for debt repayment.
[b]70 FCFA minus retenue of 10 FCFA for seeds.
[c]Millet data for 1982 and 1983 unavailable; data shown are for all cereals (millet, sorghum, maize, and rice).
[d]70 FCFA minus retenue of 15 FCFA for seeds and 5 FCFA for fertilizer.
[e]80 FCFA minus retenue of 15 FCFA for seeds and 5 FCFA for fertilizer.
[f]Price of fertilizer distributed under retenue system. In 1985/6 small amounts of fertilizer subsidized by USAID were available for cash purchase at 60 FCFA/kilo; there were no recorded sales in the Sine Saloum.

distributed between the two zones with two to four times more farmers purchasing in Nioro than in Gossas. This is because:

1) Fertilizer has been more difficult to find in Gossas (Gambian fertilizer does not get that far north and the Senegalese credit program ended one year earlier in Gossas).

2) The overall financial situation of Gossas producers has seriously deteriorated since 1980; food shortages led to emergency sales of animals and agricultural equipment. Under such conditions, fertilizer purchases had extremely low priority (see Kelly and Gaye, 1985).

Figure 1 summarizes information on total quantities of fertilizer acquired through contracts, cash purchases, and the retenue, showing the percent from each source used on different crops.[7] Retenue fertilizer accounted for 22 percent of all acquisitions while contracts represented 26 percent and cash purchases 52 percent. Total quantities used were very small, averaging two sacks per farm per year. Distribution among farmers was very uneven. The share of fertilizer acquired each year by the largest purchaser ranged from 48 to 89 percent in Gossas and 25 to 56 percent in Nioro.

Changing trends in use are clearly illustrated by figure 2 which provides additional evidence that farmers prefer to fertilize cereal crops. The increasing share of Nioro fertilizer going to corn is due to expansion of areas cultivated whereas application on millet reflects changing attitudes about the best use of fertilizer.

Table 5 shows that fertilizer prices in informal markets have gradually risen but remain below current official prices.

Forty-five percent of all fertilizer transactions took place in weekly markets, 22 percent in a purchaser's own or a nearby village, and 12 percent in major urban centers (Gossas, Nioro, Kaolack).

Forty-eight percent of purchases were negotiated with other farmers who were trying to sell retenue, contract, or smuggled Gambian fertilizer while

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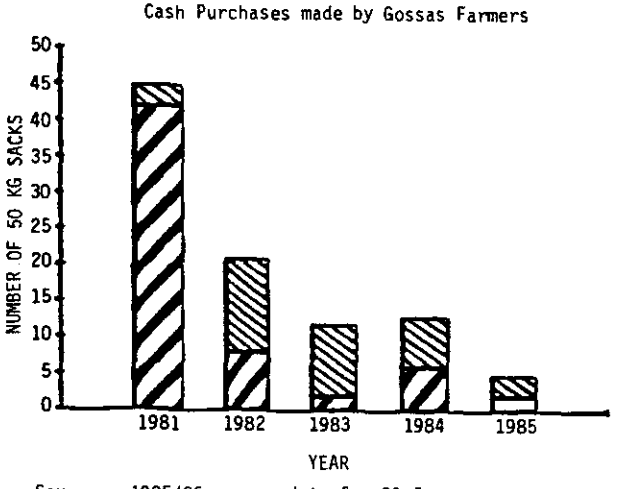
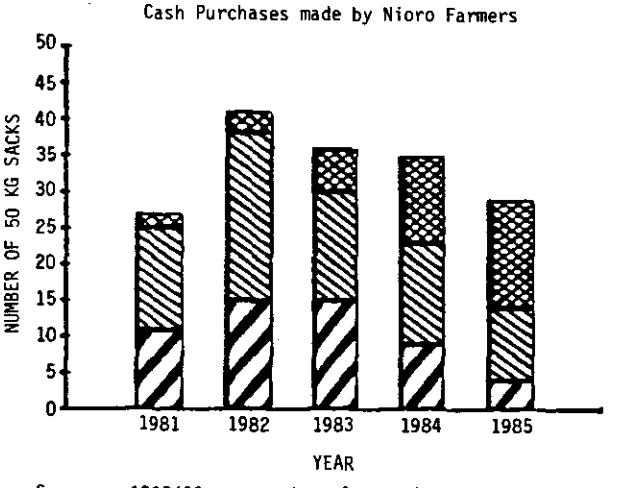
[7]The retenue was a government program which withheld part of a farmers' peanut revenues to cover the costs of peanut seed and fertilizer. Farmers who sold peanuts in official marketing channels were forced to participate whether or not they wanted the inputs. See Crawford, et al. (1985) for more details.

FIGURE 1

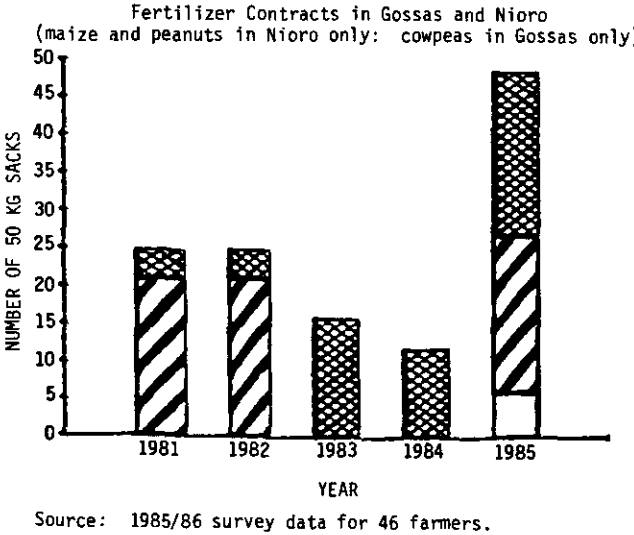
FERTILIZER ACQUISITION AND USE
1981-1985



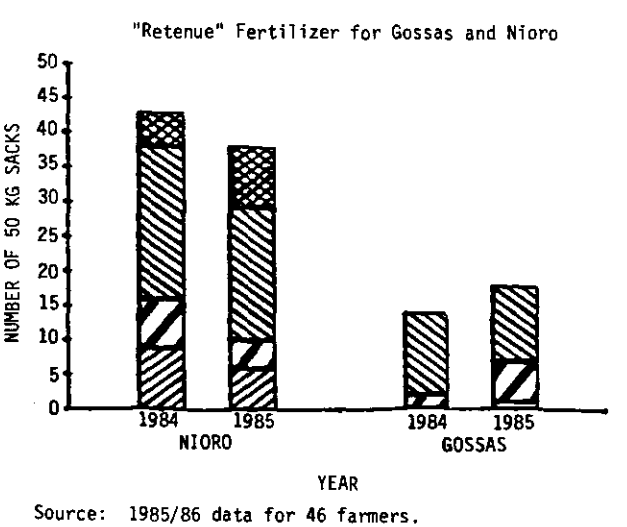
Source: 1985/86 survey data for 22 farmers.



Source: 1985/86 survey data for 24 farmers.



Source: 1985/86 survey data for 46 farmers.



Source: 1985/86 data for 46 farmers.

Note: Hatching shows proportion of each years' fertilizer employed for use specified in the legend.

TABLE 5

OFFICIAL AND INFORMAL MARKET PRICES OF FERTILIZER (FCFA/50 KILO SACK)

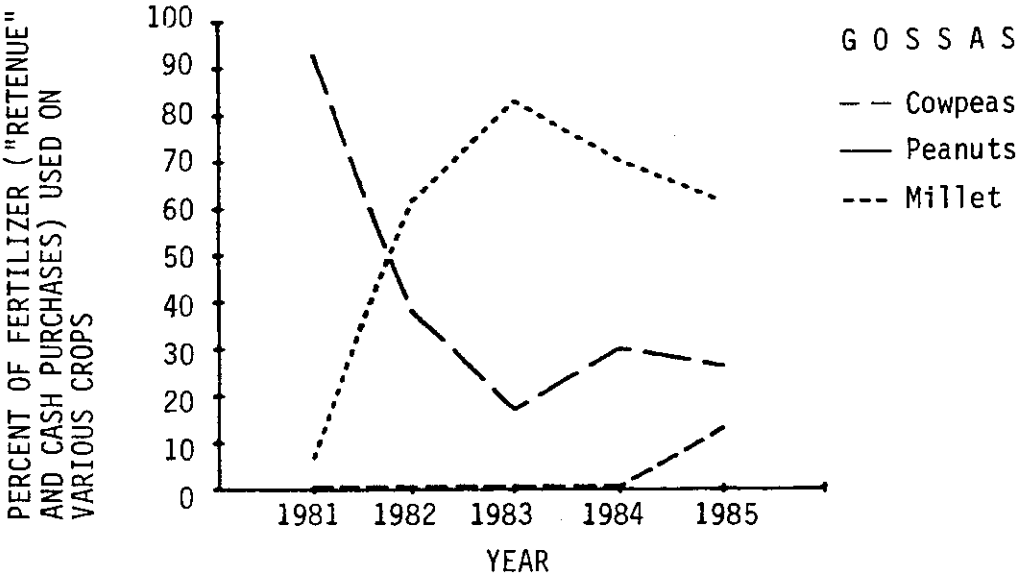
Year	Informal Market Prices	Official Price	
1981	500-1,250	1,250	
1982	500-1,500	1,250	
1983	1,000-2,500	1,250	
1984	1,000-1,700	4,550	
1985	1,500-2,500	5,250	for retenue fertilizer 3,000 for USAID subsidized fertilizer sold for cash

Note: Informal market prices failed to rise in 1984 because retenue fertilizer was distributed late and the market became temporarily flooded with farmers trying to liquidate unwanted stocks (see Crawford, et al., 1985).

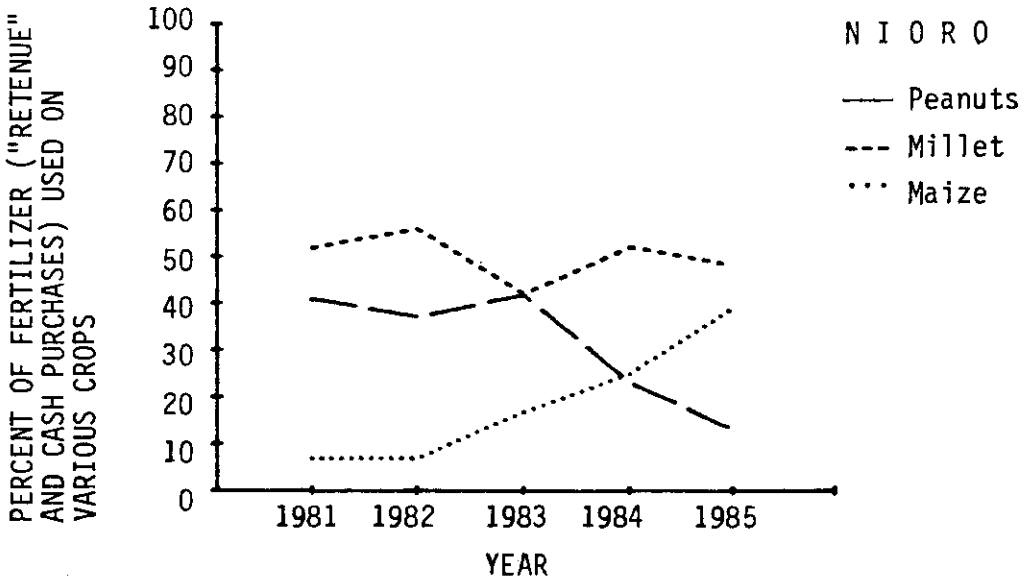
FIGURE 2

CHANGING TRENDS IN FERTILIZER USE
1981-1985

Only cash purchase and "retenue" fertilizer considered as farmers theoretically must apply contract fertilizer to specified crop.



Source: 1985/86 survey data for 22 farmers.



Source: 1985/6 survey data for 24 farmers.

forty percent were bought from traders. Official sales (by SODEVA or a cooperative) account for only 12 percent of the transactions. A sharp decline in farmer to farmer transactions is expected in 1986/7 because the retenue no longer exists, Gambia is rumored to be ending its subsidy, and few opportunities exist to obtain fertilizer on credit.

Only five farmers claimed that all fertilizer purchases were paid for with peanut revenues. Seven mentioned revenues from animal sales but in most cases the animal was not sold to finance the fertilizer purchase. Farmers were obliged to liquidate animals to buy food; some money was left over and they used it for small fertilizer purchases. Eight used revenues from livestock fattening or off-farm activities (maraboutage, village health worker, mason, petty commerce).

The conventional wisdom in Senegal holds that inputs must be available at the time of peanut marketing, when farmers have the most money, in order to encourage investment in agriculture. This conventional wisdom does not apply to fertilizer. Of 52 fertilizer transactions reported by respondents, only one took place at marketing time. Fifty-three percent of purchases were made at the beginning of the rainy season and 22 percent after crops had been planted. An additional 10 percent occurred at various times during the dry season. Fertilizer usually has not been available at marketing time; most supplies come from the Gambian distribution or the retenue, i.e. at the beginning of the rainy season. This is not, however, the primary reason for "late" purchases.

Many producers buy fertilizer with earnings from animal sales or off-farm activities. These activities make money available at the end of the dry season, partially explaining why purchases are delayed. In addition, those who do have alternative activities (particularly petty commerce) are unwilling to tie up resources in fertilizer instead of working with it throughout the dry season.

Since farmers believe that fertilizer is "like salt in the sauce," (i.e., a nice touch but not essential), this means that purchases will take place after more important investments are assured. During the 1985/6 season, as respondents got a better picture of their food and peanut revenue situation, anticipated fertilizer investments were repeatedly revised downward. Estimates by March were less than 50 percent of those in July.

Finally, to reduce risk, some farmers will not purchase fertilizer until the rains are well established and good plant emergence has occurred.

General Characteristics of Fertilizer Purchasers

Three factors distinguish fertilizer purchasers from non-purchasers:

1) Purchasing behavior during the fertilizer credit program
2) Attitudes about fertilizer and alternative investments
3) Access to non-crop revenues

Preliminary findings suggest that:

1) Farmers who had made some cash purchases during the credit program were more likely to have purchased in recent years.

2) Farmers whose combined cash and credit purchases during the credit program averaged more than 5 sacs per year were more likely to have bought in 1981-85.

3) Farmers who had non-crop revenues were more likely to have purchased than those who relied solely on crop revenues.

4) Farmers who did not buy were more likely to believe that an investment in 30 kilos of seed would increase yield more than an investment in 2 sacks of fertilizer.

5) Farmers who claim they apply fertilizer early (before the first weeding) were more likely to have purchased.

The correlation between non-crop revenues and fertilizer purchases suggests a number of different hypotheses: (1) fertilizer cannot pay for itself on a year to year basis, hence it must frequently be financed with revenues from other activities; (2) farmers using fertilizer realize enough profit to invest in non-crop activities; or (3) those with non-crop revenues have more disposable income and can therefore spend on items further down the priority list (e.g., fertilizer). The analysis conducted to date provides no clear evidence that one hypothesis is more tenable than the others. Under current circumstances (high prices, no credit, and low without-fertilizer yields) it is clear that most farmers must have non-crop revenues to make initial purchases under the new cash and carry sales system.

Not a single farmer who believed that an investment in 30 kilos of seeds would increase peanut yields more than two sacks of fertilizer

purchased fertilizer between 1981 and 1985. This suggests that attitudes about the relative productivity of seeds and fertilizer may play an important role in distinguishing purchasers from non-purchasers.

The correlation between purchases and early application requires further study: Are farmers' who apply fertilizer early getting better results (as agronomic research would suggest) and therefore encouraged to buy more fertilizer? Or, are those who apply early linked by some other characteristic (e.g., greater wealth, access to adequate supplies of labor) which facilitates early application?

A number of factors which were expected to distinguish purchasers from non-purchasers do not appear to be relevant:

1) Those farmers who possessed greater wealth in the form of animals did not have a tendency to purchase fertilizer more than others.

2) Farmers' rankings of alternative soil renewal techniques were not correlated with purchases; i.e., respondents who ranked fertilizer most effective for both peanuts and millet did not purchase more frequently than those who assigned lower value to fertilizer use.

3) Farmers with access to parcage were no less inclined than others to purchase fertilizer.

4) Farmers who believe that yields with fertilizer are always better (even if rains are not good) were not more inclined to purchase fertilizer.

ECONOMIC ANALYSIS AND INVESTMENT STRATEGIES

Economic Analyses Performed by Researchers

Researchers in Senegal have used different approaches to determine appropriate fertilizer application rates and evaluate economic returns. As a result there is little agreement on fertilizer recommendations and associated economic incentives. The method most frequently used by ISRA involves two steps: (1) a determination of appropriate fertilizer doses by assuring full nutrient replacement and (2) an ex-post economic analysis employing value/cost ratios which are calculated by dividing the value of added product by the cost of the fertilizer treatment. ISRA considered a

ratio equal to or greater than two as the minimum needed to encourage farmers to make fertilizer investments.

Value/cost ratios calculated using 1960-70s fertilizer response data from confirmation trials on farmers' fields and 1985/6 prices were greater than two for both peanuts and millet in the Sine Saloum. This was not true, however, for the North and North Central zones of the Peanut Basin (see Muon, 1985; Yung, 1984; and ISRA, 1975 for examples of this type of analysis). The fact that fertilizer use has declined even though value/cost ratios remained greater than two in the Sine Saloum suggests that the convention of using a ratio of two as an indicator of farmer behavior needs to be reviewed.

The second type of analysis uses econometric techniques to estimate the dose of fertilizer that will maximize farmers' profits. In 1976 and 1977 SODEVA with the assistance of the Tennessee Valley Authority and the International Fertilizer Development Center (IFDC) conducted controlled trials on farmers' fields to develop fertilizer response curves and identify that combination of N, P, and K which would maximize a farmers' profit for each zone covered by the study.[8] This approach resulted in optimal fertilizer levels which could not be implemented without making significant changes in the formulas currently recommended by ISRA. The most drastic changes recommended for the Sine Saloum were the elimination of nitrogen on peanuts and increase in the proportions of phosphorous and potassium in millet formulas.[9]

The debate over the differences between the ISRA and IFDC recommendations continues. Proponents of the "nutrient replacement" method warn that many of the recommendations based on "profit maximization" will lead to

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[8]"Profit maximization" was approached from two perspectives: (1) the pure profit maximizing point (value/cost ratio = 1) and (2) a more conservative, farmers' point of view which compensated for risk and real farm management conditions (value/cost ratio = 2).

[9]For example, where ISRA had recommended 150 kilos of 6-20-10 for one hectare of peanuts IFDC proposed 100 kilos of 0-27-24; where ISRA had recommended 150 kilos of 14-7-7 for one hectare of millet, IFDC proposed 110 kilos of 12-36-35 plus 82 kilos of urea. This is an over-simplified presentation of IFDC results. Those seeking more precise information should refer to IFDC, 1980.

irreversible deterioration of Senegal's soil resources; proponents of "profit maximization" hold that resources are being wasted by recommending levels of fertilizer which are not economically justified and beyond the means of the average farmer (particularly in the more arid northern zones).

While past experimental research provides some guidelines for evaluating economic returns to fertilizer, there is no question that better data are needed on yield response obtained by farmers. Some data are available from Unités Expérimentales and Programme Moyen Terme Sahel work conducted during the 1970s (see Raymond and Tournu, 1974; Raymond, Fall, and Diop, 1976.); but given the extreme inter-annual and inter-zonal variations, it is imperative that a more systematic program for collecting fertilizer response data for farmers' fields over time and space be instituted.

Economic Analysis by Farmers

This section reviews (1) the types of economic analyses farmers use when making fertilizer investment decisions and (2) the extent to which methods used by researchers might lead to the same conclusions as those used by farmers. Several techniques were employed to assess farmers' concepts of profitability:

1) Farmers who could quantify fertilizer response for a year of average rains were requested to calculate the value added per hectare and then determine if a farmer paying 18,000 FCFA for 3 sacs of fertilizer would realize any profit; if not, the farmer was asked to estimate the maximum profitable fertilizer investment.

2) These farmers, as well as those unable to quantify yield increases, were then asked the maximum price that they would be willing to pay for a sack of fertilizer.

3) Farmers were also asked to estimate the income they would have to be able to expect from a peanut field before investing 18,000 FCFA in fertilizer. This estimate was converted to kilos, and the without-fertilizer peanut yield previously cited by the respondent was subtracted from it so that the difference could be used to calculate the farmer's minimum acceptable value/cost ratio.

4) Finally, farmers were asked to state the criteria they used to judge whether fertilizer was expensive.

None of these techniques produced very satisfactory answers. Responses to the first question varied considerably partly because farmers have different perceptions of yield response or different perceptions of what return is "profitable," and partly because some have an instinctive feeling about fertilizer costs irrespective of potential returns on investment. A comparison of four answers illustrates the range of responses as well as ability to conceptualize the issue.

One farmer believed that 2 sacks of fertilizer (100 kilos) produce 300 to 400 kilos of peanuts on average. He claimed that if the fertilizer costs 5,000 FCFA per sack, the investment eats up all the profits. Assuming a 90 FCFA/kilo price for peanuts, the net benefit for 300 kilos of added product is 17,000 FCFA. In his example, it is obvious that all profits are not eaten up, yet he firmly believes that 5,000 FCFA is too much to pay for fertilizer.

A second farmer said that any price of fertilizer which left him with at least 2,000 FCFA net benefit per hectare in an average year would be acceptable. This fellow is either very risk preferring or happy with rather low returns.

A third farmer said that the gross returns on any investment should be two times the amount of the investment--once to cover the cost of the investment and once for profit. He pointed out that the cost of the fertilizer investment in this case was not only the cost of fertilizer but all additional costs of labor, transportation, etc. (This farmer, the biggest fertilizer user in our Nioro sample, was able to discuss investments and profits in terms that would please any economist yet he was unable to quantify the added product that one obtains by applying fertilizer!)

The final example is a farmer who was unwilling to commit himself to a price beyond his current rather limited means--his maximum price was 1000 FCFA per sack and he would not consider whether a higher price could be profitable.

The same type of variability is apparent in answers to the question about acceptable value/cost ratios. Nine respondents gave a value which was lower than their perceptions of without-fertilizer peanut yields, making it impossible to estimate meaningful ratios. The large number of invalid responses erodes somewhat our confidence in the apparently valid responses:

are they really the result of thoughtful analysis or merely wild guesses which happened to be larger than the previously stated values for unfertilized peanut fields? Nevertheless, ratios calculated ranged from 1.1 to 11.7 with a median value of 4. It is evident that use of a value/cost ratio of 2 is not a very good guide to farmers' behavior; first of all most farmers do not make fertilizer investments based on such ratios and secondly the median ratio suggested by farmers was 2 times the value used by researchers.

It is difficult to evaluate the maximum price farmers would be willing the pay for a sack of fertilizer. Several farmers offered very low prices, obviously taking their current financial situation into consideration. Other farmers, concerned that their responses might be used to justify higher prices, either refused to answer ("It's up to the authorities to set fertilizer prices.") or gave lower prices than they might really be willing to pay. Table 6 summarizes the responses. The 2000-2500 FCFA range was the median as well as the modal response. Farmers in Nioro had a tendency to be willing to go higher than Gossas. Of the seven Nioro farmers suggesting that they were willing to go higher than 3000 FCFA, 5 bought fertilizer during the last five years, which lends some credibility to their answers.

Farmers' criteria for judging the expense of fertilizer are listed in table 7. Three of the criteria (1, 3, and 4) all relate in some way to the problem of financial resources. Farmers do not believe that fertilizer is too expensive because average returns do not justify the investment, but because their agricultural earnings do not even cover other more important agricultural and non-agricultural needs. The key to understanding this view lies in an expenditure survey that identifies where fertilizer fits in the farmer's investment/expenditure strategy.[10]

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[10]Prior research suggests that when farmers receive their crop revenues, food and personal consumption expenditures (clothing, beds, housing repairs, etc.) are given priority. (Niang, 1984; Nguyen-Van-Chi-Bonnardel, 1978) When cash is not available, many more farmers are willing to resort to credit for food, baptisms, funerals, and weddings, than are willing to incur debt for agricultural investments. (Tuck, 1983) These findings suggest that in order to fully understand farmers' willingness and capacity to put money into agriculture better data is needed on the percent of revenues allocated to consumption expenditures.

TABLE 6

PRICES FARMERS ARE WILLING TO PAY FOR FERTILIZER (PERCENT OF FARMERS)

FCFA/50 Kilos	Peanuts	Millet
< = 1,000	6	6
1,001 - 1,500	14	6
1,501 - 2,000	14	18
2,001 - 2,500	34	29
2,501 - 3,000	11	18
3,001 - 3,500	11	15
3,501 - 4,000	6	6
4,001 - 4,500	3	3

TABLE 7

FARMERS' CRITERIA FOR JUDGING THE COSTLINESS OF FERTILIZER

Criteria	Percent of Respondents
1) It is expensive when you do not have the means to buy it at current prices	40
2) If we could count on the rains we would not say it was expensive	17
3) Price of fertilizer should be judged by the price of peanuts (5 responses) or the price of millet (1 response)	14
4) If you do not have peanut seeds fertilizer is expensive at any price	10
5) At current prices fertilizer absorbs what it brought	10
6) Expense depends on the intensity of your needs; those who have poor soils and no organic fertilizer will be willing to pay more	7
7) One judges the price by past experience and today's price is 4 times what we were accustomed to during the credit program	2

The peanut/fertilizer price relationship is used by some farmers to judge fertilizer expense. Table 8 presents a frequency distribution of acceptable price/cost ratios (price of peanuts per kilo divided by the price of fertilizer per kilo) suggested by farmers. During the credit program the ratio only exceeded 2 four times (see table 4), yet 72 percent of the farmers queried think it should be greater than 2. There is no evidence that fertilizer consumption was constrained in years that the peanut/fertilizer ration was less than 2 and credit was available; whether this will also be true in a no credit system remains to be seen.

Risk is the second most prevalent criterion for judging fertilizer expense. Seventeen percent of farmers stated that fertilizer would not be expensive if it rained, thereby implying that even at current prices it would be profitable if the rains were good. While most farmers lack the concepts of probability necessary to analyze risky investments systematically, they do classify investments into categories of more or less risky. It is on this basis that farmers invest their limited resources in animals and banabana (petty commerce) before fertilizer.

Finally, it should not be overlooked that 17 percent of farmers (criteria 5 and 6) gave responses which suggest some inclination toward analysis of marginal costs and returns--expense is judged in terms of the added value that an investment brings to the investor and those who are likely to get more added value are likely to pay higher prices.

It is highly unlikely that the criteria used for judging fertilizer expense described above would lead to conclusions about profitability similar to those of researchers using value/cost ratios or profit maximization analyses. Very few farmers have the requisite knowledge of yield response and the mathematical skills (simple addition and multiplication) to calculate potential profits accurately. More important, the types of economic analyses commonly employed by researchers inaccurately dichotomize the choice as fertilizer or no fertilizer. The real choice faced by farmers is fertilizer, or seeds, or equipment, or livestock, or....any number of non-agricultural investments and consumption expenditures.

TABLE 8

FREQUENCE DISTRIBUTION OF ACCEPTABLE PEANUT/FERTILIZER PRICE RATIOS

Ratio	Percent of Farmers
<1	4
1-1.99	25
2-2.5	54
>3	18

Farmers' Investment Strategies

Most farmers have distinct priorities for disposing of their limited incomes, based on rudimentary analyses of investment profitability and considerations such as keeping their children on the farm, maintaining sufficient liquidity to cope with emergencies (food shortages, illness) or unexpected social obligations. During the 1985/6 campaign survival, not profit, was the key decision making criterion for most farmers.

The 98 farmers interviewed in the general survey were asked how they would have invested 15,000 FCFA had they had that amount of cash available in May 1985 (i.e., just before the rains). Fifty-two percent said they would have invested in seed and 40 percent chose food. Second and third choices also indicate low priority for fertilizer (see figure 3).

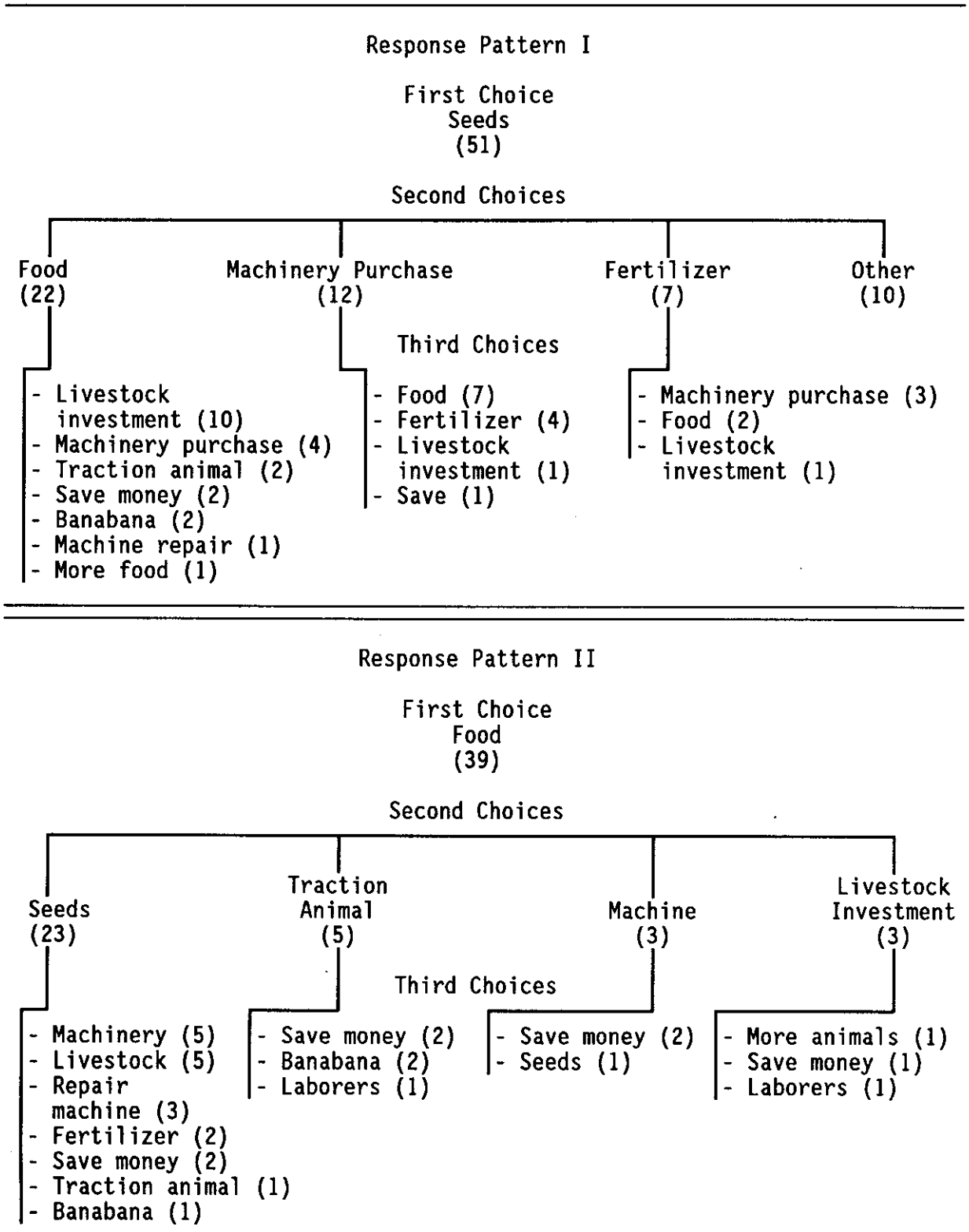
Future fertilizer demand will be determined largely by farmers' concepts of minimum peanut seed requirements and ability to secure these seeds. During in-depth interviews 69 percent of farmers stated that if they had sufficient food but no peanut seed or fertilizer at the beginning of the agricultural season, and total cash on hand was 20,000 FCFA, they would spend the full amount on seed. Seven percent would buy some seed and save the rest for day to day needs (kola, unexpected emergencies, etc.) while 24 percent would buy seeds and some fertilizer (seed purchases ranged from 50 to 95 percent of the available cash).

Seventy-seven percent of farmers specified a minimum quantity of seeds they would have to obtain before thinking about fertilizer. Replies ranged from 100 to 2000 kilos of shelled seed. The median reply was in the 300 to 500 kilo range which represents roughly 4 to 7 hectares of peanuts, exclusively for the household head. Amounts given were generally several times greater than quantities actually planted in 1985.

Discussions with farmers suggest that labor contracting procedures and obligations to provide peanut seeds to family members may be perpetuating extensive agricultural techniques and constraining fertilizer purchases. More than 70 percent of farmers would not buy fertilizer before procuring a large quantity of seed even though they believe that a fertilizer investment would increase production more than an equal amount invested in seed. This is because the head of household must be able to offer land and peanut seeds

FIGURE 3

FARMERS' INVESTMENT PRIORITIES 1985/86
(NUMBER OF RESPONSES IN PARENTHESES)



as part of the contract when hiring seasonal laborers. Similarly, if he wants to keep his sons at home, he must offer them land and seed capable of producing agricultural revenues greater than their expectations of earnings in Kaolack or Dakar. This issue requires more detailed study.

Responses to a series of questions concerning farmers' willingness to transform cash and livestock resources into fertilizer investments once more pressing food and seed requirements were met suggest that 81 percent would be willing to spend some of their remaining cash on fertilizer and 61 percent would be willing to sell some animals to pay for fertilizer. The probability of the first two conditions being met, however, is relatively low. Most farmers came nowhere close to procuring their minimum seed requirements last year and most are likely to experience the same phenomenon in 1986/7 (see Gaye, 1986, and Niang and Sarr, 1986). Survey data for the 1981-85 period show that 94 percent of 98 farmers experienced food deficits at least once; more than 50 percent have had 2 to 3 deficit years. Fifty percent of farmers in our sample feared that they would experience cereal shortfalls again this year despite the relatively good rains and high hopes for the 1986 harvest.

The relative profitability of investments that farmers claim are more profitable than fertilizer (livestock and banabana) also require further examination. No data are available on returns to banabana and it is difficult to generalize from the studies which have been done on livestock for they cover very specific zones and activities (see Faye and Landais, 1984; Demus and Tchakerian, 1977). The most recent and reliable data on cattle fattening activities in the north-central peanut basin show that in only 75 days farmers realized net profits of more than 50 percent on investments (costs of animals and feed were both included in the value of the initial investment) (Faye and Landais, 1984, p. 16). Farmers' perceptions of their profits are even greater for they do not consider the opportunity cost of crop residues used as feed. In addition to specific fattening activities, farmers think that investments in small ruminants or cattle, kept in a herd or allowed to graze in nearby fields, are dependable investments. Animals increase in value through growth and reproduction and the danger of disease or death is less than the risk of loss associated with

fertilizer. Furthermore, animals can be sold at any time, thereby providing liquidity.

These perceptions of the relative profitability of animal and fertilizer investments explain why 38 percent of farmers are unwilling to sell animals in order to purchase fertilizer. Even those willing to transform animal investments into fertilizer will not do so until the end of the dry season after food and seed is assured and fodder becomes scarce making animals more expensive to maintain.

It is difficult to quantify and compare returns to fertilizer and alternative investments, but farmers' perceptions and priorities are fairly clear. If current policies and climatic conditions continue (high cost of fertilizer, shortage of peanut seeds, poor millet harvests, uncertain rains, absence of credit) fertilizer consumption is not likely to increase.

FERTILIZER INVESTMENT DECISION MODELS

Prescriptive Models

Decision analysis has been used most frequently by agricultural economists seeking a systematic approach to analysis of risky decisions. Figure 4 illustrates a typical decision model for a fertilizer investment decision. Consequences are calculated using the perceived fertilizer yield effect reported by a farmer in our sample who used fertilizer every year.

The results show that the expected net income (the sum of the products obtained by multiplying the probability by the expected income for each state of nature) is significantly greater when fertilizer is used. Given this particular farmer's perceptions of yield response, he would be wise to invest.

This type of analysis requires information about the probabilities associated with the risky decision as well as the probable consequences given different states of nature. Data for such analyses could come from time-series data on rainfall combined with yield responses from research trials, extension demonstrations, or farmers' subjective perceptions. If data were available on alternative investments such as banabana or livestock, the decision could be between two types of investment.

FIGURE 4

DECISION MODEL OF FERTILIZER INVESTMENT USING ONE FARMER'S YIELD PERCEPTIONS

Activity	State of Nature	Prob-ability	Expected Yields (kilos/ha)	Net Benefit (FCFA)	Expected Net Benefit (FCFA)
Invest	Good	.25	3,000	260,400	165,900
	Average	.50	2,000	170,400	
	Bad	.25	800	62,400	
Do Not Invest	Good	.25	1,500	135,000	90,000
	Average	.50	1,000	90,000	
	Bad	.25	500	45,000	

The Problem: To invest 9,600 FCFA in fertilizer for one hectare of peanuts or to farm without fertilizer.

This type of decision model helps to determine what farmers should do if they want to maximize expected net revenues. Such analyses can also help policy analysts assess the potential profitability of fertilizer in rainfed agriculture since it systematically incorporates risk (value/cost analyses acknowledge the risk factor by using a 2:1 norm, but they do not try to quantify the effect). Unfortunately, the lack of reliable data on yields obtained under farmer-managed conditions makes it impossible to use this type of analysis confidently.

Furthermore, even if data were available, this type of prescriptive model does not get us closer to understanding farmers' fertilizer investment decisions. Clearly, farmers do not undertake this type of analysis--even at a very rudimentary level. Most farmers in our sample **could not** attempt such analyses because they lack the requisite concepts of probability, math skills, and written records or recall of past events. Most **would not** employ the model--even if the analysis were done and presented to them--because of their conviction that trying to second guess Allah is a waste of time (if not blasphemy!).

Hierarchical Descriptive Models

Another type of decision model can be used to depict the actual decision making process used by a farmer or group of farmers. This model requires that the criteria actually employed by farmers be identified and incorporated into a decision tree according to the priority given each criteria by the farmer. Farmers are classified by their responses to each of the criteria. Constraints on farmers' ability to implement preferred courses of action are added to the model.

One of the objectives of this research program is to develop a model that accounts for both the criteria and constraints that influenced farmers' 1981-85 fertilizer purchasing decisions and those criteria mentioned in response to hypothetical investment questions. Such a model will show how various factors and attitudes discourage fertilizer consumption, and could be used eventually to predict how many farmers are likely to purchase fertilizer, given different assumptions about the number of farmers expected to face particular constraints in any given year. This model could also

help identify policy measures that are likely to have the biggest impact on fertilizer consumption.

A simplified diagram of the final model is presented in figure 5. Modifications which will be made following additional analysis include the incorporation of additional decision factors and rearrangement of priorities among the criteria and constraints.

In most hierarchical decision models the decision maker first assesses the attributes of the investment (yield increasing potential, risk, profitability, etc.). These attributes are evaluated according to several different criteria before the farmer decides to invest or not. At this point the decision maker examines potential constraints. In reality, farmers interviewed tend to begin the decision process by assessing the constraints (with the exception of three confirmed non-investors shown at the top of figure 5). For the majority the single most important constraint is inadequate financial resources, leading to a separate decision concerning each category of necessity deemed more critical to survival than fertilizer. Each category is shown because the level at which farmers hop off the decision tree has implications for all agricultural investments, not just fertilizer. This was particularly true in 1985/6 when 46 percent of farmers did not feel they had secured an adequate supply of food.

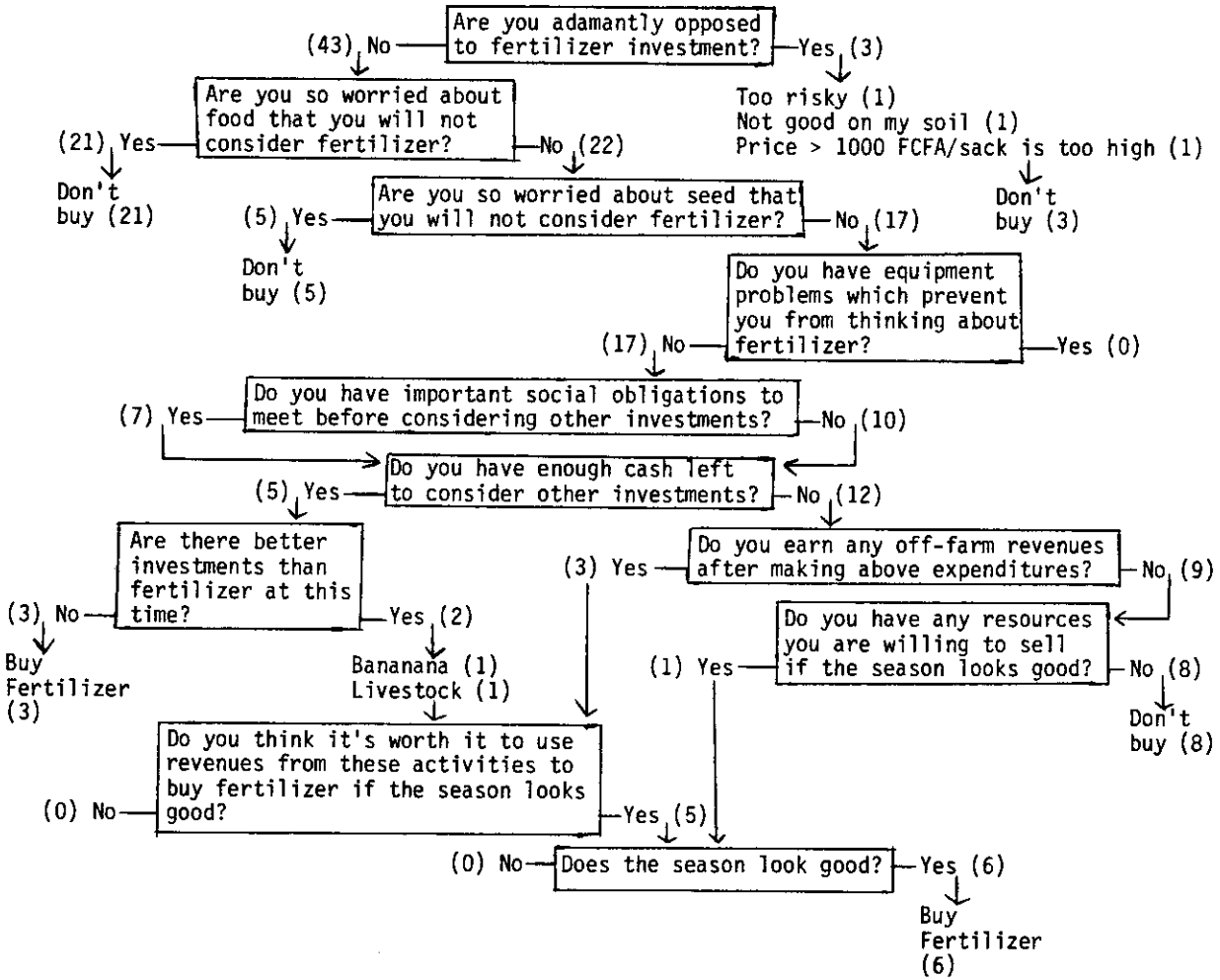
Most farmers allocate resources according to the priorities shown in the model: food, minimum acceptable level of seeds, and equipment repair. Social obligations, however, muddy the picture in many cases. Certain social obligations arrive unexpectedly and cannot be avoided (this is particularly true for the Serer who have a tradition of very costly funerals). Cash for meeting planned social obligations (marriages, debt repayment, baptisms) is usually allocated immediately after harvest and does not pose the same problem as unexpected obligations. Marriages and debt repayment to relatives and friends, however, frequently take precedence over all other concerns, including food.

If a farmer has cash left after assuring minimum food, seeds, social obligations, traction animals and equipment repair, he then assesses alternative uses such as more seed, new equipment, traction animals, cash savings, animal savings, livestock fattening, banabana, or fertilizer. Some opt for fertilizer at this time; others prefer to wait until they see the

FIGURE 5

HIERARCHICAL DECISION TREE MODEL OF FERTILIZER INVESTMENT

DECISIONS MADE BY 46 FARMERS DURING 1985/86



NOTE: Numbers in parentheses are the number of farmers making each response.

countenance of the newly arriving rainy season. Some of those who opt for savings or alternative investments before the arrival of the rains may later transform these investments/savings into fertilizer. There are also a few who increase cash holdings through off-farm activities or liquidation of assets and use this money for fertilizer if the season appears promising.

Because fertilizer is a low priority investment, it is easily preempted by innumerable emergency cash needs that occur between peanut marketing time and about one month into the rainy season. In some cases even the actual purchase of fertilizer does not signal the end of the decision process because an unexpected emergency can lead the farmer to reconvert his purchase to cash, usually at substantial loss. (This is not shown in the present model because we are only concerned with the decision to purchase.)

A number of criteria which one would expect to influence fertilizer investment--particularly access to organic fertilizers--are not yet incorporated into the model. Access to organic fertilizers seems to influence quantities of fertilizer purchased and used, but not the decision to purchase. This is probably due to the fact that no farmer has access to enough organic matter to properly treat all of his fields. Another factor which requires further analysis is the relation between increasing maize production and demand for fertilizer.

The model requires considerable refinement, but permits several conclusions. Farmers' food insecurity was the major constraint on fertilizer purchases in 1985/6. This does not mean that if the food constraint had been removed all farmers would have purchased fertilizer--most would have moved up to the next constraint level (seeds) and probably dropped fertilizer investment intentions at that point. It is a long and bumpy road from harvest to fertilizer purchase. Farmers have so many stated prerequisites to fill before considering fertilizer that increased demand in the near future is unlikely unless both cereal production and farmers' cash incomes increase significantly.

More work needs to be done on predicting what farmers will actually do if one day they do meet all their prerequisites and have a bit of cash left. Our experience in asking farmers about 1986/87 fertilizer purchase intentions several times during the 1985/86 campaign illustrates how good intentions often fail to get translated into good actions. Most farmers

recognize the benefits of fertilizer and most are cognizant of the fact that their soils are deteriorating. Given the recent history of poor rains, however, farmers who have very limited resources and no outside sources of cash are unlikely to risk fertilizer investment until production improves. This poses a significant dilemma for fertilizer policy in Senegal--is it really possible for these farmers to recover, even if the rains improve, without making any investments in fertilizer?

RECOMMENDATIONS FOR FUTURE ACTION

Steps to increase fertilizer consumption in Senegal fall into three categories:

1) Those alleviating the economic constraints (food deficits, low farm revenues, high input prices, no credit) preventing fertilizer purchases

2) Those alleviating the knowledge and belief constraints that keep farmers from investing

3) Those assuring that the distribution system responds to farmers' needs, thereby encouraging increased fertilizer consumption.

Dealing with the Economic Constraints

The priority actions for addressing the economic constraints are:

1) A concerted effort on the part of all technical services to identify the specific causes of poor millet production in those areas which have serious insect/disease problems and to recommend solutions which farmers can implement.

2) Assure that farmers are getting the best prices possible for their crops. This means timely and adequate financing of both peanut and cereal marketing activities by SONACOS, SODEVA, and the Commissariat de Securité Alimentaire. It also means assuring that official peanut prices and floor prices for cereals realistically reflect Senegalese demand and supply as well as world market prices.

3) Assure that fertilizer prices are kept as low as possible by (1) frequent review of recommended formulas in light of prices for raw materials and local productions costs and (2) use of distribution systems that reduce

administrative overhead and transportation costs (e.g., avoid programs like the retenue which require complicated record keeping procedures, deliver fertilizer on backhauls of trucks hauling peanuts to processing plants or with traders who frequent local markets).

Dealing with Attitudinal and Knowledge Constraints

Senegalese farmers still favor extensive over intensive agriculture. More seeds and more equipment in order to cultivate larger areas take priority over fertilizer purchases. This preference, however, is related more to family obligations and labor procurement practices than to a firm belief that extensive agriculture is more profitable. Consequently, it is difficult to identify remedial measures that could encourage more intensive agriculture. The solution might lie in alternative employment opportunities or the gradual transformation of the traditional contract labor system based on payment in land and seed to one of salaried workers paid in cash.

While farmers' inability to quantify fertilizer response does not appear to inhibit investment, the lack of good data on fertilizer response obtained under farmers' conditions is a serious constraint on the design of fertilizer price, credit, distribution and extension policies. Systematic collection and analysis of data on farmers' techniques and yields obtained using no fertilizer, organic fertilizer, and chemical fertilizer is a prerequisite for sound policy analysis. This data must be collected under a variety of soil and rainfall conditions. Collection and analysis of this type of data would be a very expensive undertaking and perhaps not worth the investment if drought conditions continue in Senegal. The alternative, however, is to continue to make important agricultural policy decisions without the systematic analysis necessary to evaluate alternative choices.

Dealing with the Distribution System Constraints

Aggressive marketing strategies will be required if fertilizer distributors are to sell existing stocks. Given information collected during the in-depth interviews, it is not surprising that fertilizer stocked at SONACOS collection points since December has not been selling like green

maize at the end of the hungry season. First of all, there is the timing problem--most farmers will not purchase before the rains. This can be resolved if stocks remain in place through the month of July. Second, however, is the location problem. Previous sales have taken place at local markets or in villages--that is not where most SONACOS collection points are found. Once peanuts are sold, most farmers will have no reason to return to the collection points because there will be no seed distribution this year. If SONACOS is to sell its stocks of fertilizer, some plan should be devised for placing them at more decentralized locations during June and July.

There are a few confirmed fertilizer users in the Sine Saloum who have the commitment and means to travel long distances and transport fertilizer from peanut collection points to their fields. There are many farmers, however, who believe in fertilizer but have few resources and less commitment. It is these farmers who will never go to a peanut collection point to buy fertilizer, but might invest if they saw it in local markets when they had cash in their pockets. This does not mean that there is a big demand just waiting for stocks to arrive at weekly markets. The demand, at least this year, will be very small; but there is a much better chance of selling fertilizer at local markets in June and July than at peanut collection points. The major distributors should investigate the possibility of collaborating with trucker/traders who frequent the larger weekly markets in an attempt to give farmers easier access to fertilizer.

APPENDIX 1

GENERAL CHARACTERISTICS OF SAMPLE FARMERS

Characteristic	Sample Average	Median	Minimum	Maximum
Age of principal farmer	49	49	21	79
Total number of persons/farm	10.2	8.5	2.33	37.33
Number of active workers/farm[a]	4.79	4.3	.87	19.6
Cultivated hectares/farm	9.48	7.67	.77	39.86
Hectares cultivated/active worker	2.02	1.9	.38	5.11

[a]ISRA norms used; male 15-59 years = 1; female 15-59 = .5; male 8-14 = .5; female 3-14 = .25; all others = 0.

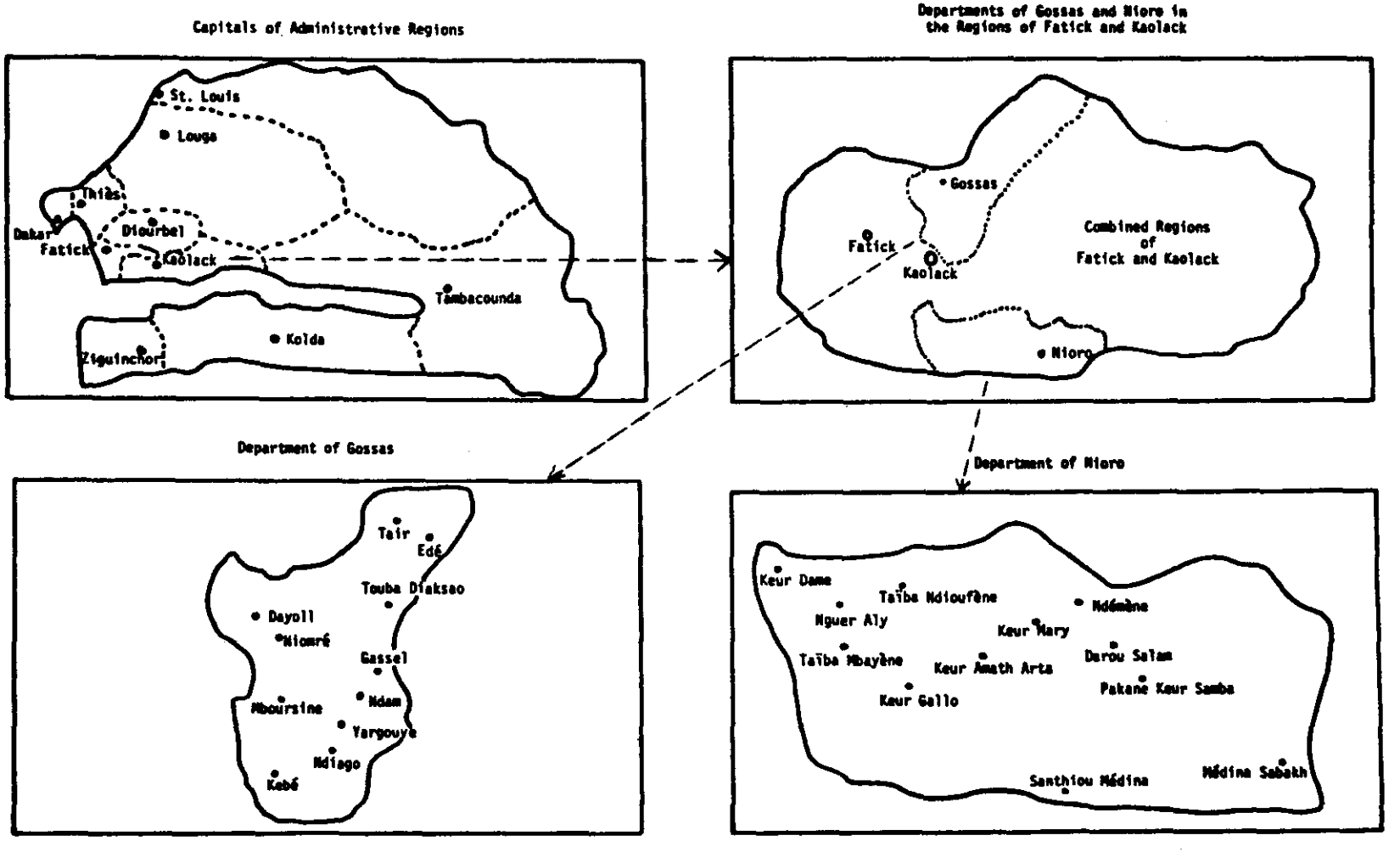
Notes:

(1) Farmers in the SODEVA sample were interviewed anywhere from one to four years during the 1981-84 period; most were interviewed 3 or 4 years. Data used to calculate the sample averages for all variables but age was obtained by averaging the data for each farmer over the number of years he was surveyed. Age is based on 1984 data.

(2) A chi-square test was performed to see if there was a significant difference between Nioro and Gossas farmers with respect to these five characteristics. The only significant difference (.005) was found with respect to cultivated area per active worker; Gossas farmers tend to have more cultivated area per active worker than those in Nioro.

APPENDIX 2

LOCATION OF VILLAGES FOR SODEVA SAMPLE
USED IN 1985/86 SURVEYS



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